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RESEARCH REPORTS

Chairman: SIR WILLIAM SLATER

EXPERIMENTAL TECHNIQUES AND THE ACTIVITY OF HERBICIDES

METHODS AND RESULTS OF SMALL SCALE TESTING OF MCPA DERIVATIVES

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Summary

This report describes a simple method of comparing the efficiency of derivatives of MCPA using mustard and buckwheat seedlings grown in boxes under glass, and in the open. The method is illustrated by two series of experiments, comparing (a) sodium and potassium salts and (b) the lower esters of MCPA.

In five trials, no difference in efficiency was found between formulations of MCPA (sodium) and MCPA (potassium), but in one trial the latter gave significantly better results. A limited comparison of esters of MCPA suggests that the butyl esters are more efficient than the lower alcohol esters.

Introduction

Mustard is a favourite test plant with those studying hormone type weedkillers, both because of its susceptibility to the chemicals and its suitability for experimental work. It was the first and obvious choice when it became evident that there was a need for a quick, accurate and reliable glasshouse technique for testing formulations of MCPA and 2,4-D derivatives, either before or concurrent with field trials. The method is described and some experimental results given in detail so that others may judge its usefulness and appraise the results obtainable when using simple equipment and a minimum of labour in preparation, application and assessment.

Experimental Procedure

Plants sown in boxes are sprayed in the seedling stage with weedkiller and the mortality assessed two or three weeks later.

A measured volume of seed, calculated to give about 250 seedings per box, is broadcast in John Innes Sterilised Seed Compost in seed trays, 48 or 64 sq. inches in area and 1½ inches deep. After sowing, the seed is covered with a fine sifting of compost and boxes are kept in the propagating house at 60^{o}-70^{o}F. until ready for spraying. This is normally when the plants have two well developed cotyledons and the first true leaves are just appearing, usually six to eight days after sowing. Before spraying, boxes that have germinated unevenly, are rejected. The remaining boxes are divided into replicates in such a way that any differences in growth are between the replicates and not within them. Because trials generally involve about 21 treatments and are carried out under controlled conditions, threefold replication was found to give sufficiently accurate results, bearing in mind limitations of time and space. The number of application rates is three or, preferably, four; the rates increasing in logarithmic progression. (Two trials quoted later are exceptions to this rule.)

Chemicals are diluted with water and the spray solution applied at 100 gallons per acre although rates as low as 30 gallons per acre can be satisfactorily distributed. A B.E.N. Model 'S.I.' spray gun, intended for poster painting is attached to an air compressor with a reservoir and operated at a pressure of 25 lb. per sq. inch. This equipment was chosen because the rate of delivery is sufficiently slow to allow the plot to be sprayed in two opposite directions and because the container empties itself completely. The spray gun is moved by hand over a square plot, the size being chosen so as to have a 4 inch discard area outside the boxes. All the replicates of a treatment are sprayed at the same time.

The boxes are handled as little as possible until the spray has dried, then they are arranged at random in compact replicates in a glasshouse or in the open, in such a way as to minimise the effects of variation in the environment. Control boxes are not sprayed but are otherwise treated in the manner described above. Regular watering is maintained in the glasshouse; and boxes in the open are watered when necessary. No nutrients are given. On completion of each test, the used soil is discarded and the boxes stood in the open, and allowed to weather for a few days. This method of decontamination has proved perfectly satisfactory and eliminates laborious washing and drying.

As the volatile and persistent nature of esters of MCPA can cause misleading results, additional precautions are taken to overcome the difficulties in testing this type of chemical. Contamination or carry-over of treatment effect could occur in at least three ways:- glassware or spray equipment might be difficult to clean between treatments; spray might drift during application, or it might volatilize from the leaves later. Special attention was paid to these points. For example, spraying was always done in the open, and immediately after treatment, all boxes sprayed with the same chemical were grouped at a minimum distance of 6 yards from boxes sprayed with another; boxes that had received different rates of the same chemical were kept several feet apart. When the spray deposit had dried completely they were moved to their final positions and placed at random in a single line across the direction of the prevailing wind. In the first experiment an untreated box was placed between each treated one and the boxes spaced 7 feet apart. In later experiments the boxes were moved progressively closer and it is now known that no undesirable effects follow even when treated boxes are only 1 foot apart. In addition to the control boxes in the experiment (which are placed at random), extra untreated boxes are also placed close to treatments that might be expected to be particularly volatile.

In the experiments described, mustard Sinapis alba L. and buckwheat Fagopyrum esculentum Moench are the only test plants. However, sugar beet Beta vulgaris L. and trefoil Medicago lupulina L. have been used in later trials. Crop plants were chosen in preference to weeds because of their higher and more reliable germination value and their availability. The species mentioned were selected because of their quick germination, ease of volumetric measurement when sowing, relatively large cotyledons, a habit which facilitates counting even when the plants are dead, and finally their reaction to hormone weedkillers.

Assessment of results

To avoid handling the plants no pre-treatment count is made, but an assessment is carried out before dead plants become indistinguishable. All the plants in each box are pulled up and placed in one of the following categories:-

(1) Unaffected - showing no indication of hormone treatment.
(2) Affected - cotyledons withering but apical shoot still green.
(3) Dead - no green tissues.

The number of plants in each category is counted and recorded. Where necessary, affected plants may be subdivided into slightly affected and seriously affected:- slightly affected seedlings show green apical shoots with leaves slightly curled and reduced in size, withered cotyledons, and shortened stem. Severely affected seedlings are almost completely dead except for the apical shoot which is still green but curled and greatly reduced in size.

The number of dead plants, or occasionally the dead plus the seriously affected plants, in each box are expressed as a percentage of the total in that box. As there are generally a wide range of percentages to be examined, the data are transformed by replacing the percentage x by the corresponding value $\sin^{-1}\sqrt{x}$. Analysis of variance is carried out on the transformed data. Results from control treatments (where the counts have always been nought) are omitted, since to include them would unjustifiably reduce the error variance.

Two series of experiments will serve to illustrate this technique. The first concerns a comparison of the biological efficiency of the sodium and potassium salts of MCPA, the second, of a series of high volatile esters of MCPA.

EXPERIMENTAL RESULTS ON MCPA (SODIUM) & MCPA (POTASSIUM)

The chemicals used were as follows:-

MCPA (potassium) A* - an aqueous solution of the potassium salt drawn from a bulk sample and containing 4 lb. active acid equivalent per gallon. (4.4 lb. total acid per gallon).

MCPA (potassium) B - an aqueous solution containing 4.4 lb. of active acid equivalent per gallon. (4.9 lb. total acid per gallon).

MCPA (sodium) ** - an aqueous solution of the sodium salt drawn from a bulk sample and containing 2.6 lb. of active acid equivalent per gallon. (4.6 lb. total acid per gallon).

Four experiments on mustard seedlings and one on buckwheat indicate that MCPA (sodium) and MCPA (potassium) in the formulations tested, are very similar in efficiency. In a single experiment on mustard during the winter months, MCPA (potassium) was superior, but this result was not repeated in trials carried out under the more normal conditions of spring and summer.

Considering first the trials where no statistically significant differences were found between the chemicals, the actual percentage kill achieved varied according to the rates used and the season (Table 1), but comparison of the chemicals at the same level of application in any one trial (No. 116 being excluded) shows that the difference on mustard was never greater than 8 per cent. and the average figure was 3 per cent. On buckwheat a difference of 13 per cent. was found at the lowest rate, but the difference was less at higher rates. In all but one of these trials the coefficient of variance was reasonably low suggesting that the non-significance was not likely to be due to a large experimental error. In the fifth trial (No. 153), however, the

* A formulation sold as a commercial product during 1954.
** A formulation sold as a commercial product during 1953 and in earlier years.

coefficient of variance was high, being more than twice as great. This trial was in the early spring. It is of interest that a trial completed in December also had a high coefficient of variance, suggesting that trials during the winter months are less satisfactory than those carried out between May and October. It was in this latter trial (116) that a significant difference was found between chemicals, MCPA (potassium) being superior to MCPA (sodium) at a rate of 20 oz. acid equivalent per acre. We have been unable as yet to repeat this result.

Experimental Results on Esters of MCPA

Five esters of MCPA, the methyl, ethyl, iso-propyl, n-butyl and iso-butyl formulated as water miscible liquids have been compared in four experiments on mustard. The n- and iso-butyl gave significantly better results than the methyl and iso-propyl esters. The iso-butyl was better than the ethyl ester also.

In this series of experiments the coefficients of variance were higher than in the previous series. However, it must be recalled that the boxes were out of doors and subject to the vagaries of the weather, less regular watering and occasional slight rabbit damage.

Discussion

The method of test described has been in use for eighteen months during 1953 and 1954 and has proved of value when testing salts and esters of MCPA and 2,4-D.

The use of seedling plants has several advantages. It increases the number of tests per season as the interval between seed sowing and treatment is minimised and because seedlings die more quickly than mature plants. It allows the inclusion of many more plants per treatment thus leading to greater accuracy. (Only 45 well developed plants could be grown in the area occupied by one box trial.) Assessment of results is easier and more reliable as the effect of sprays on seedlings can be measured quantitatively; but as death may take many weeks the effect on well developed plants is assessed qualitatively ranking by the degree of epinasty.

Rates of chemical application have been varied in these trials in relation to the species being sprayed, the time of the year and as a result of experience. The aim has always been an almost complete kill at the highest rate and some kill at the lowest. Rates between 8 and 32 ozs. of acid equivalent MCPA (sodium) and MCPA (potassium) achieve this at most seasons on mustard seedlings grown under glass, as exemplified in three of the trials quoted and confirmed by later experience. Rates between 4 and 12 oz. acid equivalent in ester form have given satisfactory results on the same crop in trials during the summer months in boxes in the open. The difference between the maximum rate of MCPA used as a salt and an ester is no indication of their relative efficiency as the two types of trial are not comparable and rates were, to some extent, chosen arbitra arbitrarily.

Trials have been conducted at all seasons, but take about twice as long to complete during the winter months and may not be as reliable. Artificial lighting has not been used as yet.

An obvious criticism of this method is that an ill-timed assessment may measure only relative speed of action and not final effect. The assessments are always delayed as long as possible, but as there is no pre-treatment count, they must be made before the dead plants have decayed beyond recognition. An experiment (No. 234, Table I) was designed to test this and a count was made before and 10, 16, 21 and 24 days after treatment. There was no significant difference between MCPA (potassium) and MCPA (sodium) at any time, indicating that these formulations do not differ either in speed of action or final effect.

However, it is worth recording that a different MCPA (sodium) formulation was significantly superior to the other formulations in the trial at 21 and 24 days after treatment, although there was no significant difference after 10 or 16 days. This factor, therefore, needs to be examined for each formulation tested.

Finally, how do results obtained in glasshouse trials compare with field performance? Comparative field testing of the ester formulations has not been undertaken. However, field testing under practical conditions of the formulations of MCPA (sodium) and MCPA (potassium) mentioned in this report has not detected any difference in their biological efficiency. A direct check has been made in two experiments each having four replicates under glass and four on field plots. Comparison of MCPA (potassium) and two formulations of 2,4-D salts on mustard, sugar beet and trefoil showed a close similarity between the two series, indicating that glasshouse tests are a useful and reliable method for determining the comparative efficiency of hormone type weedkillers.

TABLE 1

MUSTARD AND BUCKWHEAT SEEDLINGS - EFFECT OF SODIUM AND POTASSIUM SALTS OF MCPA

CROP + Ref.	CHEMICALS	RATE OF APPLICATION Oz. of acid equivalent in 100 galls. per acre									ANALYSIS after transformation Sign. diff. at 5%		Coeff. of variance	Date	Days after treatment
		ACTUAL PERCENTAGE KILL				TRANSFORMED PERCENTAGE KILL					Between Totals	Between T'ments			
		3 oz	6 oz	12 oz		3 oz	6 oz	12 oz		Total					
Mustard 177	MCPA (potassium) A*	36	50	65		37	45	54		136	Insign.	9	11.5	May	14
	MCPA (sodium)	42	58	65		38	50	54		142					
		16 oz	25 oz	40 oz	64 oz	16 oz	25 oz	40 oz	64 oz						
Mustard 820	MCPA (potassium) B*	78	90	92	97	62	72	74	80	288	Insign.	12	9.3	May	13
	MCPA (sodium)	77	88	95	98	62	70	78	83	293					
		8 oz	13 oz	20 oz	32 oz	8 oz	13 oz	20 oz	32 oz						
Mustard 153	MCPA (potassium) A	39	54	79	85	38	46	65	71	220	Insign.	19	25.9	Mar.	25
	MCPA (sodium)	44	55	86	81	41	48	69	71	229					
		8 oz	13 oz	20 oz	32 oz	8 oz	13 oz	20 oz	32 oz						
Mustard 116	MCPA (potassium) A	29	51	71	83	32	45	58	66	201	35**	18	26.3	Dec.	21
	MCPA (sodium)	16	31	35	82	22	32	34	66	154					
		8 oz	13 oz	20 oz	32 oz	8 oz	13 oz	20 oz	32 oz						
Mustard 234	MCPA (potassium) A	82	92	97	99	67	74	80	87	311	Insign.	10	7.2	Sep.	24
	MCPA (potassium) B	80	87	94	100	63	69	76	90	298					
	MCPA (sodium)	82	92	99	97	65	74	85	85	309					
		12 oz.	17 oz	24 oz		12 oz	17 oz	24 oz							
Buck-wheat 98	MCPA (potassium) A	68	80	93		56	64	75		195	Insign.	Insign.	10.2	Oct.	19
	MCPA (potassium) B	81	88	92		65	72	77		214					
	MCPA (sodium)	79	87	87		63	70	70		203					

N.B. The percentage kills given are the averages of three replicates, except 153 which is the average of five.

* Details of formulation are given in the text.

** Totals of rates of potassium salt better than sodium salt.

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TABLE 2

MUSTARD SEEDLINGS

EFFECTS OF ESTER DERIVATIVES OF MCPA

REF.	CHEMICALS Derivative of MCPA	RATE OF APPLICATION Oz. of acid equivalent in 100 galls. per acre ACTUAL PERCENTAGE KILL			TRANSFORMED PERCENTAGE KILL				ANALYSIS after transformation Sign. diff. at 5% Between Totals	Between T'ments	Coeff. of var.	Date	RESULTS Iso-butyl sign. better than:	n-butyl sign. better than:
		4 oz	7 oz	12 oz	4 oz	7 oz	12 oz	Total						
856	Methyl	35	73	95	35	59	80	174					Methyl**	
	Ethyl	16	74	96	23	59	81	163					Ethyl**	
	Isopropyl	40	59	89	38	51	74	163	29	17	16.4	Aug.	Isopropyl**	
	n-butyl	45	78	98	42	63	85	190						
	Iso-butyl	61	94	99	52	78	86	216						
835	Methyl	29	67	100	32	56	90	178					Methyl*	Methyl*
	Ethyl	37	76	100	37	62	90	189						
	Isopropyl	41	68	98	39	58	83	180	36	21	19	June	Isopropyl*	Isopropyl*
	n-butyl	60	94	100	51	76	90	217						
	Isobutyl	66	97	97	55	85	84	224						
860	Methyl	20	49	83	27	45	67	139					Methyl**	Methyl**
	Ethyl	30	51	88	33	46	70	149					Ethyl*	
	Isopropyl	22	54	81	28	47	65	140	18	11	12.5	Aug.	Isopropyl**	Isopropyl**
	n-butyl	38	64	92	38	53	74	165						
	Isobutyl	48	69	90	43	57	73	173						
			8 oz	16 oz		8 oz	16 oz							
822	Ethyl	84	98			67	82	149	11	8	5.4	May		Ethyl*
	n-butyl	94	99			76	87	163						

N.B. 1. The % kills given are the averages of 3 replicates.
2. The comparisons in the results column are based on the total percentage kill of the three rates of application. Comparison at any one level of application shows slightly different relative efficiences.

* = significantly different at the 5% level
** = significantly different at the 1% level

The Value of Different Isomers of Phenoxyacetic Acids and Phenols and the Effect of Technical MCPA

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Summary

Isomers of phenoxyacetic acids and phenols commonly found in technical MCPA* were studied in regard to their weed-killing effect as well as to their effect on some cultivated plants. It was found that among these isomers the 4-isomer, i.e. the 2-methyl-4-chlorophenoxyacetic acid, is the most effective one against the weeds. Nevertheless it is possible to avoid abnormalities on the cultivated plants by observing the right developmental stage of the plants for spraying. On the basis of these observations it is recommended that future technical products should have an active substance containing at least 90 per cent of the 4-isomer. Technical products of this type have already been manufactured and tried in Sweden. They have given satisfactory results. Observations on 2,4-dichloro-phenoxyacetic acid and impurities possibly occurring with this acid in technical products have also been made. They suggest the use of 2,4-dichlorophenoxyacetic acid in the purest possible form. The activities of 2,4,5-trichlorophenoxyacetic acid and 2,4-dichlorophenoxyacetic acid have been studied. It might be possible to use, also in agriculture, mixtures of 2,4,5-T with one of the two other acids, especially against weeds resistant to MCPA or 2,4-D.

Introduction

Observations on fields sprayed with weed-killers of the phenoxyacetic acid type had shown that these weed-killers caused abnormal heads and kernels in cereals, abnormal leaves, stem bendings and abnormal infloroscences in linseed, abnormal leaves on potatoes and so on. These abnormalities were obtained at the same time as the weeds were seriously damaged or killed. Abnormalities of the cultivated plants were often said to originate from chlorinated phenols appearing as impuritios in the weed-killers. In a survey published in 1948 Zimmerman and Hitchcock (1) discussed the possibilities of activating 2,4-dichlorophenoxyacetic acid by adding chlorinated phenols. It therefore seemed highly desirable to study the effect of different components of the technical products of hormone weed-killers. It seemed most logical first to take up the question of the effects of different components of technical methoxone, since this product is the one most commonly used in Sweden. The phenoxyacetic acids and phenols which are most likely to appear in this product were therefore chosen for the studios at the Department of Plant Husbandry. In an investigation at the Department of Plant Physiology, University of Lund, the same substances were simultaneously studies in regard to their physiological activity. Results of these studies were published by Hansen 1951 (2). The investigations at the Department of Plant Husbandry went on from 1948 to 1954. A preliminary report on results up to and including 1951 was published by the present author in 1952 (3), and a final detailed report has been submitted this year (4).

Experimental Results

Effect on Weeds

In the 1952 publication just mentioned the reaction of Sinapis arvensis and Chenopodium album after spraying with different isomers of phenols and

* formulated as "Methoxone"

TABLE 1

1. No treatment
2. 2-methyl-phenol
3. 2-methyl-4-chlorophenol
4. 2-methyl-6-chlorophenol
5. 2-methyl-phenoxyacetic acid
6. 2-methyl-4-chlorophenoxyacetic acid
7. 2-methyl-6-chlorophenoxyacetic acid

Results:

Weed species and Chemicals no.	Number and weight of weed plants on ½ square meter after spraying on			
	May 24		June 2	
	No.	g.	No.	g.
Sinapis arvensis				
1	34	500	27	419
2	36	244	12	58
3	11	59	20	146
4	19	135	18	280
5	8	116	22	204
6	0	0	0	0
7	9	16	3	17
Chenopodium album				
1	7	14	1	1
2	5	3	2	2
3	3	5	1	1
4	5	4	1	2
5	5	4	2	5
6	0	0	0	0
7	0	0	0	0
Lamium purpuroum				
1	17	5	14	11
2	14	5	12	12
3	6	7	4	4
4	8	8	7	5
5	8	6	4	3
6	0	0	0	0
7	8	7	17	9
Polygonum convulvulus				
1	15	15	18	18
2	11	7	9	16
3	20	19	13	19
4	13	13	10	18
5	6	4	3	2
6	0	0	0	0
7	6	7	9	6

phenoxyacetic acids was given. After spraying in 1951 with 1/50 mol solution of three phenols and three phenoxyacetic acids it could be shown that the pure 2-methyl-4-chlorophenoxyacetic acid was the most effective one. Some figures are given (Table 1) to illustrate the results in 1951 with these two weeds, and also with Lamium purpureum L. and Polygonum convolvulus L. which are only slightly sensitive to the treatments. These figures are based on spraying with the chemicals mentioned below.

On May 24th the weeds had 2-4 leaves, and on June 2nd they had 6-8 leaves. The results show that 2-methyl-4-chlorophenoxyacetic acid has a better effect on the weeds than any of the other five substances.

With these results in mind the experiments in 1952 and 1953 were so planned that the effect of different isomers of phenols and phenoxyacetic acids could be studied when used with the same amounts per hectare as in the technical products. These contain per litre solution 0.4-0.5 moles of 2-methyl-4-chlorophenoxyacetic acids, 0.2-0.4 moles of other methyl chlorophenoxyacetic acids, and 0.15-0.4 moles of chlorinated methyl phenols. The solution prepared for the experiments contained 0.50 moles of phenoxyacetic acids and 0.15 moles of phenols per litre. A number of experiments were carried out with such solutions. They were sprayed in amounts corresponding to 5, 10, 20 and 40 litres per hectare of a technical product with 10 per cent active substance. Depending on whether the weeds appeared in linseed or cereals one or the other of these amounts were chosen. It was found that the 4-isomer, i.e. the 2-methyl-4-chlorophenoxyacetic acid, was superior to the other ones in effect and in addition proved equally satisfactory as the combination of the 2-methyl-4-chlorophenoxyacetic acid and a chlorinated phenol. This can be exemplified by the following figures (Table 2) from one of the 1953 experiments. The weeds are given as numbers per one-fourth square meter.

TABLE 2

Treatment	Chenopodium album sprayed on May 28	Chenopodium album sprayed on June 10	Lamium purpureum sprayed on May 28	Lamium purpureum sprayed on June 10
1. Not sprayed	9	10	18	10
Sprayed with:				
2. 2-methyl-4-chlorophenol				
5 l per hectare	0	4	18	6
10 l per hectare	8	12	18	12
3. 2-methyl-4-chlorophenoxy-acetic acid				
5 l per hectare	0	0	2	0
10 l per hectare	0	0	0	0
4. Treatments 2 + 3				
5 l per hectare	4	2	0	8
10 l per hectare	0	0	4	2

Effect on Cultivated Plants

The observations made on the effect of different isomers on cultivated plants were in many respects similar to those made on the reaction of the weeds. Already in 1952 it was reported from an experiment in 1951 that barley, sprayed in a very sensitive state of development, could produce a high percentage of abnormal heads after treatment with 2-methyl-4-chlorophenoxyacetic acid. Added in amounts corresponding to 10 litres per hectare of a technical product with 10 per cent active substance, this acid gave as much as 15 per cent abnormal heads. When sprayed with four times the amount of that product it caused 85 per cent abnormal heads. When combined with a chlorinated phenol the percentage of abnormalities was approximately the same as when used alone. None of the other phenoxyacetic acids (2-methyl-6-chloro and 2-methyl-4,6-dichloro) gave the same high percentage of abnormalities. In 1952 and 1953 the same percentage, of abnormalities were not obtained. This is illustrated by the following figures (Table 3) from a field experiment in barley, where the spraying took place at a stage of development at which the barley was only slightly sensitive to the treatment.

TABLE 3

Treatment	Abnormal heads	Abnormal kernels
	%	%
1. Not sprayed	0	0
Sprayed with:		
2. 2-methyl-4-chlorophenol		
10 1 per hectare	0	0
20 1 per hectare	0	0
3. 2-methyl-4-chlorophenoxy-acetic acid		
10 1 per hectare	0.28	1
20 1 per hectare	0.30	2
4. Treatments 2 + 3		
10 1 per hectare	0.33	1.25
20 1 per hectare	0.28	2

These figures verify earlier observations in regard to the stronger effect of the pure 2-methyl-4-chlorophenoxyacetic acid and they also show that its combination with chlorinated phenols gives no better results. At the same time these figures, in relation to the ones from 1951, clearly show that abnormalities in the cultivated plants can be avoided if the plants are sprayed when at the right stage of development. This can easily be done, as Hagsand (1954 (5)) has shown. The rate of abnormalities given in the last table is of no practical importance.

In linseed similar observations were made in several experiments carried out in 1952 and 1953. The figures (Table 4) from one experiment at Kungsängen near Uppsala in 1953 are given below. They refer to spraying with an amount corresponding to 10 litres per hectare of a technical product with 10 per cent active substance.

TABLE 4

Treatment	SPRAYED ON May 28 Height cm.	May 28 Abn. stem bendings %	June 10 Height cm.	June 10 Abn. stem bendings %	June 25 Height cm.	June 25 Abn. stem bendings %
1. Not sprayed	60	0	65	0	50	0
Sprayed with:						
2. Chlorinated methyl phenols	59	3	55	0	55	3
3. 2-methyl-4-chloro-phenoxyacetic acid	45	10	43	8	55	50
4. 2-methyl-6-chloro-phenoxyacetic acid	65	1	65	0	60	3
5. 2-methyl-4,6-dichloro-phenoxyacetic acid	60	7	60	0	48	3
6. Treatments 2 + 3	47	13	40	15	47	50
7. Treatments 2 + 4	55	3	45	0	50	4
8. Treatments 2 + 5	45	7	43	0	47	3

There is no doubt that the 2-methyl-4-chlorophenoxyacetic acid has a stronger effect than any of the other phenoxyacetic acids. Also, it is definitely more effective than the chlorinated methyl phenols. From the figures in the table it is further clear that the percentages of abnormalities are lower after spraying at an early stage of development, which is completely in accordance with the recommendations for practical application of hormone weed-killers in linseed (Hagsand 1954 (5)).

DISCUSSION

The experiments during the period from 1948 to 1953 have clearly shown that the pure 2-methyl-4-chlorophenoxyacetic acid is the most effective part of the active substance in technical MCPA. The results with detailed data of these experiments, and the discussion of these results, are found in the final report (4). The above examples merely serve to summarize the results of the investigation as a whole. Those examples, however, are fully sufficient to show that the characteristic behaviour of the pure 2-methyl-4-chlorophenoxyacetic acid is exactly that of the technical MCPA. Consequently the pure 2-methyl-4-chlorophenoxy-acetic acid is the really important part of the active substance in technical MCPA. It may then be questioned why there is no higher percentage of 2-methyl-4-chlorophenoxyacetic acid in the active substance than is evidently the case for the commonly used types of technical MCPA. In Swedish products, 2-methyl-4-chlorophenoxyacetic acids constitute not more than 62-63 per cent of the total amount of phenoxyacetic acids. The experimental results above suggest that a technical product with a percentage of pure 2-methyl-4-chlorophenoxyacetic acid as close to 100 as possible should be desirable from a biological viewpoint. For technical reasons, however, it would appear, that a product with 90 per cent pure 2-methyl-4-chlorophenoxyacetic acid, or slightly above, is the most desirable one. In any case, it seems to be a mere matter of time that the chemical industrios will be producing, sooner or later technical MCPA with a content of pure 2-methyl-4-chlorophenoxyacetic acid lying between 90 and 100 per cent of the active substance. As it is also clear that 2-methyl-4-chlorophenoxyacetic acid is the substance to be analysed in the first place, there are now possibilities of using for the control of the products chemical analyses together with biological tests.

Products which are thought to meet the requirements here presented have already been made and tried. In Sweden, for example, the "Uddeholm High Isomer Trippel" from Skoghallsverken, Skoghall, the "Agroxone 4" from Plant Protection, Limited, England, and the "Cornox M" from Boots Pure Drug Co., Limited, England, have been tried. They have given good results, and continued tests of products of this type are highly desirable.

Studies on the effect of pure 2,4-dichlorophenoxyacetic acid in comparison with the effect of phenols and a few other phenoxyacetic acids appearing in small amounts together with the 2,4-dichlorophenoxyacetic acid in technical products, were carried out according to plans similar to those followed in 1952 and 1953 for methyl phenol and methyl phenoxyacetic acids. These studies dealt with 4-chlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid and the phenols corresponding to these acids. It was found that the pure 2,4-dichlorophenoxyacetic acid is far superior to the other substances in effect on the weeds, but that it is also more detrimental to the cultivated plants.

In addition, the effects of 2,4,5-trichlorophenol, 2,4,5-trichlorophenoxyacetic acid and 2,4-dichlorophenoxyacetic acid were compared. The phenol is not as effective as the phenoxyacetic acids. The two phenoxyacetic acids behave in a different way. Both of them have a good effect but act differently on the weeds. Thus 2,4,5-trichlorophenoxyacetic acid seems, for example, to be active against Galium mollugo. a species that is quite resistant to spraying with 2,4-dichlorophenoxyacetic acid. These differences in activity of the two phenoxyacetic acids raise the question also for agriculture whether thay should be used in mixtures for spraying. In forestry they are already being used in mixtures with satisfactory results. A special interest in such mixtures certainly arises now that it is being found in Sweden that a close relative of Galium mollugo, namely Galium aparine, is becoming increasingly common in winter wheat fields and cannot be effectively controlled by spraying with preparations of the type methoxone or 2,4-D.

CONCLUSIONS

Since the 4-isomer of the methylphenoxyacetic acid, i.e. the 2-methyl-4-chlorophenoxyacetic acid, is the most active ingredient in the active substance of technical MCPA, the preparations should in future be manufactured with an active substance containing at least 90 per cent 2-methyl-4-chlorophenoxyacetic acid. The preparation of technical 2,4-D should contain the highest possible percentage of pure 2,4-dichlorophenoxyacetic acid in the active substance.

The differences in the specific effects of 2-methyl-4-chlorophenoxyacetic acid, 2,4-dichlorophenoxyacetic acid, and 2,4,5-trichlorophononoxyacetic acid make it necessary to study closely the possibilities of combining 2,4,5-trichlorophenoxyacetic acid with one of the other two acids in order to control weeds, e.g. Galium species, which appear to become more common in fields where several other weeds are controlled by spraying with 2-methyl-4-chlorophenoxyacetic acid or 2,4-dichlorophenoxyacetic acid. Such mixtures should, however, be based on the pure acids.

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TECHNIQUES FOR THE RAPID EVALUATION OF POTENTIAL NEW HERBICIDES

by

K. Carpenter, M. Soundy & C. W. Wilson

(May & Baker Ltd.)

Summary

The need for continuity of method throughout all stages of weedkiller development is considered, and two pieces of apparatus are described which were designed to achieve this:-

(i) A laboratory sprayer for the treatment of weeds and crops in pots.

(ii) A field sprayer for the accurate treatments of small plots.

Details of the performance, including reproducibility, are given. With the laboratory apparatus, the standard error of the means of the deposits of each three replicates is shown to be not more than ± 0.5 galls. per acre for volume rates of 8-80 galls. per acre. Eveness of deposit is obtained by individual selection of the nozzles.

Reproducibility of results with the field sprayer as measured by total deposit over the plot is of a somewhat higher order. The effect of variation within the plot is assumed to be taken up by the normal evaluation techniques.

An example of a practical use of these machines for the rapid and accurate evaluation of a new selective weedkiller is briefly described.

Introduction

Although the final test of a new herbicide is its performance under a variety of field conditions, the large plot field trial is a slow and wasteful method for sorting out potential new materials and is only really suitable for compounds whose worth is already almost certain. For any of the earlier stages of development it is not only wasteful of material, labour and time, but suffers from dependence on the seasons. Thus interesting developments arising after mid-summer must wait for a year before fuller evaluation by this method.

For this reason various laboratory and greenhouse methods of screening and development have been evolved, some of them almost in the *in vitro* class. The more removed from reality the earlier stages are, the more wasteful the sorting out becomes, particularly at the intermediate level, where maximum activity in a particular class of compounds is being sought. It seemed to us that if continuity of technique could be maintained from screening test to field experiment, the results could be directly translated from stage to stage without needless repetition.

The first essential of such a system is to use, whole plants of the species of crops and weeds (or their close relatives), for which it is hoped the final product will be used. The screening test stage and much of the early development work, especially during the winter months, will be on a pot scale. The only published data on laboratory spray apparatus of a suitable size were on spray towers concerned with insecticide application. (Tattersfield, 1934, ten Houten & Kraak, 1949 & Potter, 1952). All these were unsuitable for weed-killer application because of the type of nozzle used.

Low volume treatments could only be obtained with them by using a very finely atomised spray on a stationary plant, giving a completely different spray pattern from that given by field herbicide machinery.

The laboratory apparatus described here was therefore evolved to apply accurately new test materials from the Research Laboratories, using the small quantities which are usually available, at the dilutions and droplet sizes employed in field practice. As the selectivity of many contact herbicides depends very largely on these two factors, this was felt to be of particular importance.

A field sprayer was concurrently evolved to bridge the gap between the laboratory apparatus and full scale spraying machinery.

A brief description of the earlier version of the laboratory apparatus was given at the 111rd. International Congress of Crop Protection in 1952, but as this has not yet been published some of the data are included here.

Results

A. Laboratory Sprayer

The machine was designed to spray weed and crop plants in their young stages growing in 3½" pots. As we wished to use nozzles of the standard field machine type we decided that the only practical solution was to imitate field conditions but to move the crop in relation to the nozzle instead of the other way round. The details of how this was achieved are as follows:-

(a) The motive power: The Chief practical difficulty here was the speed at which the plants would have to be moved. Taking into account the need for compactness and ease of operation a compromise was reached which gave us a maximum speed of 1.8' per second or a third of field spraying speed.

As it was essential for the truck to run at constant speed irrespective of load, a shaded pole induction motor was selected. The type used has a speed of 2,800 revolutions per minute.

The motor is stationary and pulls a light alloy truck along a 6' length of railway by means of a chain drive, which is in turn driven through a simple gear-box having three forward speeds and reverse. The forward gear ratios are 4:1, 6:1 and 9:1 giving us 1.8ft./sec., 1.2 ft./sec., and 0.8 ft./sec. respectively. With this gearing the motor can pull the truck loaded with six to eight 3½" pots and attain its maximum speed in the three feet of track before it enters the spray fan.

(b) The Nozzles: Our aim here was to find a type or range of nozzle which was in general commercial use, would be readily adjustable or interchangeable to give different application rates and could be made with a fair degree of precision. Nozzles giving a conical spray jet were ruled out as they covered too large a length of the railway. The fan jet type of nozzle on the other hand deposits a very narrow band of spray which gives more space and time for the manipulation of the truck.

Two main types of nozzle were available, the ceramic tipped and the all-brass or T-jet type.

The first were rejected mainly because the change in deposit due to wear was found to be appreciable in a short time.

The final choice rested with the brass or T-jet type of which a selected range of sizes were tested.

It was found that all gave a sufficiently even deposit only in the centre 9" of the jet, the outer edges giving a coarser spray of heavier droplets. This was sufficient to take two rows of 3½" pots but nozzles had to be selected which gave even deposition in the two halves of the used area. Eveness could often be improved by minor adjustments of the alignment.

(c) Pressure source: In this particular apparatus it has been convenient to use compressed nitrogen as a source of pressure although an air compressor could equally well be used. The gas is passed via a reducing valve into a 16.5 litre reservoir fitted with an accurate pressure gauge, until the desired working pressure is reached (usually in the range 30-50 p.s.i.). During spraying the gas is passed from here into a spray liquid reservoir and expels the liquid through the nozzle. As the capacity of the liquid reservoir is only 600cc. this can be emptied about three times for a drop of 1 p.s.i. in the pressure reservoir. The effect of such an decrease on the rate of spray deposition in the centre of the fan is very slight, since decrease in output by the nozzle is partly compensated by decrease in the width of the fan.

(d) Performance: The apparatus has been calibrated by weighing the spray deposit on light alloy strips. Different rates of application are obtained by using different nozzles. Those are selected from a batch of commercial nozzles of various sizes, first for amount of deposit and secondly for eveness.

Table 1

Total Deposit of Distilled Water from a Range of Nozzles

Nozzle No.	Speed ft./sec.	Mean of 12 deposits in galls/acre	σ=	S.E. of means of each three replicates
C/60/1	0.8	34.0	± 0.5	± 0.3
	1.2	22.3	± 1.0	0.5
	1.8	15.4	± 0.7	0.4
C/60/2	0.8	23.0	± 1.3	0.5
	1.2	15.5	± 0.7	0.3
	1.8	9.6	± 0.8	0.1
D/60/1	0.8	31.2	± 0.7	0.3
	1.8	13.0	± 0.5	0.3
F/45/2	1.2	44.0	± 0.7	0.3
E/45/1	0.8	7.5	± 1.0	0.5
	1.2	5.8	± 1.1	0.5
	1.8	35.6	± 1.3	0.5
F/60/1	0.8	77.4	± 0.6	0.2
	1.2	52.2	± 0.9	0.4
	1.8	34.9	± 0.7	0.4
G/45/1	1.8	86.1	± 2.0	3.0

The standard errors of these results are somewhat higher than those obtained with the improved Potter tower (Potter 1952), but compare favourably with the values given by ten Houten & Kraak (1949). In both cases precision-made nozzles were being used.

Results of tests for eveness of deposit from one nozzle on the two rows of pots are given in Table 11.

Table 11.

Distribution of Deposit for Two Nozzles

Nozzle and Test	Position	Deposit in galls/acre	S.E. of 9 runs runs on one side	S.E. between sides on each run
G/60/1 emulsion 11 before alignment	R.H.	54.8		
	L.H.	49.7	± 1.1	± 2.4
G/60/1 emulsion 11 after alignment	R.H.	52.9		
	L.H.	51.0	± 0.3	± 0.7
G/60/1 emulsion 1	R.H.	57.8		
	L.H.	55.2	± 0.6	± 1.1
G/60/1 water	R.H.	63.0		
	L.H.	61.6	± 0.4	± 0.9

(e) Housing and operation: Since one of the objects of this apparatus was the evaluation of new materials, the human toxicity hazards of which might be incompletely known, the apparatus was housed so as to isolate the operator from the spray. How this was achieved is shown in the accompanying photographs. In Fig. I, the operator's side of the apparatus is shown. Here we see the pressure and spray reservoirs, the controls for their operation, the motor and the switching gear. Access to the truck is through two sliding panels. Fig. II shows the spraying side of the apparatus with the nozzle assembly, the railway and the truck about to pass under the spray. One filling of the 600 cc. reservoir will last for 7-10 runs of the truck or 40-80 pots, according to the rate of application number of pots per run, etc.

B. Field Spraying Machine

The field spraying machine was built on exactly the same principle as the laboratory apparatus.

(a) The motive power: The spray equipment was mounted on a single wheel motor hoe which was driven by a 98 cc. petrol engine. This engine was fitted with a constant speed governor which worked very well under the conditions of use, i.e. without any significant load, to give a speed of 2.5 m.p.h. (S.E. of 16 runs at different dates = ± 0.1%).

(b) The nozzles: The same type of nozzles were used as in the laboratory apparatus. Three, selected for eveness of spray pattern, were mounted in a boom 18" apart to give a swath width of 4'6".

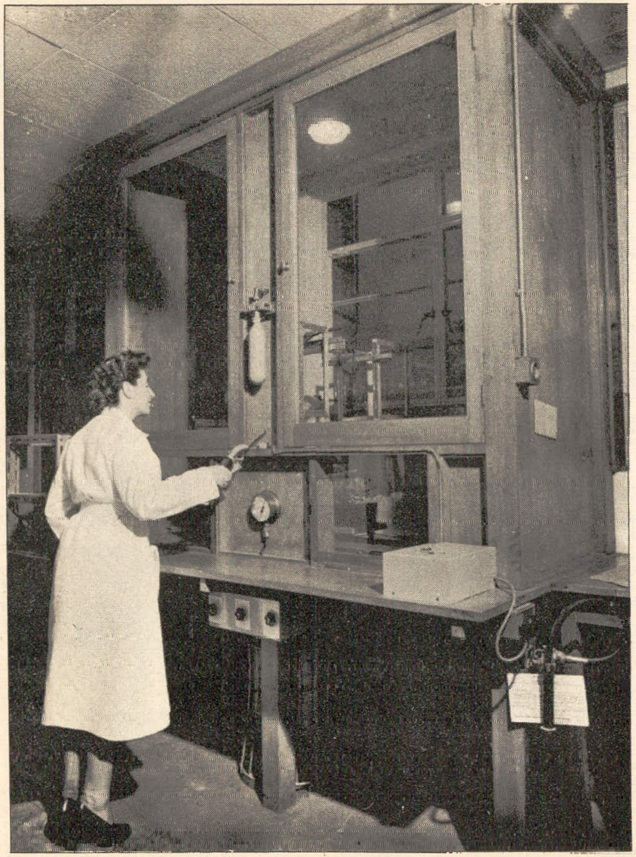

Fig. I - General view of the laboratory sprayer

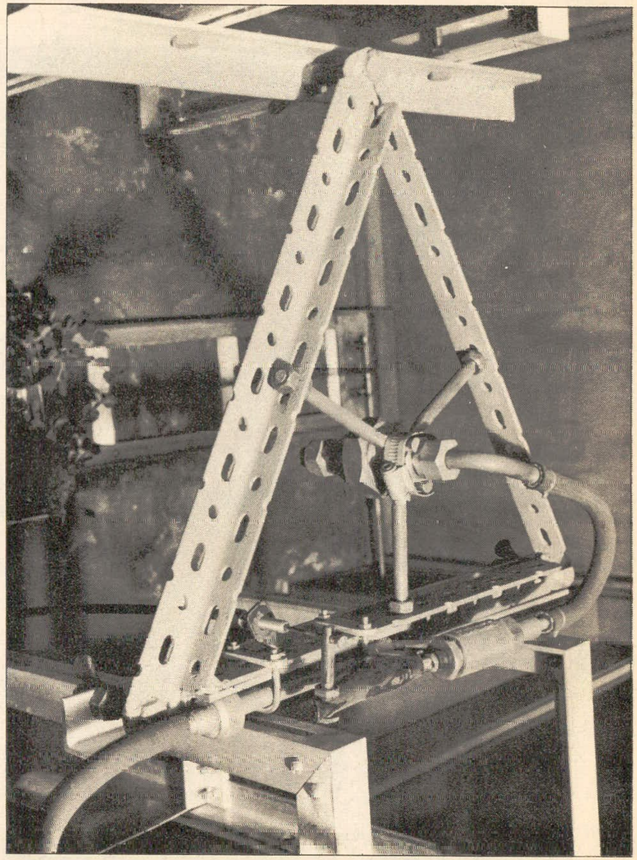

Fig. II - Laboratory sprayer - details of nozzle assembly

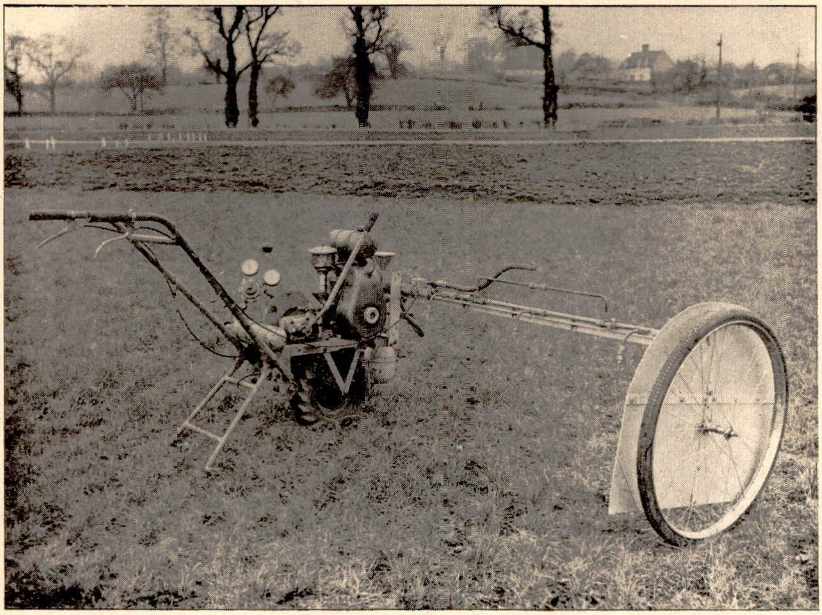

Fig. III - The field plot sprayer

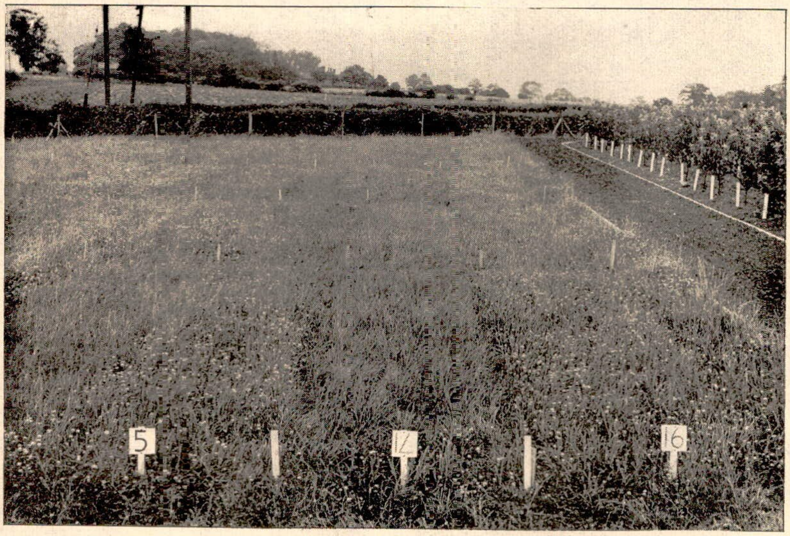

Fig. IV - General view of the type of plot layer used with the field sprayer.

(c) Pressure source: A small cylinder of compressed gas at approximately 2,000 p.s.i. was mounted on the machine and fitted with a reducing valve. For the sake of compactness the low pressure gas reservoir was omitted.

(d) Mounting: The mounting of the spray apparatus on the machine is shown in Fig. III. The far end of the boom is supported by a bicycle wheel and the height of the boom above ground can be adjusted to suit the height of the crop. Ideally that should be 18" clearance.

(e) Performance: The machine was intended to spray four replicate plots 4'6" wide and 20' long at one filling, (Fig IV). It was therefore calibrated by filling the spray reservoir with approximately the quantity of water needed to do this, and the distance travelled to obtain complete run out was measured. This does not of course give any measure of the evenness of deposition, but it is assumed from the other data that this is sufficiently good to average out over the plot area in terms of weeds killed. The results of such calibrations are given in Table III.

TABLE III

Performance of Field Sprayer with Various Sets of Nozzles, all Operating at 30 p.s.i.

Nozzles	Volume applied galls./acre	for 16 replicates as % mean	S.E. of means of each 4 replicates as % mean
C60	7.9	± 0.3%	± 0.1%
D60 (1952)	10.4 x	± 0.3% x	± 0.1%
D60 (1953)	10.7	± 0.2%	± 0.2%
F60 (1953)	15.7	± 0.1%	± 0.1%
F60 (1954)	15.1	± 0.2% x	± 0.1%
G60	20.6	± 0.2%	± 0.2 +

x Eight replicates only

Discussion

A. Laboratory Sprayer

Table 1 shows that the standard of accuracy and reproducibility is fairly high. In terms of deposit the standard errors are fairly constant, whatever the volumes of water. Thus the higher volume nozzles give the greater degree of accuracy and in development work, where such accuracy is generally needed, nozzles giving about 50 galls per acre are used for preference. The '45' series of nozzles, having only a 45° spread of fan, are less wasteful than the '60' series and are therefore used for higher volumes but will not, at our trolley speeds, give low volume deposits.

The agreement between deposits and the two halves of the spray area is good (Table 11) providing that the nozzle is accurately aligned. This Table also illustrates the effect of formulation on the amount of deposit, surface tension agents generally producing a lower rate by altering the spread of the fan. This effect is more pronounced with very low volume nozzles, differences being as much as 30% reduction in deposit.

The standard errors for three replicates at a time are given because this is the minimum of replication allowed and is usually limited to screening tests. For toxicity studies eight or more may be employed.

The limiting factor of the reproducibility of results with this machine is thus likely to be the evenness of development of test plants before and after spraying. This can only be achieved by having adequate glasshouse space with reasonably controlled growing conditions. With such facilities a considerable quantity of screening and development work can take place in the winter time, on both weed killing power and crop toxicity (Carpenter & Soundy, 1953).

Some weed species are not easily grown in quantity in the winter months even with artificially improved conditions. It is usually best to find substitutes for these which have been shown to give similar responses with known herbicides. Some which we have found useful are:-

<u>Chenopodium amaranticolor</u> for <u>Chenopodium album</u>

Shirley Poppy for <u>Papaver rhoeas</u>

White Mustard for <u>Sinapis arvensis</u>

Perennial weeds cannot be submitted to the test but one can at least be sure that results obtained with annual weeds will be reproducible in the field.

B. The Field Sprayer

The apparently greater accuracy of the field sprayer is, of course, due to the difference in method of calibration, which only gives an estimate on mean deposit over the whole plot area at each reading. The evenness of deposit within the plot can only be controlled simply by selection of nozzles on evenness of spray pattern. The significant feature of the calibration results is the high degree of reproducibility between replicates and between runs at widely separated dates, especially as the machine has been in constant use. The standard error of each four replicates is given because this is the normal arrangement in all our field experiments.

The small size of the plots is no disadvantage with accurate application methods and facilitates the use of compact layouts with a high degree of evenness of weed population and crop growth. On the other hand the close similarity between the spray characteristics of this machine and those used in practice enables the results from the small plots to give a reliable indication of field performance on a commercial scale. Naturally such dangers of commercial application as overlapping, under and overspraying, too early and too late spraying, must be allowed for by examining a wide range of applications rates and stages of growth of crops and weeds. Adequate safety margins can then be calculated.

C. Practical Working of Techniques

By suitable combinations of results from both laboratory and field sprayers all the aspects indicated above can be examined rapidly and with very small quantities of material, agriculturally speaking. New series of potential herbicides can be thoroughly examined in the winter months and a few of the most active selected for field experiments in the following spring. Problems arising from these field experiments can be examined in detail concurrently in the greenhouse for the most promising candidates as soon as they arise. Frequently these can be confirmed in the field during the same season.

An example of the working of this system has arisen this year following the discovery by Professor Wain of the greater selectivity of the substituted γ-phenoxybutyric acids (Wain, 1954). As the synthesis of the 2:4-D. and 2:4:5-T. series was carried out in our Dagenham laboratories by Dr. K. Gaimster when working under Prof. Wain as a candidate for the Ph.D. degree (Gaimster, 1954) we were aware of this development and followed it up in a series of experiments which were parallel to those of Prof. Wain, but with a different emphasis.

By using the methods described above γ (4-chloro-2-methyl) phenoxybutyric acid was shown to combine weed killing power approaching that of M.C.P.A., although differing in detail, with a much higher degree of selectivity in favour of seedlings of clover varieties. Many of the details were worked out in the glasshouse in the early months of 1954 and as a result a comprehensive series of field experiments of the small plot type were laid down. These established the practical value and reliability of the compound beyond doubt.

Details of safe growth stages of crop varieties have been further examined in subsequent greenhouse and plot experiments until development is now at a stage where practical use can be recommended. (Plate 4 shows a typical standard plot layout comparing the toxicity of this compound and M.C.P.A. against white clover.)

It must be emphasised, that with this particular type of compound the problem was greatly eased by our already extensive knowledge of the behaviour of the corresponding phenoxyacetic acid and the knowledge that this was the active principle, biologically speaking. With members of a completely new series, much more confirmation over a longer period would be necessary.

Acknowledgements

The authors would like to thank Mr. J. P. Howard for his considerable contribution to the technical development and construction, of these sprayers.

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AN EXPERIMENTAL TECHNIQUE FOR INVESTIGATING LEACHING OF HERBICIDES

G. S. Hartley and P. O. Park (Pest Control Ltd.)

There is considerable interest in the application of herbicides to the soil, either deliberately to arrest the germination of weeds which have not yet appeared, or incidentally to other applications. In either case a hazard to the crop seeds may arise. The permanence of herbicidal action in the soil is therefore a matter of some importance.

The herbicide may be decomposed by inanimate or biological mechanisms in addition to being leached downwards by rain. It seemed therefore desirable to design some apparatus which would enable the leaching and decomposition processes to be separated, and the significance of the former to be measured. In sampling soil from different small depths, it is notoriously difficult to avoid mixing; preferably therefore a method of analysis in situ is desirable. Since we are in some cases (e.g. the hormones) concerned with chemicals which are more sensitively detected by biological response than by chemical analysis, we decided to use the effect on seeds for determining the presence of the herbicide.

We therefore constructed an apparatus in which a vertical column of soil can be subjected to artificial rain but which can at the end of the experiment be turned horizontally and opened along the side so that a line of seeds can be sown at a standard depth, their position along the line representing however different depths in the original percolation experiment. The state of the seedlings after a suitable interval then gives us as it were an automatic chromatogram of the distribution of herbicide.

We have only recently started to use this technique. It has already revealed that there are very big differences in the rate of leaching of different herbicides, Dinoseb for example being much more strongly retained by the soil than MCPA, and TCA leaching out most rapidly of all those examined. It is of interest that, in the only soil so far examined, namely a typical potting mixture, MCPA is surprisingly rapidly decomposed. In the experiments so far undertaken the columns were uniformly filled with the same composition, whereas, to represent most agricultural conditions, it would be necessary to work with a complete soil profile.

Our main object however in presenting this note is not to describe results but to demonstrate a method which others interested in this field may perhaps find useful. The apparatus involved is more easily demonstrated than described, and we have therefore brought the machine along to the conference, complete with "live" graphs and a number of photographs of results of typical experiments. These will be available for inspection by anybody who is interested in this subject.

DISCUSSION ON FOUR PREVIOUS RESEARCH REPORTS:

Dr. K. Holly: The technique described by Dr. Hartley and Mr. Park is very interesting, but at the moment it seems to be mainly for demonstration. If it is going to be used as a precise quantitative tool, some allowances must be made for uneven distribution of nutrients in the columns. This may be due to an initial variation or due to leaching of the nutrients in the course of the experiment.

Mr. P. O. Park: In the six columns demonstrated, we have included a control; a completely untreated soil running simultaneously with the columns treated with herbicides. The plants show that there has been very little leaching of nutrients, such as would affect the evenness of growth of indicator plants, nor can there be any wide variability in the nutrient status of this artificial soil. This might not be so on natural soil profiles.

Mr. J. G. Elliott: Has Mr. Carpenter had any trouble with his small plot sprayer in manoeuvring on and off the plot? Uniform weed infestations in the field are difficult to find and it is desirable to have the maximum area in the plot and the minimum discard for moving the machine. I would have thought that he would need a considerable area for manoeuvring.

Mr. K. Carpenter: We usually have a standard method of laying out plots that requires a 6 foot runway between the random blocks but none between individual plots. If all four replicates are sprayed at the same time only the three cross paths are wasted. The machine is easy to manoeuvre as the boom is made of light alloy and where there is acute shortage of space much narrower runways can be used.

Both the engine clutch and the spray shut-off are operated by handle-bar levers through Bowden cables, one on each handle-bar. Movement and spraying can thus be started and stopped almost simultaneously.

SPRAYING EQUIPMENT FOR THE EXPERIMENTAL APPLICATION OF HERBICIDES

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Introduction

This paper describes briefly a pneumatic type knapsack sprayer and two Land Rover mounted sprayers all of which have been developed by the Unit of Experimental Agronomy specially for the application of liquid herbicides in experimental work. The sprayers have been used extensively during the 1953 and 1954 spraying seasons and have reached the stage when further improvement is likely to be a matter of detail rather than of principle.

PNEUMATIC TYPE KNAPSACK SPRAYER (Fig. I, II & III)

This equipment, which is now being manufactured commercially under the name 'Oxford Precision Sprayer', has been designed with the following objects in view:

1. It must apply accurately volume rates between 5 and 100 gallons per acre on plots of up to 1/200 acre in area, larger plots being permissable with lower volume rates.

2. The spray applications should, if required, resemble applications made by commercial low volume or dual purpose sprayers operating at pressures of up to 60/lb/sq. in.

3. There should be no wastage of the spray fluid.

4. All parts in contact with the spray fluid must be easily dismantled for cleaning.

5. It must be able to spray a large number of plots in a day without unnecessary time being spent on filling, washing and adjustments.

6. It must be adaptable for varying needs and capable of being transported in the luggage boot of an average car.

7. It should be capable of spraying corrosive liquids if required without undue deterioration.

8. It should be usable in undeveloped parts of the world.

9. It should be light in weight.

Description

A light alloy air pressure container carried on the back of the operator is pressurised to 110 lb/sq. in. through a car type 'Schrader' valve. A convenient source of pressure is the compressed air line available at most garages, or in the field a portable compressor or tyre foot pump. Each container is tested before use to 220 lb/sq. in. by the manufacturers and has a bursting pressure of not less than 500 lb/sq. in. A safety valve operates at about 140 lb/sq. in.

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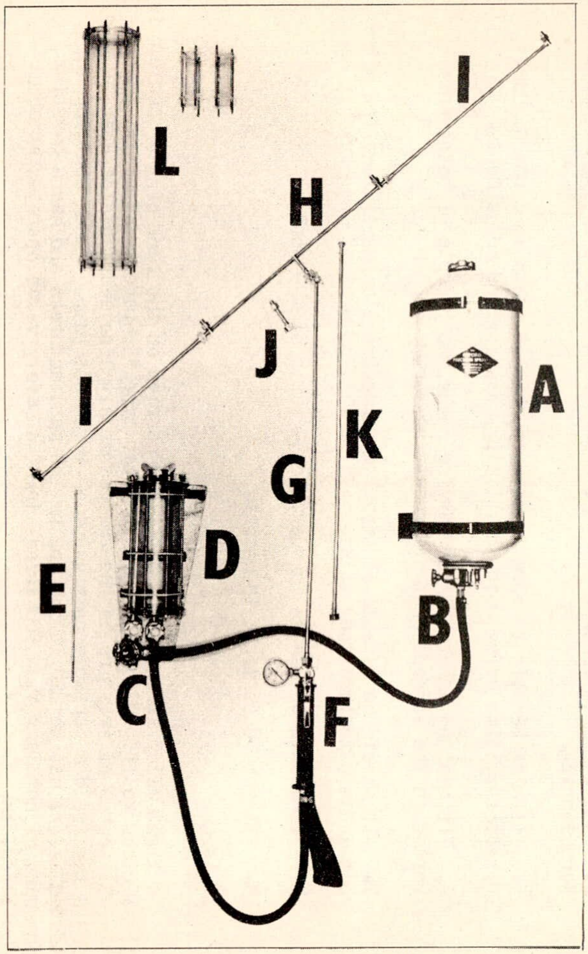

FIG. I.

OXFORD PRECISIOR SPRAYER

A - air pressure container.
B - base plate of air pressure container with 'schrader' valve air inlet, outlet tap and safety valve.
C - pressure reducing valve, air inlet tap and liquid outlet tap mounted on base plate of liquid container.
D - liquid container (3 pint size) mounted on breast plate.
E - accessory air tube to convey air to top of liquid container when the 5 pint liquid container is used.
F - handle assembly with fore-arm rest, handle containing filter, trigger tap and pressure gauge.
G - main lance section.
H - centre boom section with two jets.
I - outer boom section with one jet.
J - adaptor for use when single jet only is required.
K - additional lance section.
L - liquid container tubes (1 and 5 pints capacity) and tension rods.

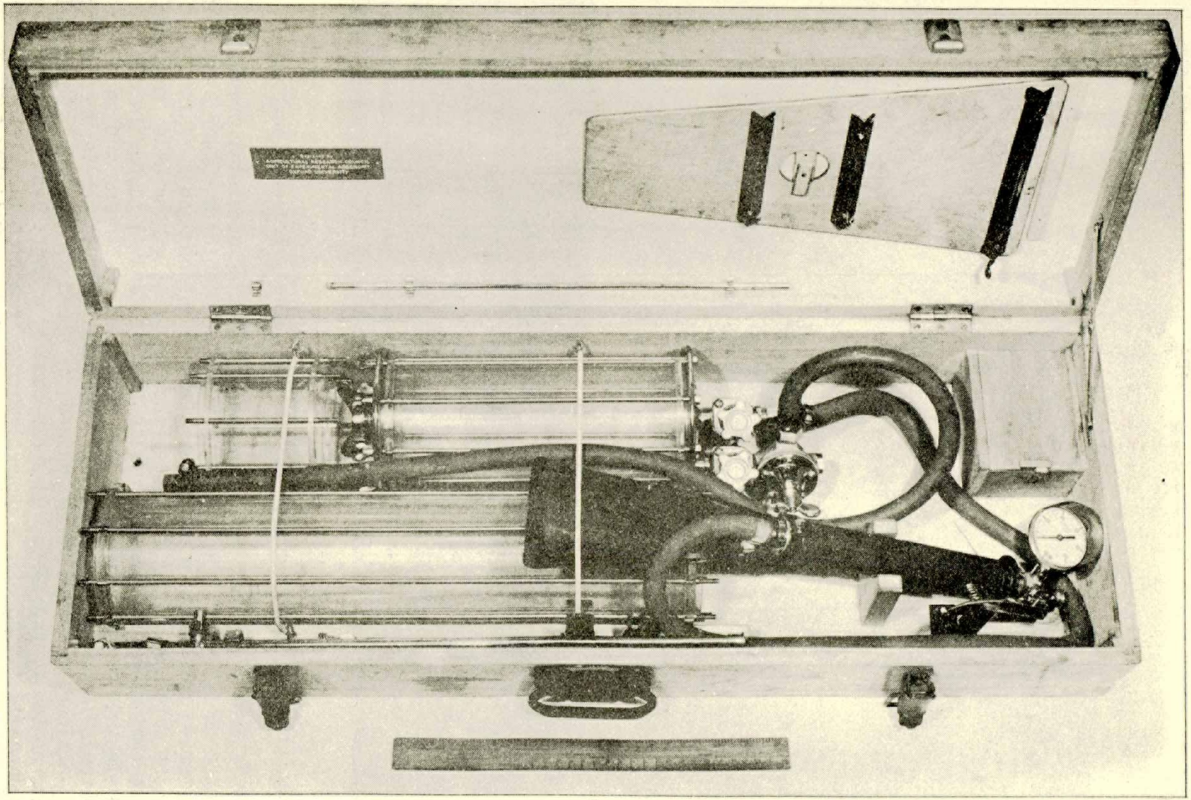

Fig. 11. OXFORD PRECISION SPRAYER

For transport and storage, all components except for air containers and windshield are packed into box as shown.

Fig. III. Oxford Precision Sprayer. Method of operation.

The spray liquid is carried in a transparent plastic[x] and metal pressure container mounted on a breastplate and slung from the webbing shoulder straps of the air container. Three liquid container sizes have been used: 1 pint, 3 pint and 5 pint capacity. The container ends are easily removable from the plastic tube so that change of container size involves only a change in the length of plastic tube and supporting rods. This can be carried out in the field without tools in under five minutes. The liquid container is pressurised from the air container, pressure being adjusted by a reducing valve. The liquid container is connected to the lance and spray boom by a short length of pressure tubing. The lance is fitted with a sensitive trigger action tap giving instantaneous cut-off; a large capacity fine mesh filter is fitted into the handle. Two lance sections are available giving a maximum length of 6 feet. At the end of the lance a single jet or a spray boom can be fitted.

x 'Perspex' acrylic tubing

The spray boom is in three sections. If the centre section only is used, a swathe width of 3 feet is obtained utilising two ceramic fan jets at 18 inch spacing. The centre and two outer sections have a total width of 4.5 feet giving a swathe width of 6 feet. The boom can, of course, be readily modified for any desired jet type or spacing.

A celluloid and light alloy angle windshield for the boom has proved effective when the centre boom section only is used, but has been unsatisfactory when fitted to the 4.5 foot boom because of the surface area presented to the wind and the air turbulence caused by it.

Two models of the 'Oxford' sprayer have been constructed: (1) a 'standard' model, the metal parts of which are mostly of chromium plated brass, for use with non-corrosive liquids, (2) an acid-resisting model in which parts liable to corrosion are made of stainless steel or ebonite.

Production of the latter type has proved difficult and expensive because of the working properties of stainless steel and our present view is that the standard model for general experimental work is the more satisfactory, even for occasional use with corrosive liquids providing the equipment is washed thoroughly after use.

Weight of the equipment has been reduced wherever possible; the operator carries only 18½ lbs including air and liquid containers and lance and boom assemblies. The air and liquid containers alone weigh 12 lbs.

Operation

The equipment can be used by one person, but an additional person facilitates assembly and filling. A team of two is ideal, one operating the equipment, the other mixing and handling the spray solutions and attending to the change-over of air containers.

When using an 'Oxford sprayer a plot size of 12 yards x 2 yards (C.1/200 acre) has been found convenient for many types of herbicide experiments where volume rates of up to 100 gallons per acre are required. Smaller plots can be easily sprayed, also larger plots of up to 1/10 acre but the volume rate may be limited by the capacity of the liquid container. The maximum plot size that can be conveniently sprayed at up to 30 gallons per acre is in the region of 1/60 acre e.g. 20 yards x 4 yards. This is about the minimum plot size for cereal yield trials when 8'6" cut pusher type combine harvesters are to be used for yield assessment; plots of twice this length are very desirable if accurate comparisons are required.

These larger 1/30 acre plots may be sprayed at up to 15 gallons per acre with the 'Oxford' sprayer, but this might be tedious as a routine procedure.

Before each day's spraying, both air containers are pressurised to 100 - 110 lb/sq. in. Each container charge will deliver about 45 pints of liquid at 30 lb/sq. in., the amount depending on the initial charge pressure and the number of liquid container fillings made. The latter will be influenced by the spraying technique adopted. If low volumes or small plots are used, it will be possible to have enough spray fluid in the liquid container to treat all replicate plots of any one treatment without refilling thus economising in air; for higher volume rates and larger plots it may be necessary to refill the liquid container after each plot sprayed and more air will therefore be consumed. In general, our experience has been that two fully charged air containers will give sufficient air pressure to spray the majority of 1/200 acre plot field experiments carried out by the Unit of Experimental Agronomy.

Accuracy

The accuracy of the sprayer is, assuming accurate delivery and application from the jets, influenced mainly by the pressure at the jets and speed of travel. The pressure gauges used are claimed by the manufacturers to be accurate to ± 1 - 2% and are located so that no significant pressure drop takes place between the gauge and the jets when the sprayer is delivering its maximum recommended throughput (60 gallons per acre at 2 m.p.h. with 6 foot swathe). The speed of travel is, of course, subjective and a matter of practice, but it has been found easy to attain an accuracy of ± 2%. A good check on accuracy is obtained if the exact quantity of liquid for each plot is put into the liquid container as a routine procedure.

The method of walking is important in attempting to obtain a uniform boom speed. Long slow steps give rise to an irregular movement; while short quick steps allow an even forward motion. A convenient speed is 2 m.p.h. A short length of chain suspended from the boom so that its end brushes the top of the crop or weeds to be sprayed helps to maintain the boom at the required height.

Ceramic fan jets are used at present because they are cheap and light and obtainable in a wide range of orifice sizes; The individual jets are matched for throughput. The spray pattern is far from perfect, but at least it is representative of that obtained with many commercial spraying machines. Improved jets will be substituted as and when they become available.

Materials

As has been stated, stainless steel has proved difficult to work, particularly in the fabrication of the handle and trigger tap. A promising alternative material is ebonite, which has shown considerable resistance to strong acids and oils in preliminary tests. The design of the tap allows the assembly to be made from a single piece of ebonite rod.

All taps work on the principle of a diaphragm being pressed against two concentric orifices and all but the lance trigger tap are obtainable as proprietory products. The taps have proved reliable in operation and are light in weight and cheap. Oil resisting synthetic rubber is used for the diaphragms. The body of the taps are of acid-resisting bronze or ebonite where they come into contact with liquid, or light alloy in the case of the air taps.

The liquid container is constructed from ⅛" x 4" o.d. plastic tubing. This has proved reliable in practice and has shown no deterioration with a wide range of herbicide formulations.

LAND ROVER SPRAYERS

The Unit of Experimental Agronomy has during the last four years carried out in co-operation with the N.A.A.S. an extensive programme of field experiments, chiefly on cereals and on grassland. Preliminary results and the general administration of some of these experiments have been briefly recorded by Fryer (1) and Elliott (2). During this period about a hundred and eighty experiments have been sprayed involving some six thousand plots. The majority have been sprayed by means of two mobile large plot sprayers mounted on 'Land Rovers'. It is not feasible to give detailed descriptions of these machines but a short survey of their more interesting features is given below.

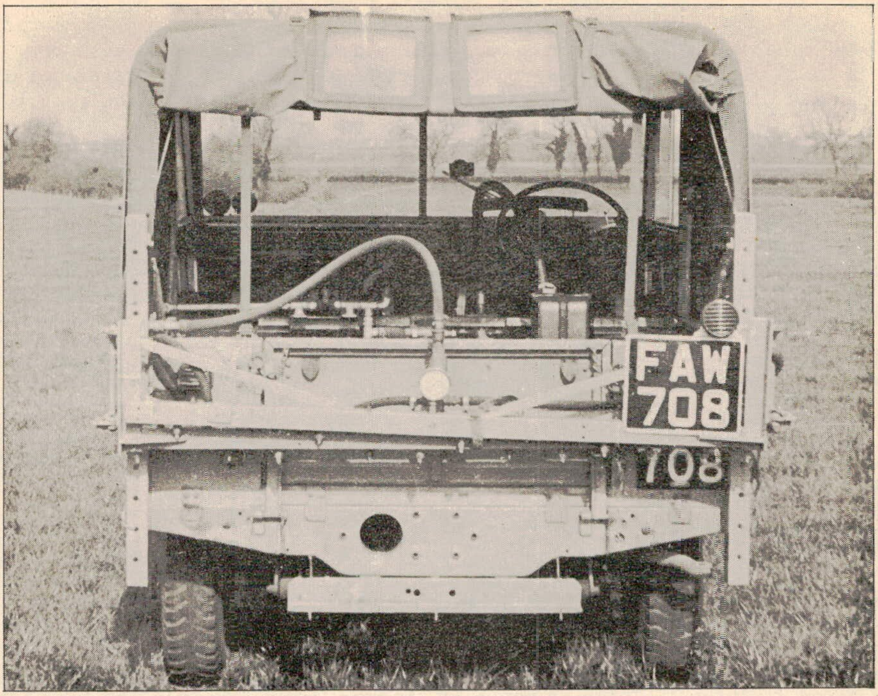

Fig. IV. LAND ROVER SPRAYER FOR LOW VOLUME APPLICATIONS. General view - boom closed, ready for road transport.

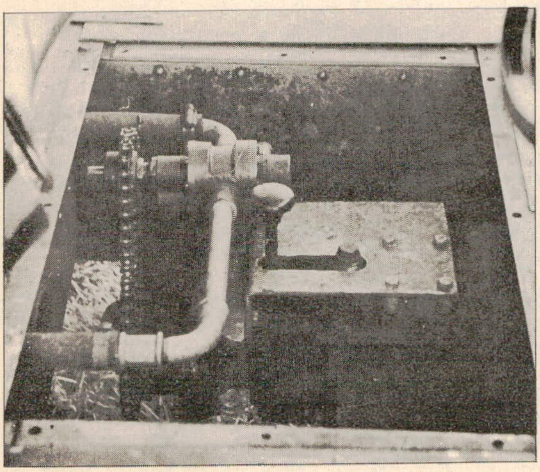

Fig. V. LAND ROVER SPRAYER FOR LOW VOLUME APPLICATIONS. Showing pump drive and mounting under centre seat.

Fig. VI. LAND ROVER SPRAYER FOR LOW VOLUME APPLICATIONS. Showing speedometer and drive for use while spraying.

Sprayer for Low Volume Applications (Fig. IV, V and VI)

One of these Land Rovers has been equipped with an half inch gear pump driven by chain from the central power take-off assembly and is positioned under the central seat. The pump operates at about 1,000 r.p.m. when the vehicle is travelling at 4 m.p.h. with the transfer gear box engaged.

The spray liquid is carried in 4 gallon 'jerricans' and is fed to the pump by means of a pipe inserted into the filler orifice. A quick-action lever tap for controlling the spray is situated near the driver. A by-pass circuit with a spring-loaded relief valve allows ready pressure adjustment. The 15 foot boom assembly is based on that from a well known proprietory sprayer, the vertical steel joists being permanently mounted on the vehicle. The sprayer can start work within ten minutes of arriving at a field. The carrying capacity of the vehicle is in no way reduced by the equipment. A specially made speedometer indicates accurately ground speeds of up to 12 m.p.h., the required speed being maintained by the use of a hand throttle control.

This equipment is suitable for spraying at volume rates up to 30 gallons per acre at 4 m.p.h. and pressures up to 60 lb/sq. in. Plot size is limited only by the capacity of the liquid containers used.

General Purpose Sprayer (Fig.VII, VIII, IX, X, XI)

The second Land Rover has permanently fitted to it more elaborate equipment, allowing it to be used for the rapid and accurate spraying of experiments involving the comparison of up to three different volume rates, the maximum rate being well over 100 gallons per acre at 4 m.p.h. In addition to normal crop spraying, it can be used for special applications such as scrub and roadside verge spraying. The proto-type of this equipment was built at Long Ashton Research Station and the existing equipment at the National Institute of Agricultural Engineering.

The equipment consists basically of three independent spraying circuits, each with its own pump, controls and spray boom. Four 20 gallon tanks, generally used for the high volume spray liquids, are connected by a manifold and multiway tap to the suction side of a 1½ inch gear pump. Medium and low volume spray liquids are carried in specially adapted 4 gallon jerricans and are fed to a 1 inch and a ¾ inch gear pump respectively. Each pump is fitted with an intake and output filter and a by-pass circuit incorporating a relief valve and feeds to one of three spray booms mounted on a framework at the rear of the vehicle. The height adjustment of this framework allows a vertical movement of over 4 feet and the booms can also slide in a fore and aft direction to ensure that the rear of the vehicle is not sprayed when cone jets are used with the boom at its maximum height. Each boom is fitted with a pressure gauge.

The pump drive is an interesting feature of the equipment. A countershaft is mounted on the floor of the Land Rover at the rear and driven by chain from the rear power take-off. A swinging arm is pivoted on this shaft, transmitting power by a second chain to a shaft at its upper end. This shaft is fitted with a dog clutch which engages in a similar clutch on the shaft of each of the three pumps. The latter are mounted so that their shafts lie on the arc traced by the swinging arm dog clutch. A fixed quadrant takes the weight of the drive off the pump shafts and allows positive location of the driving clutch.

The main tanks are built as a single unit to reduce weight and keep the centre of gravity as low as possible to allow spraying on slopes. They are self-draining and fitted with a large filter basket and a watertight cover so

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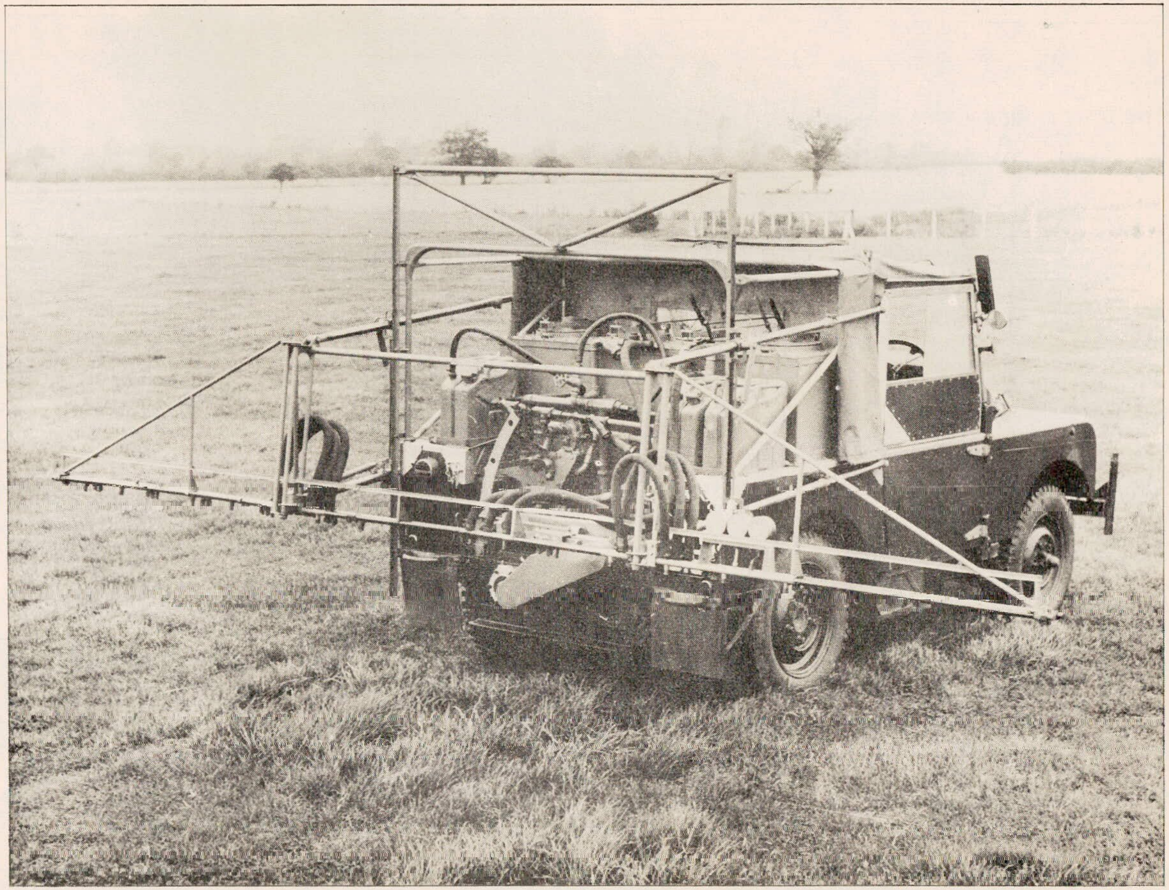

Fig.VII. Land Rover Sprayer - General Purpose Model. General view - booms open.

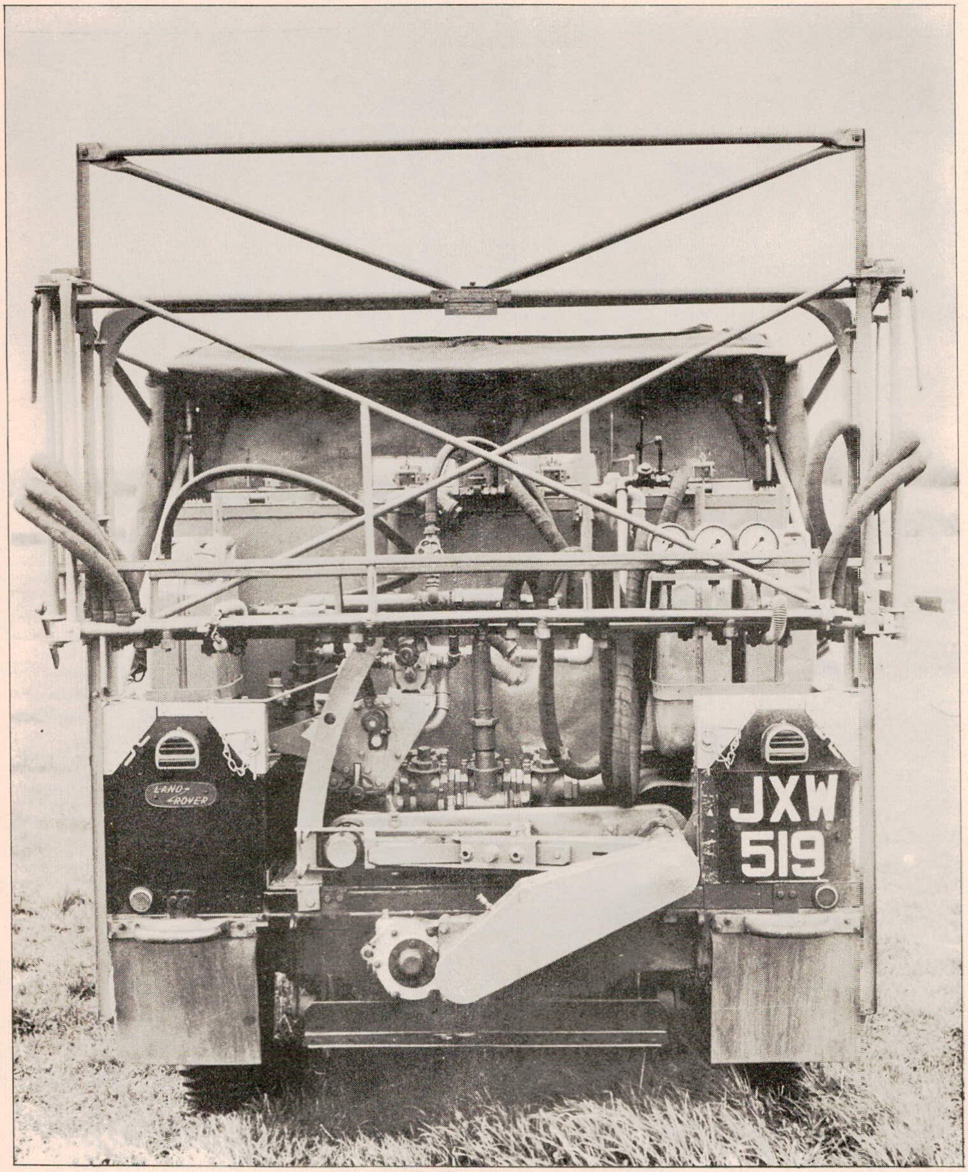

Fig.VIII. Land Rover Sprayer - General Purpose Model. Booms closed ready for road transport.

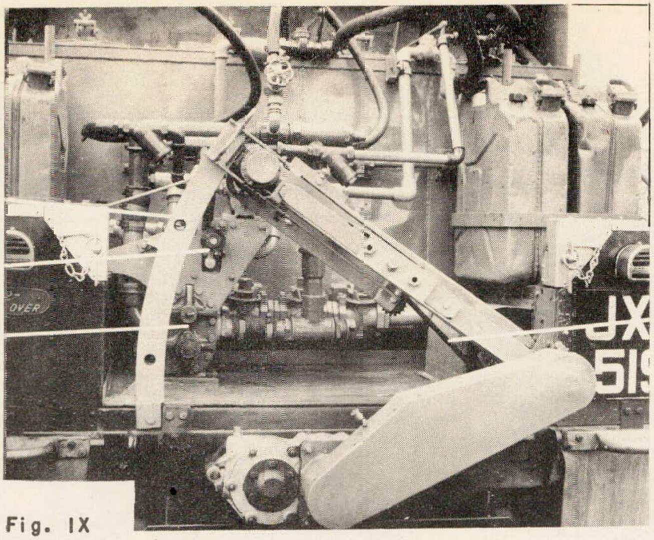

Fig. IX

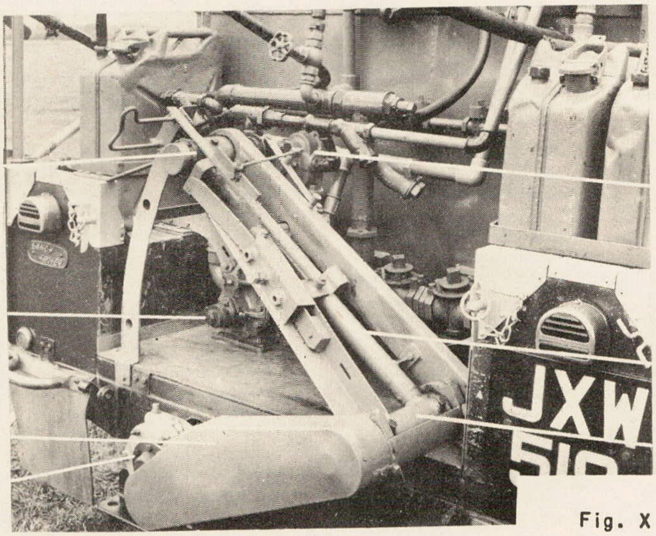

Fig. X

FIGS. IX & X. Two close-up views showing details of pump drive. An enclosed chain drive (A) transmite power from the power-take-off (B) to a counter shaft (C), which forms the axis of a swinging arm (D). A semi-enclosed chain drive (E) on the swinging arm transmits power to the pump drive shaft (F), which connects to the pump shaft through a dog clutch (G); the pumps are mounted so that their shafts lie on the arc traversed by the pump drive shaft. The swinging arm is located for a given pump by means of a fixed quadrant (H). In both photographs the pump drive is connected to the ¾ inch pump (J). The 1 inch (K) and 1½ inch (L) pumps can be seen in Figure IX.

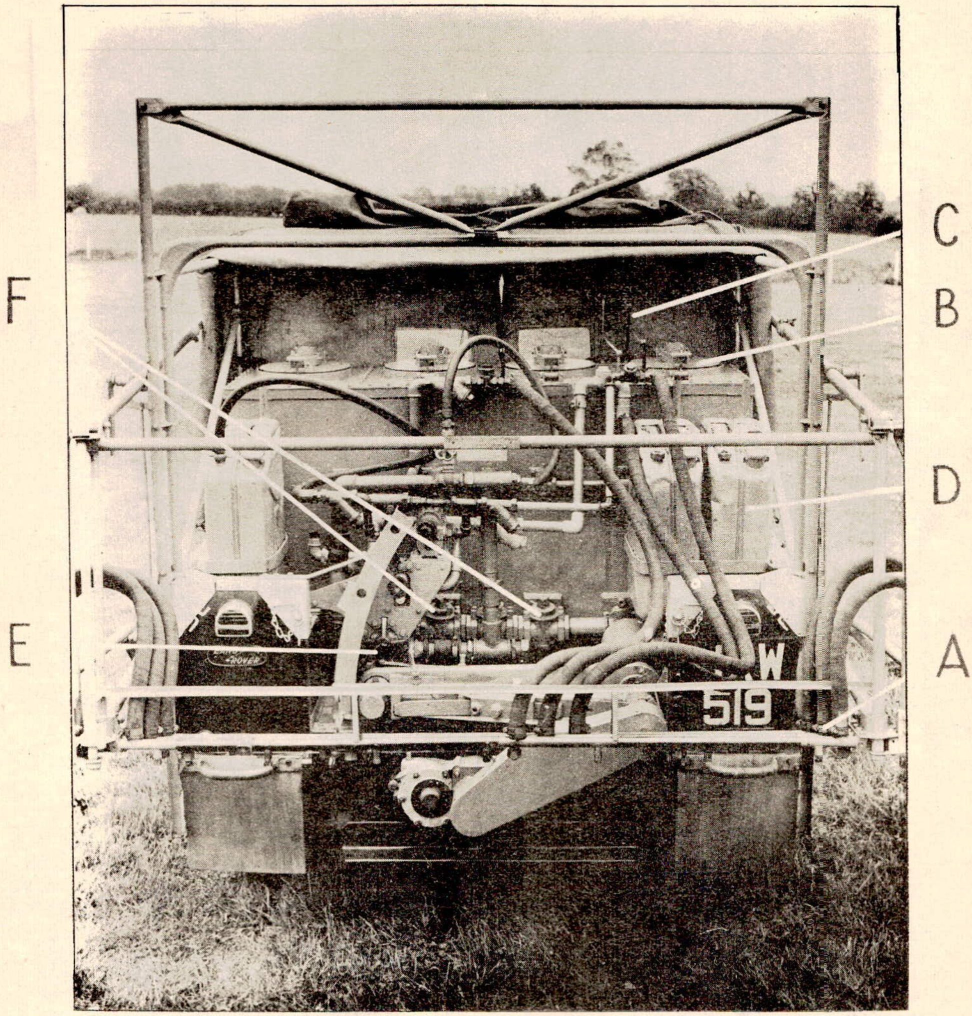

FIG. XI. Close-up rear view showing general layout. Centre section only of spray boom assembly visible. Note the triple booms for different volume rates (A). Liquids for high volume application are contained in four unit-construction 20 gallon tanks, on the top of which the filler-caps (B) and control levers (C) can be seen. Liquids for lower volume applications are in 'jerricans' (D). The pump drive is connected to the $1\frac{1}{2}$ inch pump (E). Two out of the four $1\frac{1}{2}$ inch taps (F) for the 20 gallon tanks are visible.

that no leakage occurs while travelling on the road or over rough country. The tanks are zinc sprayed internally to resist corrosion.

The problems of preventing road-dust from entering the spraying circuits and contamination of the operator's hands with poisonous spray liquid have been overcome by permanent connection of all parts of each circuit. This has been aided by mounting the spray booms at the rear of the vehicle allowing them to fold inwards for travelling. This applies to both of the Land Rover sprayers.

The Land Rover sprayer can travel as a self contained unit, providing all spray treatments have been mixed before starting. A rack for 'jerrican' transport is provided on the front bumper in addition to two at the rear of the machine. Normally, a second vehicle carries chemicals, water supply and auxilliary equipment in order to reduce the load on the Land Rover. The latter has, in fact, withstood the heavy load extremely well; no special modifications, apart from heavy duty springs at the rear, have been necessary.

The accurate control of ground speed while spraying is aided by an engine governor and an aircraft-type electrical tachometer. The equipment is readily operated by the driver alone; all controls being conveniently placed.

Detailed drawings of the larger of the two Land Rover sprayers are available from the National Institute of Agricultural Engineering, Silsoe, Bedfordshire.

DISCUSSION

The respective uses of the knapsack and the Land Rover equipment can be fairly clearly defined. Plot size, availability and cost of chemicals and the size of the experimental area are the chief factors concerned. The Land Rover sprayers are unavoidably wasteful of the spray liquid as the spray circuits have to be filled before the spraying of a plot begins and hold liquid that must be discarded after the spraying of a single treatment has been completed. Their use, therefore, is largely restricted to development work with herbicides that are already commercially available. Another drawback inseparable from their use is the relatively larger discard area around each replicate to allow manoeuvring in and out of the plots. This may not be important in cereals or in grassland work but is often disadvantageous by increasing the total area of an experiment, thus limiting the number of plots and possibly increasing the experimental error.

A further disadvantage with the centrally mounted boom is the wheel-marking of the plots; this can in some measure be compensated for by running the sprayer over the unsprayed plots, but a better solution is to use a boom projecting to one side only of the vehicle and run the wheels on discard areas between the plots.

In spite of these drawbacks, the Land Rover sprayers have proved invaluable tools for experimental spraying, being versatile, accurate and economical in man power and time, vital factors in weed control work when the spraying season is short.

The knapsack equipment possesses none of the drawbacks mentioned, but its scope is obviously limited by the plot size and volume rates stated above. Within its limitations it has proved very satisfactory and has largely replaced the Land Rover sprayers, except where plot size or spraying technique have necessitated use of a bigger machine.

In conclusion it may be said that, while the equipment described above has proved satisfactory for a large variety of experimental applications of herbicides, there is still much room for improvement; it is anticipated that modification of the existing equipment; and if necessary design of new equipment, will be carried out from time to time and as new spraying techniques and new chemicals requiring a different type of spray application are developed.

Acknowledgements

The authors wish to acknowledge the willing help given by many people and organisations, in particular: Dr. H. G. H. Kearns and Mr. N. G. Morgan of Long Ashton Research Station, Mr. H. J. Hamblin and Mr. F. W. Raybould of the National Institute of Agricultural Engineering, Mr. H. G. East of H. G. East & Co., Longworth Road, Oxford and Mr. M. Thornton, Department of Agriculture, Oxford University.

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SOME OBSERVATIONS ON THE RELATIONSHIPS BETWEEN SPRAYING TECHNIQUE AND BIOLOGICAL EFFICIENCY

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ANDERS BENGTSSON (Department of Plant Husbandry, Royal School of Agriculture, Uppsala, Sweden)

Summary

The results from the laboratory and field experiments can be summarized as follows:-

1. MCPA and dinoseb have a stronger effect on linseed and peas at low-volume spraying and at spraying with small droplets.

2. The volume (= concentration), the droplet size and the surface tension change the selectivity.

3. Studies of retention and ability to retain liquids can give valuable contributions to the possibilities of judging in advance the outcome of a spraying.

Introduction

At the Department of Plant Husbandry of the Royal School of Agriculture an investigation was started in 1949 of the biological and the technical problems that are of fundamental bearing on the construction of sprayers. The investigations aimed at throwing light upon the effect of different technical factors on the biological effect on spraying. The mode of action of the chemical weed-killers and the reaction of the plants to such technical factors as volume and droplet size highly affect the construction of the sprayers. Modern herbicides have enlarged the basis for the use of the chemical weedkillers and, therefore, the constructive development of sprayers is more urgent than ever.

Retention and Wettability

At spraying a larger or smaller quantity of the liquid which falls on a plant will be retained on the surfaces of the leaves. Different species will have in this respect different retention ability. Several different factors affect the retention. These factors can be of biological or technical nature:

1. The morphology of the plant (leaf structure, hairiness, angle of inclination of the leaf-surface).

2. The physical-chemical characters of the leaf-surface. (Difference in wettability).

3. The physical-chemical properties of the spraying liquid (surface tension).

4. The volume rate.

5. The droplet size.

Factors 1 and 2 are biological, whereas 3, 4 and 5 are technical. Of these, factors 4 and 5 have a direct and decisive bearing on the construction of the sprayers.

The knowledge of the behaviour of the droplets on a leaf-surface is indispensable for the discussion of technical problems in spraying. Thus it is of interest to know how large a quantity of the spray will be retained at varying volume rates, droplet sizes, and surface tensions. Different workers have also tried to determine the size of the retention by laboratory experiments (4).

In retention experiments the present authors have used water solutions of indigo carmine or nigrosine. The apparatus used in these experiments has previously been described in part (2).

The experiments with different volume rates have been carried out with a Teejet fan-nozzle (650067, pressure: 5 kg/cm^2, mean diameter = 88 μ). In order to determine the droplet size slides covered with a layer of oil were exposed under the sprayer. The droplets were photographed and the film projected by a microprojector and the droplet size determined. Various volumes were obtained by giving the sprayer different speeds over the object. The results obtained with different volume rates show that at any given droplet size a greater proportion of liquid is retained at a small volume than at a large one. The difference in retention at low and at high volume is more marked for plants with small wettability (large contact angle) than for plants with great wettability (small contact angle). The size of the retention is highly dependent on the surface tension of the spray. This is evident from the following figures for the retention on barley and peas sprayed with different volumes and with liquids of different surface tension.

<u>Barley</u>

Litre per hectare	53	53	425	425
Surface tension, dyn/cm	50	35	50	35
Retention, per cent	26.8	61.4	10.7	57.3

<u>Peas</u>

Litre per hectare	66	146	510	1090	510
Surface tension, dyn/cm	50	50	50	50	35
Retention, per cent	11.1	5.5	5.1	5.0	39.1

The droplet-size experiments have been made with an atomizer essentially built as a cone nozzle. In the swirl chamber there are intakes for compressed air, and a nozzle. Different droplet sizes can be obtained with swirl plates with different size and angle of the grooves and with differently large orifice discs. The pressure of the spray and of the air-current is likewise of great importance for the droplet size. The arithmetical mean of the diameters of the droplets (number mean diameter) and the diameter of a droplet of mean volume (volume mean diameter) are:-

	Number mean diameter	Volume mean diameter
Small droplets	38 μ	55 μ
Medium droplets	80 μ	146 μ
Large droplets	110 μ	216 μ

For the rest the same apparatus has been used as in the volume experiments.

In the droplet-size experiments the retention was studied on plants in the field as well as in greenhouse. Small droplets are better retained on the plants than are large ones. The difference in the retention is largest for plants with low wettability, i.e. fat hen (Chenopodium album), while it is considerably smaller for plants with high wettability as in the charlock. (Sinapis arvensis). The difference in retention of the spray applied in small and large droplets, respectively, is likewise highest when a large volume is used as will be seen from the following figures, in per cent, on the retention on linseed, sprayed with various volumes and droplet sizes. (Surface tension of the liquid: 50 dyn/cm).

l/hectare	Small droplets	Medium droplets	Large droplets
160	14.4	6.2	4.8
600	10.7	2.6	2.1

Experiments with MCPA and dinoseb

The results obtained from the retention experiments carried out in the laboratory and in the field with varying volumes show that a larger quantity of active substance is retained on the surface of the plant if sprayed with a low volume than with a large one, if the same quantity of active substance is distributed per unit. A larger amount of herbicidal substance is likewise retained by the plant if the spraying is done in the form of small droplets.

In the laboratory experiments the same apparatus has been used as in the retention experiments. The volume experiments were carried out with peas and linseed. The experiments with MCPA ("Agroxone" - 10% MPCA in the form of sodium salt was used) showed that the reaction of cultivated plants was stronger for a low-volume than for a high-volume spray, if the same quantity of active substance was applied. Experiments in linseed with dinoseb (Sevtox) in varying volumes prove that the application of a low volume may have a fatal effect, if the same quantity of active substance is used as applied with a high volume. In experiments with white mustard (Sinapis alba) with droplets of varying sizes a stronger effect was obtained by spraying with small droplets of dinoseb than with large ones, while no statistically significant differences between the varying droplet sizes were obtained in the experiments with MCPA.

The field experiments were carried out with a specially constructed plot sprayer. This sprayer is carried by two motor-cycle wheels and a pivot wheel and is equipped with a four-stroke BSA-engine with a centrifugal regulator. The engine drives the sprayer over a gearbox and a shaft. A 2.500 r/m and over 16 gears the speed can be varied from 0.33 m/s to 1.59 m/s. The engine also drives a rotary compressor which provides the nozzles used in the droplet-size experiments with air. The boom is on the right-hand side of the sprayer. This construction prevents the operator from treading on the plots already treated. The sprayer also provides a protective zone of 120 cm. between the plots - the gauge of the sprayer - which also reduces the risks for drifting to the neighbouring plots. In order to eliminate the spray drift, the herbicides were applied on those days only when the effect of the wind could be neglected. When Teejet-nozzles were used, the compressor was replaced by a tube of compressed air.

The purpose of the field experiments in this investigation has been to find how the plants - cultivated plants as well as weeds - react against such purely technical factors as volume and droplet size and, above all, how the selectivity changes under the influence of these two factors.

Field experiments with different volumes comprise experiments in peas, linseed and cereals with MCPA, and in linseed with dinoseb. In some experiments the reaction of the cultivated plants has been examined, in other experiments both cultivated plants and weeds (3).

Peas (Torsdags II) sprayed with varying volumes show, as was the case in the laboratory experiments, a stronger reaction for a low volume than for a high one.

In linseed a stronger bending of the stalk was obtained at low-volume than at high-volume spraying. Also the growth in length was affected by the volume: the lower the volume the greater the reduction in growth. Experiments in linseed sprayed with dinoseb in different volumes shows that the use of a low volume can have a fatal effect, if the same quantity of active substance is used at low and high volume.

The weed-killing effect of MCPA applied in different volumes on spring cereal was investigated with the droplet size used in the experiments, there is nothing to indicate that the effect at low volume (100 1/ha) was weaker than at high volume (900 1/ha). Low volume spraying is, however, not possible when contact herbicides are used.

Field experiments with varying droplet size were carried out with MCPA and dinoseb. A number of cultivated plants and weeds have been examined.

The effect of MCPA on cereals does not seem to be influenced by variation of the droplet sizes. Only in the laboratory experiments has the frequency of abnormal spikes been significantly higher at a fine spray than at a coarse one.

Peas show a stronger bending when sprayed with MCPA in small droplets than in medium-size or large droplets. The yields are also affected. In the experiments of 1954 the yield was reduced by a fine spray, while a coarse spray resulted in an increase of the yield (0.4 - 0.8 kg MCPA per hectare, volume: 220 1/hectare).

In experiments with linseed and flax a more pronounced bending of the stalk was produced when the plants were sprayed with small droplets than when sprayed with somewhat larger droplets. The spraying took place about one month after the emergence, the plants being then 15 - 20 cm high. Both the quantity and the quality of the flax fibre was reduced to a greater extent at spraying with small droplets.

The effect on weeds of MCPA-spraying is on the whole of the same proportion for all droplet sizes. Weeds with small wettability (fat hen) behave as linseed and peas. Charlock on the other hand is less dependent upon droplet size. These differences were also found in the retention experiments.

In experiments with dinoseb not only cultivated plants but also weeds such as charlock show a stronger reaction for a small-droplet spray than for a large-droplet one.

DISCUSSION

The results obtained in these experiments suggest that in certain cases volume and droplet size are of great importance. The influence of the volume has been established by several workers, among others Blackman (1) and Holly (4). The volumes generally used in Sweden vary between 150 and 400 litres per hectare, but England and the U.S.A. practise low-volume spraying to a large extent. The results have proven this method to be a good one for cereals. The droplet size has been a matter of greater controversy. The experiments reported in the present paper seem to indicate that the selectivity decreases with reduced droplet size. Besides, the stronger drift to which the small droplets are exposed, cannot be disregarded. "Coarse sprays of rather high surface tension are superior for many herbicidal spray jobs" (Loomis (5)).

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DISCUSSION ON TWO PREVIOUS RESEARCH REPORTS

Mr. P. Hebblethwaite: I would like to compliment the last speaker on his foresight in choosing this subject for research. In spite of the amount of work that has been done on the chemistry and biology of herbicides, there is remarkably little information available for the designers of spraying machinery and particularly for the designers of spray nozzles. We frequently hear of British fan-type nozzles being compared adversely with their transatlantic equivalent. If the basic information on optimium droplet spectrum were available, I feel sure that our own nozzles could be just as good. I hope the lead given by this paper will be followed by research workers in this country.

We heard from Mr. Culpin yesterday that there is still some doubt about the optimum droplet size to achieve penetration in dense foliage. Does the work just presented provide any information on this subject? Which of the droplet sizes showed greatest ability to penetrate foliage?

Mr. A. Bengtsson: I can't answer Mr. Hebblethwaite's question as we have not yet obtained results with weed experiments.

Professor G. E. Blackman: I think I ought to say that Dr. Helqüist spent some time with us at Oxford learning these techniques before he took up this research and that we are extremely interested in this work. It is difficult to define a droplet spectrum without also considering the physical characteristics of the spray. I do not think it is possible to be very specific in these matters. 60 microns might be the best for one type of spray and 150 microns for another. I too would like to congratulate the Swedish people for their work on these lines because it is I agree very important.

Professor Hugo Osvald: I would like to say how much we appreciate the collaboration we have had in the past years with the scientists at Oxford. It has been very useful to us and we hope that it will continue in the future.

Mr. W. Ochiltree: Is Mr. Fryer satisfied that there may not be some degree of contamination when switching from one treatment to another? Is it his practice to flush with water when switching from one system to another or does he just evacuate by air pressure?

Mr. J. D. Fryer: When spraying a dose range of a single chemical, we do not wash out the system when transferring from one treatment to another. We do, however, remove all liquid from the system by reversing the direction of rotation of the gear pump before introducing the new concentration. The amount of contamination would be insignificant under those circumstances. When we change from one chemical to another we do wash with water before introducing the second chemical. We are quite satisfied that there is no undue contamination using these machines in this way.

Mr. J. G. Elliott: There are on the Land Rover three completely different spraying systems. The danger of contamination is likely to arise when a high volume solution follows a low volume solution in the circuit. By having three completely different circuits this source of contamination is eliminated. Our normal practice after emptying the system by 'Suck-back' is to flush the system with the new treatment for a set time before spraying, after all, water can be a contaminant in low volume spraying because it alters the concentration of the solution.

Mr. S. G. Jary: Could Mr. Fryer tell us, if, when operating the small sprayer, the man walks forwards or backwards? The photograph looks as though he is walking forwards over the plot he has just sprayed. I find that it is better to walk backwards.

Mr. J. D. Fryer: It is our normal procedure to walk forwards and if we are worried about walking on the treated area we can hold the boom out to one side and walk in the pathway between the plots.