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THE EFFECTS OF VOLUME, DROP SIZE AND CONCENTRATION, AND THEIR INTERACTION, ON THE CONTROL OF APPLE POWDERY MILDEW BY DINOCAP

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INTRODUCTION

To assist the spraying department of the National Institute of Agricultural Engineering in the design of an orchard sprayer it was necessary to determine the effect of various factors, namely, volume, drop size, and concentration, and their interaction, on the control of one of the main economic diseases of fruit trees, the powdery mildew of apple, Podosphaera leucotricha (Ell. and Ev.) Salm. In order to avoid the unnecessary complication of field variability, due to uncontrolled environmental conditions and the lack of adequate replication, it was decided to work under greenhouse conditions with small rooted shoots in pots, using an accurate technique for powdery mildew assessment (Kirby and Frick, 1963), and a specially designed spraying cabinet for chemical application (Byass and Charlton, 1968).

MATERIALS AND METHODS

Dinocap was chosen as the representative commercial fungicide for apple powdery mildew control and a 50% liquid formulation was used to avoid the added complications of suspended particles.

The spraying cabinet, described fully by Byass and Charlton, consists of an electrically-driven dished spinning disc which projects a spray of uniform droplets horizontally into the cabinet. The drops (100-400 µm diameter) follow a trajectory depending on their size and velocity and eventually fall vertically as a single band through a slot in the false floor onto the potted plants conveyed on an endless belt beneath (Fig. 1). The roughening or oxidation of the metal disc to improve wetting and therefore uniformity of drop size did not work for this particular dinocap formulation. Instead it was necessary to cover the disc surface with a Whatman No. 1 filter paper before a satisfactory performance was obtained. This paper had to be renewed between experiments.

Three drop sizes were selected to cover the range from high to low volume application, small (100 µm diameter), medium (175 µm), and large (400 µm), together with five concentrations of dinocap, the strongest containing 0.05% active ingredient and the remainder being successive twofold dilutions.

In order to obtain an accurate measure of the amount of spray per unit area received by the target, 0.2% of the inert fluorescent compound 3S (based on sodium naphthylamine trisulphonate)was added to the dinocap solution. The deposit obtained on glass slides was measured by fluorimetry and expressed as µl of spray fluid per slide or per cm^2. The deposit of dinocap per unit area ($\mu g/cm^2$) was given by the weight present in this volume.

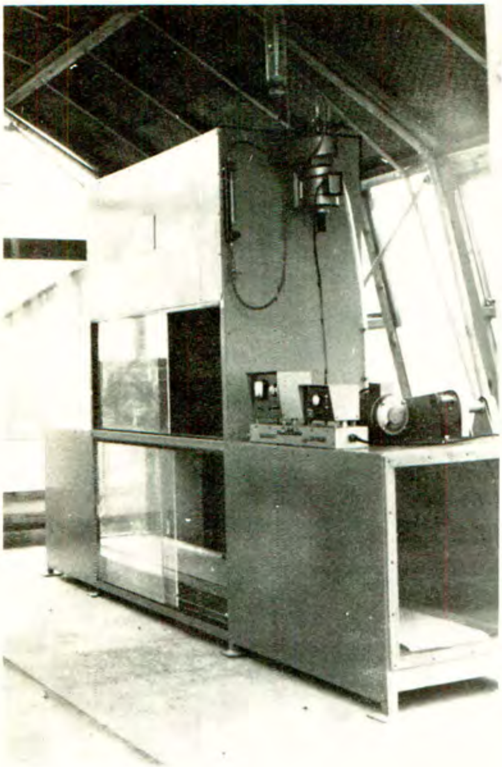

Figure 1

The spray application cabinet showing the plant conveyor, spinning disc assembly and speed controls

Figure 2 (below)

Apple rootstocks prepared for upper (right) and lower leaf surface treatment

Application of dinocap

The usual method of application was to fix the disc speed to give a required drop size at a suitable flow rate with a given concentration of dinocap, and then to vary the dose by altering the conveyor speed. For larger doses, particularly with the 400 µm drops, it was necessary to run the plants two or more times through the spray arc and build up the required dose by a succession of applications. However careful the control of the flow rate and the disc speed (now achieved by electronic monitoring circuits) small variations in drop trajectory did occur and the proportion of spray arriving at the target varied. To overcome this an accurate measure of the amount of spray received by the target was found to be more satisfactory than an attempt to reproduce a precise dose. Due to the physical properties of this formulation, changes in concentration of dinocap usually required a fresh disc setting for a required drop size.

Assessment of powdery mildew

To assess the effect on apple powdery mildew, rooted shoots of the rootstock cultivar M.III with 5-6 in (125-150 mm) of growth were selected and marked in the normal way. Ten such plants, each with two shoots, were used per treatment and were placed on the conveyor belt in two lines of five beneath the false floor facing the spray aperture. Glass slides on carriers were placed in front and behind them to enable an accurate measure of the dose received by the leaves to be determined. Depending on the dose required the plants were run through the spray once, twice, or more times, always in a forward direction. After treatment their position on the belt was noted, and they were then removed from the cabinet to dry before being taken to the mildew house. When all the treatments had been completed the plants were placed in the inoculation tower 24 hours before infection in the normal way.

In order to study the effect on the under-surface of leaves the shoots had to be bent over and fastened down prior to spraying (Fig. 2). It was necessary to inoculate these stocks on the same day before re-orientation of the shoots ocurred, to ensure that only the sprayed surface was presented to the conidia. The shoots were unfastened as soon as the plants were removed from the tower 24 hours after inoculation.

The number of lesions present on the upper or lower surface of the third, fourth and fifth leaves of each shoot were counted usually 11 days after inoculation and the percentage control for the treatments calculated.

RESULTS

Effect of drop size on powdery mildew control

A comparison of the three drop sizes, 100 µm, 175 µm and 400 µm diameter, at 0.025 and 0.05% dinocap (Table 1) showed that the medium sized drops (175 µm) were preferable to the large sized drops (400 µm) at both concentrations, and that there was no further advantage in using the smallest drops (100 µm) despite the greater cover afforded by the finer spray (Fig. 3).

Further tests (Table 2) confirmed the superiority of the medium sized drops, particularly at the lower doses, over the 100 µm and 400 µm drops, but as the dose increased these differences became less apparent and little difference was observed between the three drop sizes in the region of 90% control. This effect seems to be independent of concentration, although the more dilute the spray the less effect the drop size has on mildew control, due to the extra cover gained by all three drop sizes.

Figure 3

Leaf cover provided, indicated by light coloured areas, by stated doses of 400, 175 and 100 µm diameter drops

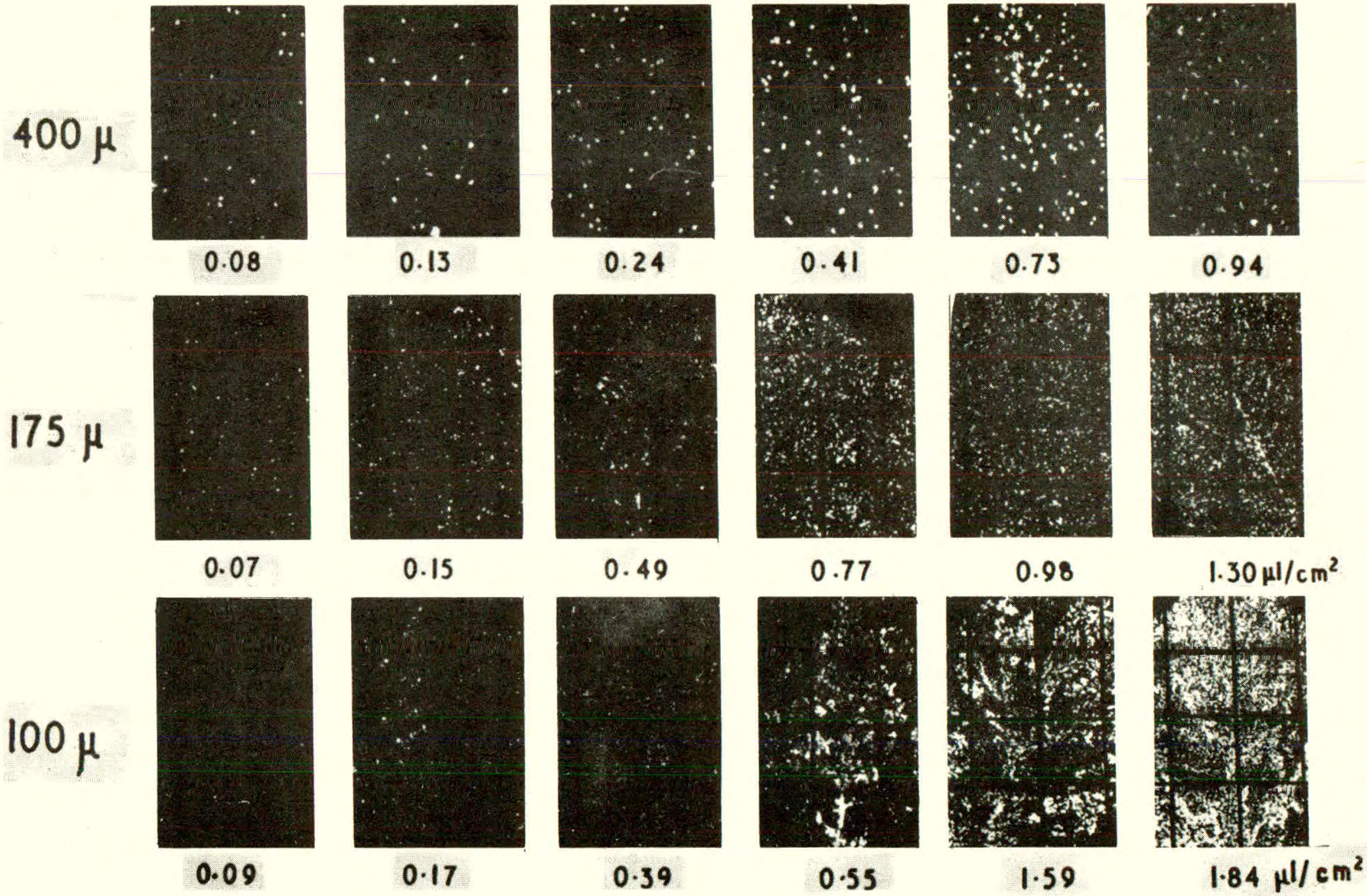

Table 1

The effect of different drop sizes on the percentage control of apple powdery mildew on two separate occasions

Concentration of dinocap	*Actual deposit of dinocap, $\mu g/cm^2$	Drop size, µm		
		100	175	400
(a)	0.127	-	73.2	-
0.025%	0.168	-	-	62.1
	0.172	73.3	-	-
(b)	0.25	-	-	49.4
0.05%	0.28	-	88.8	-
	0.33	69.7	-	-

* Calculated from the determined volume (µl) of spray fluid per slide

Effect of concentration and volume applied for a given drop size on powdery mildew control

Under these conditions cover is defined as the number of drops per unit area, while dose is defined as the amount of chemical per unit area. The results in Table 3 relating to a given cover are linked by diagonal lines, while those relating to an equivalent dose are read down the table.

With both the medium (175 µm) and the large (400 µm) drops control, at a given dose, improved with dilution, illustrating the importance of the extra cover afforded by the larger number of drops of the diluted spray. An increase in concentration, at a given cover, however, when a similar number of drops is present, led to improved control with 175 µm drops, and possibly with 100 µm drops (Table 1), but had much less effect on the 400 µm drops.

Effect of the leaf surface

A better control of powdery mildew was obtained on the upper surface of apple leaves with 175 µm drops at a concentration of 0.05% and with 400 µm drops at a concentration of 0.00625% than on the lower surface (Table 4). This is no doubt due to the unevenness of the under-surface caused by veins and hairs which initially intercept and retain impinging spray droplets.

The advantage of the smallest drops (100 µm) for under-surface sprays is again not conclusive. On one occasion (Table 5) they did slightly better than the medium sized drops (175 µm) while on the other they were slightly worse. This is hard to understand as their size and number should enable them to penetrate any network of hairs better than larger drops. The medium sized drops were again much superior to the largest drops for a given concentration.

Table 2

The effect of different drop sizes at given concentrations of dinocap on the percentage control of apple powdery mildew on three separate occasions

Concentration of dinocap	(a) 0.025%				(b) 0.025%				(c) 0.05%			
Drop size	100 µm		175 µm		175 µm		400 µm		175 µm		400 µm	
Intended deposit of dinocap, µg/cm^2	A	C	A	C	A	C	A	C	A	C	A	C
0.026	0.017	36.0	-	-	-	-	-	-	-	-	-	-
0.052	0.053	51.4	0.047	61.0	0.057	39.2	-	-	-	-	-	-
0.104	0.103	78.3	0.081	85.3	0.101	56.7	0.096	38.6	0.130	66.3	-	-
0.208	0.200	89.7	0.191	92.4	0.222	74.4	0.207	71.9	0.213	71.9	0.268	59.0
0.416	0.331	92.8	-	-	-	-	0.406	83.8	0.463	87.8	0.320	44.8
0.832	-	-	-	-	-	-	-	-	-	-	0.728	92.0

A = Actual deposit of dinocap in µg/cm^2 calculated from the determined volume of spray fluid per slide

C = Percentage control

Table 3

The effect of changes in concentration of dinocap at given drop sizes on the control of apple powdery mildew on five separate occasions

	Intended deposit of dinocap, µg/cm^2	0.013		0.026		0.052		0.104		0.208		0.416	
Drop size, µm	Dinocap concen-tration, p.p.m.	A	I C	A	I C	A	I C	A	I C	A	I C	A	I C
(a) 400	31.2	0.014	8 25.1			0.039	32 60.0			0.119	128 86.8		
	62.5	0.013	4 18.4			0.050	16 41.7			0.197	64 93.9		
	125	0.013	2 19.2			0.052	8 29.9			0.216	32 89.6		
(b) 175	31.2	0.016	8 29.1	0.027	16 50.8	0.058	32 76.5						
	125	0.013	2 17.2	0.023	4 36.3	0.062	8 68.0						
	500	0.018	½ 14.3	0.020	1 47.7	0.062	2 52.8			0.265	8 91.9		

Table 3 (cont)

	Intended deposit of dinocap, $\mu g/cm^2$		0.013			0.026			0.052			0.104			0.208			0.416		
	Drop size, µm	Dinocap concentration, p.p.m.	A	I	C	A	I	C	A	I	C	A	I	C	A	I	C	A	I	C
(c)	400	62.5	0.016	4	24.6	0.033	8	53.2	0.059	16	80.0	0.110	32	87.0	0.227	64	93.4			
		125	0.022	2	66	0.027	4	35.0	0.048	8	54.6	0.126	16	70.6	0.177	32	93.4			
(d)	175	125	0.014	2	9.2	0.030	4	32.5	0.600	8	57.7	0.104	16	78.4						
		500	0.015	½	21.6	0.030	1	23.9	0.052	2	33.8	0.120	4	58.9						
(e)	400	125							0.041	8	50.9	0.097	16	73.7	0.177	32	88.5	0.400	64	97.3
		500							0.052	2	18.0	0.110	4	29.2	0.227	8	64.6	0.351	16	69.2

I = Intended volume of spray fluid, µl/slide

A = Actual deposit of dinocap in $\mu g/cm^2$ calculated from the determined volume of spray fluid per slide

C = Percentage control

Table 4

The effect of the surface of apple leaves on the percentage control of apple powdery mildew using two different drop sizes on two separate occasions

	(a) Concentration of dinocap - 0.05% Drop size - 175 µm				(b) Concentration of dinocap 0.00625% Drop size - 400 µm			
Intended deposit of dinocap, $\mu g/cm^2$	A	C Upper surface	A	C Lower surface	A	C Upper surface	A	C Lower surface
0.013	0.024	7.3	0.017	1.6	0.015	4.3	0.015	12.5
0.026	0.024	8.4	0.033	21.8	0.036	29.4	0.035	21.2
0.052	0.059	41.5	0.069	23.1	0.068	62.6	0.064	35.9
C.104	0.089	71.9	0.117	49.3	0.130	85.7	0.114	63.6

A = Actual deposit of dinocap in $\mu g/cm^2$ calculated from the determined volume of spray fluid per slide

C = Percentage control

Table 5

<u>The effect of different drop sizes at a given concentration of dinocap on the percentage control of apple powdery mildew on the under-surface of leaves on four separate occasions</u>

Concentration of dinocap - 0.025%

	(a)				(b)			
Drop size	100 µm		175 µm		400 µm		175 µm	
Intended deposit of dinocap, $\mu g/cm^2$	A	C	A	C	A	C	A	C
0.026	0.023	0.0	0.025	39.2	-	-	0.031	30.9
0.052	0.058	10.5	0.055	1.5	0.053	43.0	0.045	48.6
0.104	0.129	44.4	0.107	28.6	0.105	32.6	0.143	62.8
0.208	0.230	70.1	0.214	55.9	0.278	51.8	0.175	71.3
0.416	-	-	-	-	0.468	77.0	-	-
	(c)				(d)			
0.026	0.035	17.4	0.021	36.1	-	-	0.026	47.5
0.052	0.044	23.6	0.051	27.9	0.053	48.3	0.055	73.3
0.104	0.114	27.9	0.108	43.9	0.107	53.6	0.103	72.9
0.208	0.175	51.6	0.225	54.3	0.149	58.8	0.217	83.9
0.416	-	-	-	-	0.253	56.1	-	-

A = Actual deposit of dinocap in $\mu g/cm^2$ calculated from the determined volume of spray fluid per slide

C = Percentage control

DISCUSSION

It is difficult to separate the effects of drop size, concentration, and dose on the control of apple powdery mildew because there is evidently an interaction between these factors. Only a limited number of treatments could be made in one experiment and in one or two instances anomalous results were obtained under the closely controlled conditions, particularly when using the under-surface of leaves, which could not be explained or related to any factor. Drop size, at medium and low doses and at the higher rather than the lower concentrations, has been found to have a marked influence on the control of mildew by dinocap. Drops of 175 µm diameter were superior to drops of 400 µm on either the upper or lower surfaces. There was no advantage in using small drops (100 µm); this is very surprising particularly when the actual cover of a spray of this nature is considered. It is also difficult to understand why these small drops are unable to reach the under-surface of apple leaves better than the larger ones. The hairiness of this surface could be responsible for this failure, the small drops impinging on or being attracted to the hairs whilst falling. This might not apply if they are given extra momentum as in a fast-moving column of air.

When applying fungicidal sprays, adequate cover, which implies the reasonable distribution of a certain minimum level of deposit, is the prime consideration. The degree of cover needed, however, will depend on the disease to be controlled and the range of action of the deposit. In the present study cover has been found to be all-important, and the greater the number of spray drops per unit area of leaf the better the control of mildew, even at the very low concentrations. This control improved at all three drop sizes with dilution for a given dose, and the more dilute the spray fluid the less effect drop size had over control.

Control of mildew was also found to improve with concentration for a given cover in the case of the medium sized drops (175 µm), and possibly those of 100 µm or less, and suggests the operation of an increased vapour action from the more concentrated deposit on the surrounding conidia. Bent (1967) has demonstrated the vapour action of deposits of various fungicides, including dinocap, which is also well known for its fumigant action. This improvement in control, however, does not occur with the larger drops (400 µm) and suggests that, at the level of dose employed, these drops are still sufficiently scattered for the stronger concentrations to have little or no added vapour effect.

The work has made it possible to answer such questions as, 'What is the efficiency of deposits of equal density but differing in particle size?', and to show that a high-level deposit badly distributed is less efficient than a low-level deposit well distributed.

Acknowledgements

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A TECHNIQUE FOR THE SUB-SURFACE PLACEMENT OF HERBICIDES FOR RESEARCH PURPOSES

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INTRODUCTION

A frequent present day agricultural practice in the use of soil acting herbicides is to incorporate them as soon as possible after application. A herbicide applied to the soil surface may become exposed to a number of inactivation processes and may, in fact never reach the target, the uptake zone of the weeds.

Before soil acting herbicides can have an effect on the weeds they must move from the surface, or be introduced into the body of the soil where they are then available for uptake. The movement depends either on mass flow in rainwater or on mixing by conventional tillage implements, such as harrows or a rotary cultivator. With these processes optimum herbicidal effect may not be achieved because of excessive dilution or uneven distribution.

Annual weeds tend to have a shallower root system than perennials and surface application may be satisfactory for these, but perennials, such as couch, constitute an important problem and because of their deeper root systems, the most effective method of control may depend upon placement of the herbicide.

PRELIMINARY POT EXPERIMENTS

Before proceeding with the design of a placement machine or field experiments, a greenhouse experiment was undertaken to investigate various deposits in the soil:

1. mixing the herbicides into the soil,
2. placing the herbicide as a layer 1 in (25 mm) above the rhizomes of *Agropyron repens*,
3. placing the herbicide as a layer 1 in (25 mm) below the rhizomes of *Agropyron repens*.

Assessments based on shoot counts and fresh weights showed that for all doses of EPTC (0.125, 0.5 and 2.0 lb/acre; 0.14, 0.56 and 2.24 kg/ha) treatment 3. gave a degree of control as good as treatment 1., and treatment 2. was only slightly less effective.

EVALUATION OF PLACEMENT METHODS

In order to assess the best placement patterns in the field, tines for use on a tractor mounted toolbar were made and fitted with spray nozzles or small holes to create different deposits beneath the soil, namely,

(a) a cylindrical pattern created by dribbling the liquid from a pipe mounted behind a straight tine. This is the simplest deposit to create and employs tines similar to those used to apply liquid fertilisers;

(b) a vertical layer created by fitting a spray nozzle between two crescent shaped trailing edges behind a vertical tine, this produced a thin vertical liquid layer from the surface down to about 6 in (150 mm);

(c) a horizontal layer created by mounting a spray nozzle beneath a modified 'A' blade (Shepherd, 1968). Two sizes of blade were tried, in one the width of the trailing edge was 10 in and in the other 24 in (0.254 and 0.61 m).

A series of experiments was conducted using different herbicides and measuring the effect in terms of reduction of couch shoots. With the chemicals used and in the conditions of these trials the most effective placement technique was found to be a horizontal layer of herbicide created by the 'A' blades. No difference, in terms of biological control, was found between the two sizes of 'A' blades when used to create a complete horizontal layer. There was an advantage, in terms of reduced implement draught, in using the 24 in (0.61 m) wide blades.

These blades were fitted with a single, wide angle spray nozzle mounted centrally and 6 in (152 mm) forward of the trailing edge. A series of experiments was carried out using up to four of these blades, making a treatment swath of 8 ft (2.4 m). Conditions were encountered where the toolbar on which the blades were mounted was not of sufficient strength. In designing a more robust arrangement an attempt was made to reduce the draught of the machine.

In addition to reducing the forces imposed on machine members, a lower level of draught would have the important effect of bringing the operation of the machine into a lower regime of the slip/pull curve of the tractor. The result would be a smaller variation in the forward speed, due to soil conditions and consequently a more uniform distribution of chemical along the direction of travel.

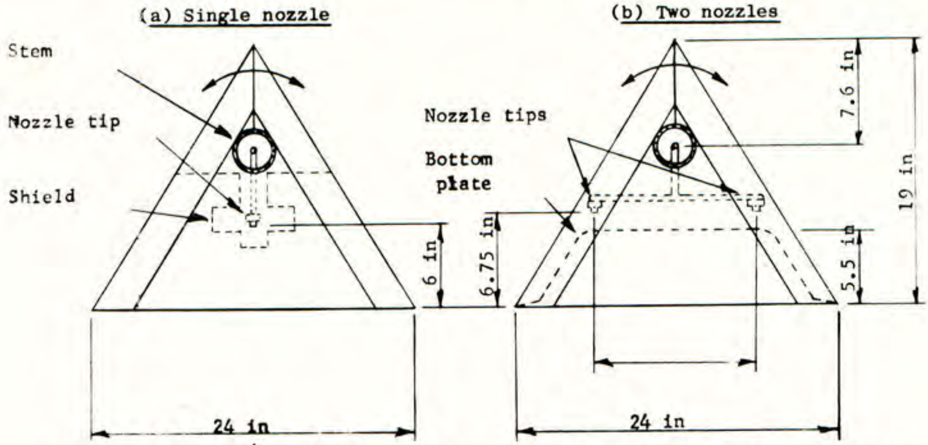
MACHINE OUTLINE

A promising method of obtaining a worthwhile reduction in the general level of draught appeared to be by the use of a form of rotary oscillation of the blades as suggested by Kofoed, (1969). In Fig. 1 the blade is shown in plan view. The leading edge of the blade is turned downwards leaving space beneath the blade to mount a spray nozzle. The axis of oscillation was positioned 7.6 in (193 mm) from the point of the blade and an angular movement of $\pm 8^{\circ}$ was imparted to each blade from the tractor p.t.o. via an eccentric drive. Four blades were mounted at a transverse spacing of 1 ft $10\frac{1}{2}$ in (0.57 m) with a fore and aft separation of 42 in (1.07 m) between alternate blades using a commercial toolbar.

With a single, wide angle nozzle distributing the spray beneath each blade, Fig. 1a, the varying spray deposit across the blade width, resulting from the nozzle's triangular distribution pattern was reflected in an uneven weed control. This showed the desirability of improving the evenness of the deposit across the blade. Two even-spray tips, reduced in overall size were mounted beneath the blades, Fig. 1b.

Figure 1

Arrangement of nozzles under 24 in blade



To facilitate changing herbicides between trials, with the minimum amount of washing out, a pneumatic method of liquid delivery has been employed. It consists of two, 2 gal (9.1 l) cylinders, the herbicide being put in one cylinder and the other cylinder used as an air reservoir which is pressurised from a p.t.o. driven air pump. The air pressure applied to the top of the liquid reservoir is controlled by a pressure reducing valve between the cylinders.

DRAUGHT MEASUREMENT

A preliminary trial to investigate the reduction in draught resulting from the oscillation of the blade was carried out in a dry, heavy soil. At a depth of 2 in (50 mm) and at speeds ranging from 1 - 3.5 mile/h (1.6 - 5.6 km/h), the mean draught was reduced by between 8 and 23% in 20 observations. With the blades working at 4 in (100 mm) depth and forward speeds in the range 1 - 1.8 mile/h (1.6 - 2.9 km/h) 16 observations showed draught reductions of 7 - 17%, but four observations in two runs at 2.1 and 2.7 mile/h (3.4 and 4.3 km/h) gave increases of 1 and 10% respectively when the blades were oscillated.

Each run consisted of a comparison of draught with the blades fixed and blades oscillating, in that order, along the length of the field. Runs under different speed conditions were randomised across the width of the field but the absence of randomisation in the order of treatments within each run leaves the results open to influence by any progressive change in soil conditions along the length of the field. Further work is necessary to determine more precisely the effect of oscillating the blades.

DEPOSIT TRACING

During the development of this machine and evaluation of its performance in biological terms, it has been necessary to correlate the biological results with the deposition of chemical in the soil. For this purpose a qualitative indication has been obtained by a fluorescent tracer and photography. Quantitative measurements have been made in the field using a radio-active technique and operating conditions have been simulated, for one blade, in the laboratory using paper strips to study the distribution of dye from the nozzle(s) under it.

(a) Fluorescent tracing technique

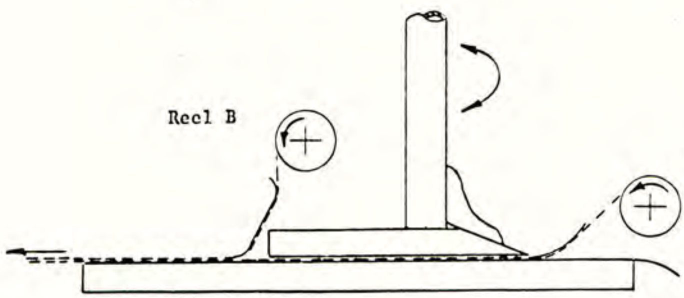
A fluorescent pigment, Saturn Yellow, was added to the herbicide and the deposit beneath the soil examined by exposing a vertical soil face after the passage of the blades. This exposed face was illuminated by ultra-violet light under a blackout and the resultant fluorescence recorded photographically. The fluorescent deposit has not always been faithfully recorded by the camera as it appears to the naked eye but the technique has proved useful. Although it has not given a quantitative evaluation of the deposit it has indicated the extent of the initial distribution of the herbicide.

(b) Radio-active tracing of the deposit

When the spray distribution was changed from the single wide angle nozzle to two even-spray nozzles a quantitative comparison of the two systems was carried out using Rhubidium-86 as a radio-active tracer. Both nozzle systems were used to apply the radio-active solution and 11 core samples were taken across the working width of two blades. These samples were replicated five times along the direction of travel. The coefficients of variation of the mean sample activities for the single and two-nozzle systems were 64% and 17% respectively. The two-nozzle system will therefore be used for future work. The radio-active technique of measuring the distribution in the soil is not a convenient method to employ for each experiment, because of the precautions required when it is used.

Figure 2

Arrangement of paper strips for deposit measurement



(c) Spray deposit from simulated working conditions

In this technique, a fluorescent dye, consisting of 0.5% weight to volume solution of Fluorescent Salt 3S was sprayed on to a paper strip passing under the blade - from reel A in Fig. 2 - with another strip passing over the rear face of the blade - from reel B. Under test the blades oscillated at the same amplitude and frequency as were used in field experiments. After spraying, the two paper strips were immediately stapled together, cut into 2 in squares and the dye extracted. Three replicates, down the line of the paper strip, were examined and the coefficients of variation of the mean deposits for the single- and two-nozzle systems were 49% and 26% respectively.

BIOLOGICAL RESULTS OF FIELD EXPERIMENTS

The lateral distribution of the layer of herbicide was initially poor and the degree of control was correspondingly variable. Further experiments are needed to assess the machine's biological capabilities using the improved nozzle arrangement.

In an experiment to control *Agrostis gigantea* in potatoes, using EPTC, Table 1, the herbicide was applied immediately prior to ridging and planting on 8th April, 1969. These further cultivations may have tended to mask any effect due to a poor initial distribution and no evidence of crop damage, due to poor lateral distribution could be seen. The assessment was accomplished by counting the couch shoots in a 10 ft (3 m) length of crop ridge in each plot on 5th June, 1969.

Table 1

A comparison of treatments for the control of *Agrostis gigantea* by EPTC

Treatment	Couch shoot number expressed as percentage of the rotary cultivated plot — Replicate I	II	III	Mean
No EPTC				
Rotary cultivation at 5 in (127 mm)	123	79	98	100
Blades 2 in (51 mm) deep	67	75	104	82
Blades 6 in (152 mm) deep	30	94	108	77
EPTC at 4 lb a.i./ac (4.48 kg/ha)				
Surface sprayed and rotary cultivation to 5 in	18	17	16	17
2 in placement	25	21	52	33
2 in placement and rotary cultivation to 5 in	12	5	10	9
6 in placement	38	42	83	54
EPTC at 8 lb a.i./ac (8.95 kg/ha)				
Surface sprayed and rotary cultivation to 5 in	3	5	8	5
2 in placement	19	20	27	22
2 in placement and rotary cultivation to 5 in	4	3	11	6
6 in placement	68	73	45	62

In an experiment to control Agropyron repens in field beans, Table 2, the soil received no further disturbance after the application of the various treatments on 25th March, 1969. The poor lateral distribution was much more apparent and was not improved even by rotary cultivation. A quadrat, 6 in by 6 ft (0.15 by 1.83 m) was placed across each plot (size 6 ft by 60 ft) at four stations and the number of couch shoots counted on 5th June, 1969. In both experiments, the range of couch shoot counts, within the rows or quadrats is expressed as a percentage of the mean emergence on the rotary cultivated plots.

Surface spraying and immediate mixing, by rotary cultivator, gave the best control in both experiments. Next best was the 2 in placement of herbicide followed by subsequent mixing and 2 in placement, without subsequent mixing, was third. Rotary cultivation fragments the rhizomes of couch. This fragmentation stimulates many of the dormant buds to break, resulting in a greater number of shoots. In contrast, the 'A' blades do not fragment the rhizomes to the same extent and this may account for the somewhat fewer shoots on the plots treated in this way.

Table 2

A comparison of treatments for the control of Agropyron repens by EPTC

Treatment	Couch shoot numbers expressed as percentage of rotary cultivated plot: Mean of Replicate I	II	III	Mean of all counts
No EPTC				
Rotary cultivation at 5 in	125	106	70	100
Blades 2 in deep	99	-	93	93
EPTC at 4 lb a.i./ac				
Surface sprayed and rotary cultivation to 5 in	22	17	3	12
2 in placement	13	45	7	20
2 in placement and rotary cultivation to 5 in	17	19	55	28
5 in placement	122	64	70	36
EPTC at 8 lb a.i./ac				
Surface sprayed and rotary cultivation to 5 in	0	0	7	4
2 in placement	11	99	2	36
2 in placement and rotary cultivation to 5 in	11	7	35	16
5 in placement	40	47	177	88

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Remarks by Dr. G. S. HARTLEY in opening a discussion on

IMPROVED APPLICATION IN RELATION TO BIOLOGICAL REQUIREMENTS

In the design of pesticide distribution equipment one should be concerned with:

(a) The possibility of putting the pesticide maximally where the biologist wants it and minimally where he does not want it.

(b) Optimum or adequate distribution in the sense of uniformity of spread within the target area.

(c) Minimal escape from the target area, such escape producing local drift damage, general pollution and wastage which vary in importance with the chemical and situation.

(d) Reasonable control of dosage.

I have attempted to list these in descending order of importance, while admitting that in some situations and with some pesticides (c) may be of overriding importance. There is, however, a common tendency to give the priority in reverse order, although one has no need for accurate control of an ill-defined rate of application to the wrong place. The great attention given to dosage has really as its main objective the simplification of the job of the accountant in farm and factory, but some of the papers reveal deviations from intended unifor ity so great that there is a real technical problem also.

I have no doubt that (a) is the most important question. It is also the one most difficult to answer, and this is the excuse for its receiving, at present, least attention, certainly as far as the equipment designer is concerned. He, like the formulator, has a difficult compromise course to steer among conflicting requirements and he naturally gives most attention to the requirements which can be put definitely: these are usually the physical requirements such as no-drift, no settlement in tanks, no blockage of filters or nozzles, no corrosion etc.

The biological requirements are more difficult to define and require more research. It is therefore a very satisfactory beginning that several contributions to this conference do concern simultaneous research, involving collaboration between stations, into what should be the biological demands on the machine designer. It is on these papers that I have been asked to initiate discussion and I shall not be concerned with the papers in which uniformity of distribution and means to measure it are judged by internal standards of perfection of the machine as a spreading tool.

The interesting paper by Courshee seems to me to come clearly in the first class although it is the only one with "uniformity" in the title. Courshee is looking at uniformity, not, in the example he treats in detail, as between one square cm and the next but on a very much larger scale. In spraying vast areas for residual attack on locusts, time may be all too short and the operation is very costly. To stripe the area rather than attempt to "colour wash" it uniformly saves both time and money. The insect is mobile and will soon run into trouble on the next stripe if it is missed by the last one. If one looks at this with engineering or planning perfection in mind, the question Courshee asks might be put "how badly can I do the job, in the interests of economy of time and money, and get an adequate result?". From the point of view of strategy against a very widely distributed pest it is important to know the answer to this question as the choice may well be between bringing 50% of the swarms to 99% extinction and bringing 90% to 90% extinction - a choice heavily in favour of "skimping".

Courshee's question is one which could with advantage be examined in many cases of pesticide application. The answers would be very different according to the behaviour of the pest, the type of economic loss it brings and the mode of action of the pesticide and particularly whether it has repellent or attractant action or is associated with another compound having such action. There are situations where a not fully uniform application has advantage in saving time or money but where the biological effect or selectivity of the chemical goes through an optimum as for instance when an insecticide can be so thinly spread and taken up into leaf surface constituents that its action is lost. Another extension of the question could be whether, in a vegetable row-crop for human consumption, it might be best to spray 1 row in every 10 with an attractant plus powerful residual toxicant, and 9 rows with a harmless repellent. It is an old gardener's dodge but should interest be renewed with the use of modern sophisticated machinery? For the pre-pack or deep-freeze market it is probably better to have a pre-located 90% of the crop 100% perfect rather than 100% of the crop with 1% of randomly spaced imperfections.

I would not go all the way with one of Courshee's parallels - he suggests that a bad distribution of fertiliser should be acceptable if all the doses are in the range of linear yield response. The catch is of course that the unevenness of ripening would be a serious difficulty in the way of harvesting the full increase of yield. I have no doubt Courshee would accept this qualification. I have no doubt also that whatever arguments of a similar kind could be put forward, there would be factors overlooked. I only wish here to emphasise the main general point of Courshee's argument, that the desirable, or optimal, degree of uniformity should be a subject of objective biological-mechanical-economic study.

Courshee's paper, as already mentioned, deals with deliberately non-uniform application on a large scale. In the last paper there is mention of distribution of pesticide in the soil in lines or vertical bands. Otherwise there is no concern in these papers with localised placement. A little more will be heard of this when we come later in this conference to granule application. There are of course operations which are more efficiently performed with granules, but very often a spot or line treatment could be just as easily performed with liquid. The tendency, verbally, to contrast granules and "spray" instead of granules and "liquid" serves to emphasise this misconception.

I think it is a matter of regret that this conference has not included any papers on localised application. The chemical industry has served agriculture very well. Of course, along the line, mistakes have been made. We hear a lot now about general pollution of the environment which is probably the least important of them. Encouragement of the development of resistance and failure to exploit to the full improvement of selectivity by placement have been much more serious. It is time we gave more attention to other advantages of chemical control than those associated with widespread distribtuion. There have been important advances, but this conference seems to have nothing to say about them.