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# NEW DEVELOPMENTS IN SWATH MATCHING

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Summary A new development of swath matching aids is discussed, that of the closed circuit television system. Also a new method of measuring the accuracy of spraying in the field by using aerial photographs is explained.

## INTRODUCTION

In recent years there have been several developments aimed at improving the accuracy of spraying, particularly so in the aids designed to assist in matching the adjacent bout or swaths of the crop sprayer as it progresses across the field. Since the initial request to the NIAE by the British Crop Protection Council in the early 70's to investigate swath matching aids, the Institute has looked at many commercial instruments mostly in the navigational field which with suitable modifications might have been suitable for this purpose, also the Institute has continued to monitor any developments in swath matching systems as well. A review of these investigations in to swath matching aids was the subject of a paper given at a Subject Day on Spraying held at the NIAE in October 1977. (Lawrence, 1977). At that time reference was made to the possible future use of close-circuit television as a means of swath matching.

## METHOD

This method has, in fact, now 'arrived', the unit is manufactured by Pye Business Communications of Cambridge and consists of two cameras and a monitor; the cameras are contained in two specially made housings which protect the cameras from spray and dust. These housings are fitted one to each end of the sprayer boom and look ahead in the direction of travel at a line of foam blobs which have been laid down on the previous bout of the sprayer, and this picture is transmitted to a monitor fitted in the tractor-cab sighted in front of the driver; also fitted in the tractor-cab is a control to select which of the two cameras is in use. The advantage of this system is that the foam blobs are viewed as if by the human eye, so that if the line of blobs tends to be a little scattered, one can average off and compensate for this variability. Another feature of the television system is it's adaptibility, the system may be used for other purposes as well, for example, observation of a particular section of a grain-handling or drying plant; it can be used for security purposes and it has already been used for observation of lambing pens and there is undoubtedly many other uses to which it can be put.

At the present time the farmer has a wide choice of swath matching aids and these methods include tramlining and the alternative ways of producing these. All these different methods provide a highly controversial topic amongst farmers and in order to evaluate the efficiency and accuracy of these various swath matching systems, Spraying Department of the NIAE, have evolved with the co-operation of ADAS Aerial Photographic Unit based at Cambridge a method of using aerial photography to measure the accuracy of spraying in the field. In past years these measurements had to be carried out by hand, were painfully laborious and slow, and at the most only some forty actual measurements were made per field. With the present method at least 100 measurements may be carried out per field; if the field is a large one this number may be increased two or three times, consequently, the measure of accuracy is very much greater.

The method of operation used in aerial photography is as follows. On the selection of a particular field for investigation, two markers are placed ideally on the field headland 100 m apart, at right angles to the direction in which the spraying has taken place. The aircraft flies over the field initially at 3,000 ft to provide a general view of the field and it's relation to the surrounding fields. A further flight some 1,300 ft above the field is then made and a series of photographs taken, both using panchromatic and infra-red film. The number of photographs taken being dependant on the size of the field.

At the present time, due to the effects of aberration it has been found necessary to largely discard at least 1 in. round the edge of the photograph for measurement analysis, but in order to qualify this error it is intended in the very near future to place markers at set distances across the field to completely fill the frame of the photograph, then to photograph from the air and having then established the inherent error, be able to use the whole area of the photographic print. At the present time the tractor and sprayer wheelmarks on the photograph are highlighted by hand before passing through the chart reader at Rothamsted for analysis, the results are then processed through the computer and are presented as measurements of swath accuracy in terms of the number of times the sprayer has under or over-lapped and the percentage of matching errors are also provided.

## DISCUSSION

An initial trial of aerial photographic measurements of swath matching accuracy was carried out last year and although there were a few minor difficulties the results were promising and illuminating. Consequently, this year a much more comprehensive programme was prepared; already a few different swath matching methods have been photographed during the initial spraying season and although it is too early as yet to provide any actual results from these photographs, it is intended to carry out more aerial surveys during this Autumn which should reveal some of the problems in matching swaths particularly when applying pre-emergence sprays. It is then the intention to publish the results of these findings this Winter and the results should provide data on the accuracy of the various swath matching methods which are practiced today.

## References

LAWRENCE, D.C. A review of swath matching methods. Paper pres. NIAE Subject Day "Spraying on Large Cereal Farms", Oct. 1977.

# THE REASONS FOR C.D.A. (CONTROLLED DROP APPLICATION)

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Summary Data made possible by laser beam drop analysis show that great misconceptions exist about drop spectra. To date drops under approximately 50 µm went undetected. Low and high pressure nozzle drop spectra show some surprising results when compared to that of Controlled Drop Applicators.

Drop measurement has always been a laborious business and, due to the difficulty of collecting smaller drops, rather unpredictable and inaccurate. Now, thanks to measuring instruments such as the Malvern and Knollenberg, drops can be measured that in former times definitely went undetected; whether by Magnesium Oxide plates or any other conventional methods.

The detection of drops is done by laser beam. The spray is projected through the laser beam which measures the defraction of light caused by the different sizes of drops. This information is fed into a computer which provides a complete print-out of volume percentage and number percentage of the drops so measured.

The advantage of this equipment is that the size of drops can be determined immediately they are issued, and it is not necessary to await sedimentation. Therefore, the actual drop size can be accurately determined before any other factor such as evaporation comes into play. We have used six examples of such computer print-outs which are given at the end of this paper together with graphs of number and volume percentages.

These six computer print-outs are divided into two main groups. One group showing drop spectra where the aim is to produce large drops in the range of 250 to 300 µm, the other where the aim is to produce small drops in the range of 75 to 150 µm.

The first three are as follows:-

1. Drops produced by the Herbi run at 2000 R.P.M. set to produce 250 µm drops - this is an example of classical rotary atomisation, i.e. single drop formation.

2. The 'Battleship' run at 2000 R.P.M. with very much higher feed, but still set to produce 250 µm drops, but based on ligament formation.

3. Drops produced by the low pressure type Spraying Systems SS8002 LP Fan Jet nozzle with 1 bar pressure. Set to produce large drops.

The second three are:-

4. High pressure type Spraying Systems SS8002 Fan Jet nozzle at 3 bar pressure. Set to produce small drops.

5. Mini Ulva atomiser run at 5900 R.P.M. Set to produce 100 µm drops.

6. Battleship atomiser run at 6000 R.P.M. Set to produce 75 μm drops.

We have inserted the mean drop size in front of drop ranges printed out. These mean figures are shown on the analysis table and used to calculate the number of drops produced in each range from a total of one litre liquid. In this table we have shown Dosage Variation 'A' and Dosage Variation 'B'. In the case of 'A' this is the volume difference between the mean drop size. In the case of 'B' this is the volume difference between the group's lower and upper limits.

In Herbicide and other applications where drift should be avoided at all costs it is essential to have practically no drops below 100 μm. When using large drops by necessity of cost effectiveness water has to be used as a carrier liquid as volumes in excess of 10 l/ha. have to be used to obtain adequate drop density.

On the other end of the scale, however, when we are trying to produce small drops we advocate the use of a non-evaporating carrier liquid, such as oil, in order to prevent the small drops losing their impact efficiency by evaporation. The small drop size range will leave, in the case of the Mini Ulva over 20 drops and in the case of the Battleship over 60 drops per square centimetre, when 1 litre per hectare of total spray liquid is applied. For cost effectiveness 1 to 2 litres of such an expensive carrier liquid is justifiable. However, as can be seen from the table no drops larger than 136.58 μm (160.29-112.86 μm) and no drops smaller than 10.29 μm (11.43-9.14 μm) are being produced.

The Spraying Systems SS8002 nozzle is supposed to be one of the best nozzles available and is widely used for what people assume to be accurate spraying. We feel that this paper amply illustrates, without further comment, the necessity to investigate all nozzles used for pesticide application for their actual drop spectrum, in order to avoid the environmental and health hazards inherent in the conventional method of pesticide application.

We, certainly are not proud of the still relatively wide variation in drop sizes produced by rotary atomisation, but are constantly striving to narrow the drop spectrum, in order not to waste valuable chemicals by overdosing with large drops and at the other end of the scale to avoid environmental and health hazard by millions of small drops.

In the analysis table we give an efficiency factor expressed by VMD/NMD. If this figure is 1, it shows completely evensized drops each containing the same amount of pesticide and having identical flight behaviour. The higher the factor the worse are the CDA characteristics of a spray pattern. We have been using this factor for the last 20 years to determine the quality of spray patterns and we have been joined by a number of scientists in its usage.[1] This figure is the simplest way of showing CDA characteristics and we make a plea that it should be used more widely in future. A pre-requisite for its efficient use is, of course, that all drops produced by a nozzle are measured, which is now made possible by these new laser beam based instruments.

Rotary atomisation has the advantage that by altering the rotational speed and/or the feed rate, one can produce a predictable drop size, with a comparatively narrow drop spectrum.

By choosing a drop size which gives the most efficient impaction on the intended target, farmers have been able in the last few years, to get efficient pest control with drastically reduced amounts of active ingredient. This was predicted in my Brighton Paper 1969.[2] This aspect of C.D.A. is even more important than the reduction of total spray liquid used.

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| | HERBI 2000 RPM 60ML/MIN | BATTLE-SHIP 2000 RPM 1 L/MIN | FAN JET SS8002 LP @ 1 BAR 700ML/MIN | FAN JET SS8002 @ 3 BAR 700ML/MIN | MINI-ULVA 5900 RPM 30ML/MIN | BATTLE-SHIP 6000 RPM 50ML/MIN |
| TARGET DROP SIZE | 250 µm | 250 µm | LARGE | SMALL | 100 µm | 75 µm |
| ACTUAL DROP SIZE VMD | 259 µm | 250 µm | 273 µm | 192 µm | 104 µm | 75 µm |
| ACTUAL DROP SIZE NMD | 214 µm | 170 µm | 38 µm | 12 µm | 88 µm | 65 µm |
| EFFICIENCY FACTOR (VMD/NMD) | 1.21 | 1.47 | 7.18 | 16.00 | 1.18 | 1.16 |

| MEAN DROP SIZE µm | DOSAGE VARIATION A (*) | DOSAGE VARIATION B (*) | NUMBER OF DROPS X $10^6$ FROM 1 LITRE | | | | | |
|---|---|---|---|---|---|---|---|---|
| 412.29 | | | 12.97 | 11.49 | 14.74 | 6.87 | 0.00 | 0.00 |
| | 7.46 | 43.30 | | | | | | |
| 211.00 | | | 98.76 | 100.77 | 66.59 | 73.62 | 0.00 | 0.00 |
| | 3.69 | 12.47 | | | | | | |
| 136.58 | | | 25.24 | 49.59 | 62.60 | 133.49 | 230.78 | 0.00 |
| | 2.66 | 6.88 | | | | | | |
| 98.58 | | | 7.84 | 24.42 | 55.33 | 178.64 | 1048.29 | 421.99 |
| | 2.32 | 5.34 | | | | | | |
| 74.43 | | | 3.07 | 13.86 | 51.48 | 226.74 | 619.73 | 2613.53 |
| | 2.18 | 4.71 | | | | | | |
| 57.43 | | | 1.31 | 8.37 | 48.73 | 280.73 | 260.72 | 1802.66 |
| | 2.14 | 4.59 | | | | | | |
| 44.58 | | | 0.63 | 5.62 | 50.47 | 372.01 | 115.74 | 804.11 |
| | 2.14 | 4.58 | | | | | | |
| 34.58 | | | 0.29 | 3.53 | 48.40 | 457.41 | 47.15 | 301.16 |
| | 2.10 | 4.40 | | | | | | |
| 27.00 | | | 0.14 | 2.28 | 47.93 | 565.38 | 20.04 | 115.92 |
| | 2.08 | 4.34 | | | | | | |
| 21.14 | | | 0.00 | 1.45 | 48.00 | 707.71 | 8.72 | 45.39 |
| | 2.08 | 4.31 | | | | | | |
| 16.57 | | | 0.00 | 1.00 | 47.49 | 876.54 | 3.54 | 17.79 |
| | 2.07 | 4.29 | | | | | | |
| 13.00 | | | 0.00 | 0.83 | 47.71 | 1094.44 | 1.65 | 6.75 |
| | 2.02 | 4.05 | | | | | | |
| 10.29 | | | 0.00 | 0.00 | 44.37 | 1243.64 | 0.94 | 3.07 |
| | 2.02 | 4.10 | | | | | | |
| 8.14 | | | 0.00 | 0.00 | 47.27 | 1698.10 | 0.00 | 0.00 |
| | 2.03 | 4.10 | | | | | | |
| 6.43 | | | 0.00 | 0.00 | 44.59 | 1898.34 | 0.00 | 0.00 |
| T O T A L | | | 150.25 | 223.21 | 726.10 | 9813.66 | 2357.30 | 6132.37 |

| | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| FIGURES BELOW REFER TO DROPS BETWEEN (µm):- | | 412.29-211.00 | 412.29-211.00 | 412.29-211.00 | 136.58-74.43 | 136.58-74.43 | 98.58-57.43 |
| DOSAGE VARIATION A (*) | | 7.46 | 7.46 | 7.46 | 6.17 | 6.17 | 5.06 |
| DOSAGE VARIATION B (*) | | 43.30 | 43.30 | 43.30 | 15.30 | 15.30 | 11.30 |
| TOTAL NUMBER OF DROPS IN THIS RANGE X $10^6$ | | 111.73 | 112.26 | 81.33 | 538.87 | 1898.80 | 4838.18 |
| TOTAL VOLUME % IN RANGE | | 96.20 | 91.74 | 86.63 | 31.11 | 96.75 | 95.46 |
| TOTAL NUMBER % IN RANGE | | 74.36 | 50.30 | 11.20 | 5.49 | 80.55 | 78.88 |
| DROPS FROM ONE LITRE BELOW 50 µm | NUMBER X $10^6$ | 1.06 | 14.71 | 426.63 | 8913.57 | 197.78 | 1294.19 |
| | % NUMBER | 0.70 | 6.59 | 58.75 | 90.81 | 8.39 | 21.10 |
| DROPS FROM ONE LITRE BELOW 30 µm | NUMBER X $10^6$ | 0.14 | 5.56 | 327.36 | 8084.15 | 34.89 | 188.92 |
| | % NUMBER | 0.09 | 2.49 | 45.08 | 82.36 | 1.48 | 3.08 |
| DROPS FROM ONE LITRE BELOW 10 µm | NUMBER X $10^6$ | 0.00 | 0.00 | 91.86 | 3596.44 | 0.00 | 0.00 |
| | % NUMBER | 0.00 | 0.00 | 12.65 | 36.64 | 0.00 | 0.00 |

* Dosage variation A - derived from group mean B - derived from group limits

| SIZE RANGE | MEAN DROP SIZE µm | DROP RANGE IN µm | | VOLUME PERCENTAGE | CUMULATIVE VOLUME PERCENTAGE | NUMBER PERCENTAGE |
|---|---|---|---|---|---|---|
| 15 | 412.29 | 562.86 | 261.71 | 47.60% | 52.43% | 8.63% |
| 14 | 211.00 | 261.71 | 160.29 | 48.60% | 3.84% | 65.73% |
| 13 | 136.58 | 160.29 | 112.86 | 3.40% | 0.48% | 16.80% |
| 12 | 98.58 | 112.86 | 84.29 | 0.39% | 0.08% | 5.22% |
| 11 | 74.43 | 84.29 | 64.57 | 0.07% | 0.02% | 2.04% |
| 10 | 57.43 | 64.57 | 50.29 | 0.01% | 0.00% | 0.87% |
| 9 | 44.58 | 50.29 | 38.86 | 0.00% | 0.00% | 0.42% |
| 8 | 34.58 | 38.86 | 30.29 | 0.00% | 0.00% | 0.19% |
| 7 | 27.00 | 30.29 | 23.71 | 0.00% | 0.00% | 0.09% |
| 6 | 21.14 | 23.71 | 18.57 | 0.00% | 0.00% | 0.00% |
| 5 | 16.57 | 18.57 | 14.57 | 0.00% | 0.00% | 0.00% |
| 4 | 13.00 | 14.57 | 11.43 | 0.00% | 0.00% | 0.00% |
| 3 | 10.29 | 11.43 | 9.14 | 0.00% | 0.00% | 0.00% |
| 2 | 8.14 | 9.14 | 7.14 | 0.00% | 0.00% | 0.00% |
| 1 | 6.43 | 7.14 | 5.71 | 0.00% | 0.00% | 0.00% |

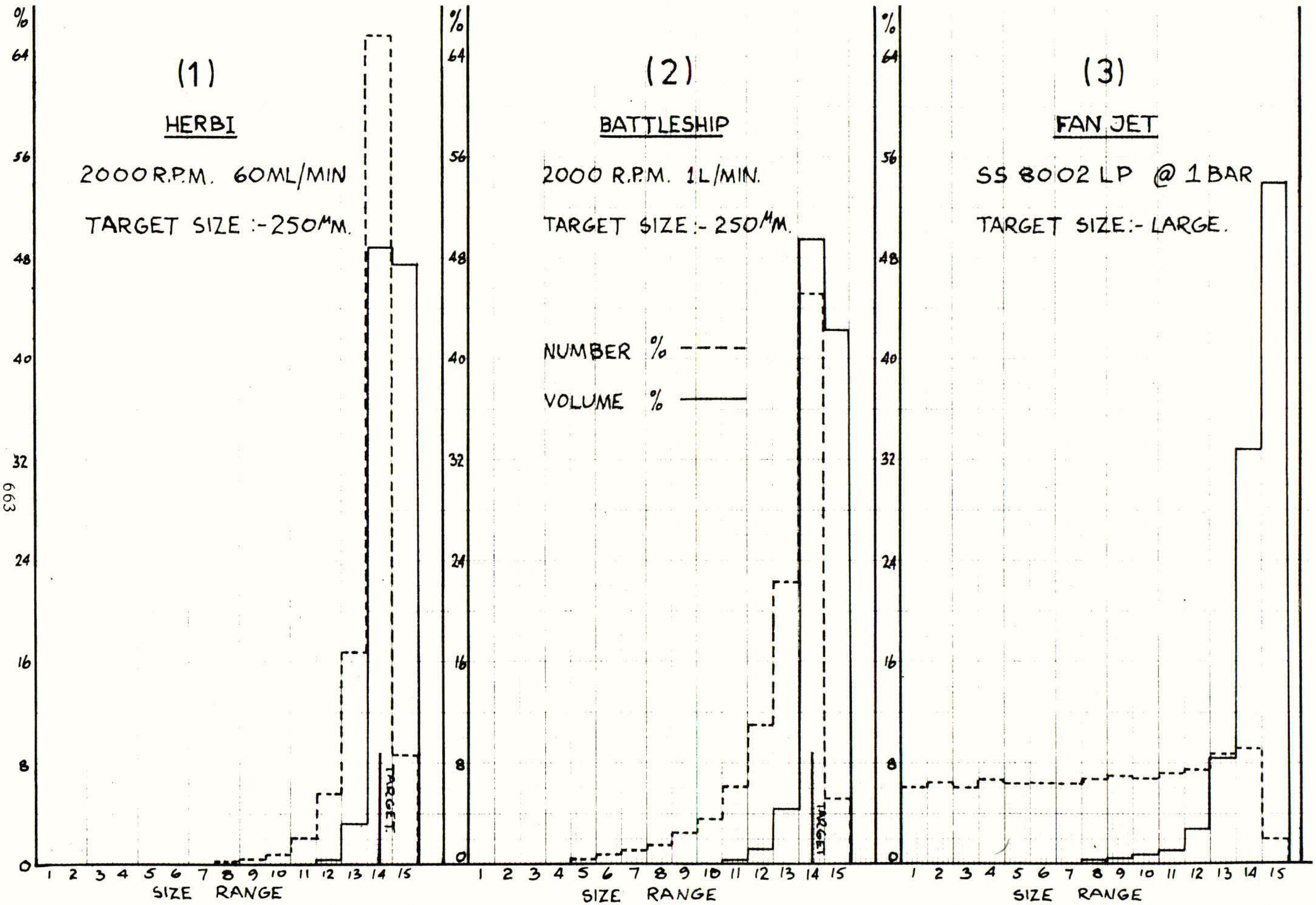
(1) HERBI 2000 RPM 60 ML/MIN

| | | | | | | |
|---|---|---|---|---|---|---|
| 15 | 412.29 | 562.86 | 261.71 | 42.16% | 57.84% | 5.15% |
| 14 | 211.00 | 261.71 | 160.29 | 49.58% | 8.26% | 45.15% |
| 13 | 136.58 | 160.29 | 112.86 | 6.62% | 1.64% | 22.22% |
| 12 | 98.58 | 112.86 | 84.29 | 1.22% | 0.42% | 10.94% |
| 11 | 74.43 | 84.29 | 64.57 | 0.30% | 0.12% | 6.21% |
| 10 | 57.43 | 64.57 | 50.29 | 0.08% | 0.04% | 3.75% |
| 9 | 44.58 | 50.29 | 38.86 | 0.03% | 0.01% | 2.52% |
| 8 | 34.58 | 38.86 | 30.29 | 0.01% | 0.00% | 1.58% |
| 7 | 27.00 | 30.29 | 23.71 | 0.00% | 0.00% | 1.02% |
| 6 | 21.14 | 23.71 | 18.57 | 0.00% | 0.00% | 0.65% |
| 5 | 16.57 | 18.57 | 14.57 | 0.00% | 0.00% | 0.45% |
| 4 | 13.00 | 14.57 | 11.43 | 0.00% | 0.00% | 0.37% |
| 3 | 10.29 | 11.43 | 9.14 | 0.00% | 0.00% | 0.00% |
| 2 | 8.14 | 9.14 | 7.14 | 0.00% | 0.00% | 0.00% |
| 1 | 6.43 | 7.14 | 5.71 | 0.00% | 0.00% | 0.00% |

(2) BATTLESHIP 2000 RPM 1000 ML/MIN

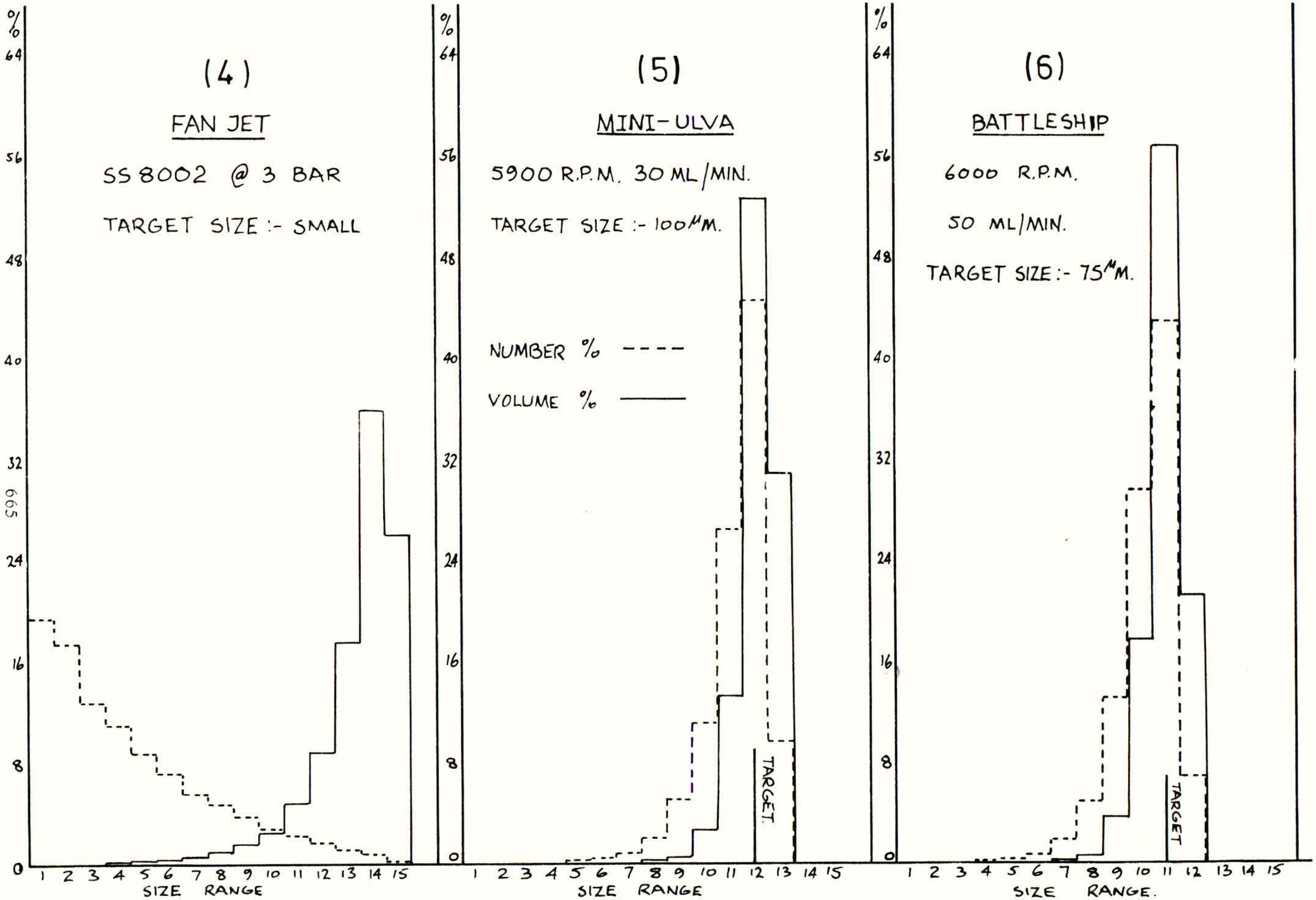
| | | | | | | |
|---|---|---|---|---|---|---|
| 15 | 412.29 | 562.86 | 261.71 | 53.92% | 46.08% | 2.03% |
| 14 | 211.00 | 261.71 | 160.29 | 32.71% | 13.37% | 9.17% |
| 13 | 136.58 | 160.29 | 112.86 | 8.35% | 5.02% | 8.62% |
| 12 | 98.58 | 112.86 | 84.29 | 2.77% | 2.25% | 7.62% |
| 11 | 74.43 | 84.29 | 64.57 | 1.11% | 1.14% | 7.09% |
| 10 | 57.43 | 64.57 | 50.29 | 0.48% | 0.66% | 6.71% |
| 9 | 44.58 | 50.29 | 38.86 | 0.23% | 0.42% | 6.95% |
| 8 | 34.58 | 38.86 | 30.29 | 0.11% | 0.32% | 6.72% |
| 7 | 27.00 | 30.29 | 23.71 | 0.05% | 0.27% | 6.60% |
| 6 | 21.14 | 23.71 | 18.57 | 0.02% | 0.25% | 6.61% |
| 5 | 16.57 | 18.57 | 14.57 | 0.01% | 0.23% | 6.54% |
| 4 | 13.00 | 14.57 | 11.43 | 0.00% | 0.23% | 6.57% |
| 3 | 10.29 | 11.43 | 9.14 | 0.00% | 0.23% | 6.11% |
| 2 | 8.14 | 9.14 | 7.14 | 0.00% | 0.22% | 6.51% |
| 1 | 6.43 | 7.14 | 5.71 | 0.00% | 0.22% | 6.14% |

(3) FAN JET SS8002 LP @ 1 BAR


(1)
HERBI
2000 R.P.M. 60ML/MIN
TARGET SIZE :- 250ᴹM.
(2)
BATTLESHIP
2000 R.P.M. 1L/MIN.
TARGET SIZE :- 250ᴹM.
NUMBER %
VOLUME %
(3)
FAN JET
SS 8002 LP @ 1 BAR
TARGET SIZE :- LARGE.
%
64
56
48
40
32
24
16
8
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
SIZE RANGE
TARGET

663

| SIZE RANGE | MEAN DROP SIZE µm | DROP RANGE IN µm | | VOLUME PERCENTAGE | CUMULATIVE VOLUME PERCENTAGE | NUMBER PERCENTAGE | |
|---|---|---|---|---|---|---|---|
| 15 | 412.29 | 562.86 | 261.71 | 26.17% | 73.83% | 0.07% | (4) FAN JET SS8002 @ 3 BAR |
| 14 | 211.00 | 261.71 | 160.29 | 35.77% | 38.07% | 0.75% | |
| 13 | 136.58 | 160.29 | 112.86 | 17.52% | 20.54% | 1.36% | |
| 12 | 98.58 | 112.86 | 84.29 | 8.78% | 11.76% | 1.82% | |
| 11 | 74.43 | 84.29 | 64.57 | 4.81% | 6.95% | 2.31% | |
| 10 | 57.43 | 64.57 | 50.29 | 2.73% | 4.22% | 2.86% | |
| 9 | 44.58 | 50.29 | 38.86 | 1.69% | 2.53% | 3.79% | |
| 8 | 34.58 | 38.86 | 30.29 | 0.97% | 1.56% | 4.66% | |
| 7 | 27.00 | 30.29 | 23.71 | 0.57% | 0.99% | 5.76% | |
| 6 | 21.14 | 23.71 | 18.57 | 0.34% | 0.64% | 7.21% | |
| 5 | 16.57 | 18.57 | 14.57 | 0.21% | 0.44% | 8.93% | |
| 4 | 13.00 | 14.57 | 11.43 | 0.12% | 0.31% | 11.15% | |
| 3 | 10.29 | 11.43 | 9.14 | 0.07% | 0.24% | 12.67% | |
| 2 | 8.14 | 9.14 | 7.14 | 0.05% | 0.20% | 17.30% | |
| 1 | 6.43 | 7.14 | 5.71 | 0.03% | 0.17% | 19.34% | |
| 15 | 412.29 | 562.86 | 261.71 | 0.00% | 100.00% | 0.00% | (5) MINI-ULVA 5900 RPM 30 ML/MIN |
| 14 | 211.00 | 261.71 | 160.29 | 0.00% | 100.00% | 0.00% | |
| 13 | 136.58 | 160.29 | 112.86 | 30.78% | 69.22% | 9.79% | |
| 12 | 98.58 | 112.86 | 84.29 | 52.59% | 16.63% | 44.47% | |
| 11 | 74.43 | 84.29 | 64.57 | 13.38% | 3.25% | 26.29% | |
| 10 | 57.43 | 64.57 | 50.29 | 2.59% | 0.67% | 11.06% | |
| 9 | 44.58 | 50.29 | 38.86 | 0.54% | 0.13% | 4.91% | |
| 8 | 34.58 | 38.86 | 30.29 | 0.10% | 0.03% | 2.00% | |
| 7 | 27.00 | 30.29 | 23.71 | 0.02% | 0.01% | 0.85% | |
| 6 | 21.14 | 23.71 | 18.57 | 0.00% | 0.00% | 0.37% | |
| 5 | 16.57 | 18.57 | 14.57 | 0.00% | 0.00% | 0.15% | |
| 4 | 13.00 | 14.57 | 11.43 | 0.00% | 0.00% | 0.07% | |
| 3 | 10.29 | 11.43 | 9.14 | 0.00% | 0.00% | 0.04% | |
| 2 | 8.14 | 9.14 | 7.14 | 0.00% | 0.00% | 0.00% | |
| 1 | 6.43 | 7.14 | 5.71 | 0.00% | 0.00% | 0.00% | |
| 15 | 412.29 | 562.86 | 261.71 | 0.00% | 100.00% | 0.00% | (6) BATTLESHIP 6000 RPM 50 ML/MIN |
| 14 | 211.00 | 261.71 | 160.29 | 0.00% | 100.00% | 0.00% | |
| 13 | 136.58 | 160.29 | 112.86 | 0.00% | 100.00% | 0.00% | |
| 12 | 98.58 | 112.86 | 84.29 | 21.15% | 78.85% | 6.88% | |
| 11 | 74.43 | 84.29 | 64.57 | 56.43% | 22.41% | 42.61% | |
| 10 | 57.43 | 64.57 | 50.29 | 17.88% | 4.53% | 29.39% | |
| 9 | 44.58 | 50.29 | 38.86 | 3.73% | 0.80% | 13.11% | |
| 8 | 34.58 | 38.86 | 30.29 | 0.65% | 0.15% | 4.91% | |
| 7 | 27.00 | 30.29 | 23.71 | 0.12% | 0.03% | 1.89% | |
| 6 | 21.14 | 23.71 | 18.57 | 0.02% | 0.01% | 0.74% | |
| 5 | 16.57 | 18.57 | 14.57 | 0.00% | 0.00% | 0.29% | |
| 4 | 13.00 | 14.57 | 11.43 | 0.00% | 0.00% | 0.11% | |
| 3 | 10.29 | 11.43 | 9.14 | 0.00% | 0.00% | 0.05% | |
| 2 | 8.14 | 9.14 | 7.14 | 0.00% | 0.00% | 0.00% | |
| 1 | 6.43 | 7.14 | 5.71 | 0.00% | 0.00% | 0.00% | |


(4)
FAN JET
SS 8002 @ 3 BAR
TARGET SIZE :- SMALL
(5)
MINI-ULVA
5900 R.P.M. 30 ML/MIN.
TARGET SIZE :- 100 µM.
NUMBER % - - - -
VOLUME % ———
(6)
BATTLESHIP
6000 R.P.M.
50 ML/MIN.
TARGET SIZE :- 75 µM.
%
0 8 16 24 32 40 48 56 64
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
SIZE RANGE
TARGET

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# DROP SIZE SPECTRA AND SPRAY DISTRIBUTION FROM A MICRON BATTLESHIP DISC

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Summary Measurements were made of the performance of a Battleship disc rotating at two speeds (2000 and 3000 rev/min) and fed at two rates (500 and 1000 ml/min). The results showed that speed and feed rate both affected the drop size spectrum and spray distribution. Ligament formation was more regular at 2000 rev/min, 500 ml/min than under the other conditions.

## INTRODUCTION

Techniques developed for a research project at the NIAE (Byass et al 1976) were used to examine the drop size spectra and spray distribution patterns produced by a Battleship disc (Bals 1978), of the type using two liquid feed tubes. The disc was operated at speeds of 2000 and 3000 rev/min and feed rates of 500 and 1000 ml/min. The spray solution was water containing 0.1% (v:v) Agral+ wetting agent.

## DROP SIZE

The drop size spectra were measured from short duration flash photographs using an image analysing computer. Examples of enlarged portions of the photographs are shown in Figs. 1 - 4. 32 photographs were examined to obtain the 4 size spectra shown in Fig. 5.

The Battleship disc is designed to produced spray by the break-up of liquid ligaments formed from the teeth around the disc edge. It can be seen in Figs. - 1 - 4 that 2000 rev/min, 500 ml/min (Fig. 1) was the only one of the 4 conditions which produced fairly regular ligaments. In the other 3 cases the ligaments were seen to be irregular, and occasionally, the spaces between the disc teeth were filled with liquid causing atomisation to take place from there instead of from the teeth as intended.

The failure of the disc to produce regular ligaments under certain circumstances is due to the tendency for a disc to become overloaded or flooded as disc speed or feed rate increase (Hinze and Milborn 1950). Overloading of a disc generally gives rise to a coarser spray than would have been expected had regular ligament formation predominated. This effect is illustrated in the spectra shown in Fig. 5.

The irregular spray formation at 2000 rev/min, 1000 ml/min provided a coarser spray than did the regular formation at 2000 rev/min, 500 ml/min. The v.m.d. at 1000 ml/min was 290 µm compared to 230 µm at 500 ml/min, and the spectrum was much wider in the former case.

Comparison between the spectra for 500 ml/min at the two speeds indicates that overloading was occurring at the higher speed, since if regular ligament formation had predominated in both cases, then the v.m.d. of the spray produced at 3000 rev/min would have been smaller than that produced at 2000 rev/min (Frost 1978). They were however similar. The spray produced at 3000 rev/min, 500 ml/min was therefore coarser than would have been the case had regular ligament formation predominated. The curve for 3000 rev/min, 500 ml/min shows a peak between, 100 µm and 180 µm. It is likely that this corresponds to the mean size of drop produced by the regular ligaments that were present.

The spray formed at 3000 rev/min, 1000 ml/min had a v.m.d. of 250 µm. This was larger than that at 3000 rev/min, 500 ml/min, due to the greater degree of overloading, but lower than that at 2000 rev/min, 500 ml/min due to the more energetic atomisation.

## SPRAY DISTRIBUTION

Spray distribution patterns were obtained, indoors, by attaching the disc to a conveyor and passing it at a speed of 2 m/s over strips of 50 mm wide chromatography paper laid normal to the direction of travel. A fluorescent dye (0.2% w.v. UV39) was added to the spray solution, and this was then extracted from 50 mm lengths of the paper. Fluorimeter readings of the extracts provided a measure of the amount of spray deposited on each 50 mm square of paper. The results are shown in Fig. 6.

The swath width at 2000 rev/min, 500 ml/min was about 1.25 m. The application rate that would be obtained at a forward speed of 2 m/s with discs spaced this distance apart on a boom is about 33 l/ha. For comparison the swath width produced by the Micron Herbi* disc at 2000 rev/min, 60 ml/min is about 1 m (Lake et al 1976). Discs spaced this distance apart would give an application rate of about 5 l/ha at 2 m/s forward speed. The v.m.d. of the spray from the Herbi at 2000 rev/min, 60 ml/min is about 210 µm, compared to 230 µm for the Battleship at 2000 rev/min, 500 ml/min, but the drop size spectrum is narrower in the former case.

Since all the drops leaving a disc do so with approximately the peripheral speed of the disc, the distance they travel depends upon their size. For example the pattern obtained at 2000 rev/min, 1000 ml/min (Fig. 6) is wider than that for 2000 rev/min, 500 ml/min, due to the relatively larger drops present in the former case. It follows from this that in general, for a spinning disc, uniformity of spray distribution decreases with increasing uniformity of drop size. It should also be noted that patterns of the type shown in Figs. 5 - 8 indicate only the relative volumes of spray deposited. The spray coverage that is obtained depends also upon drop size. Hence the coverage provided by a given volume of spray deteriorates towards the extremes of the pattern.

## CONCLUSIONS

Of the four conditions tested, the more uniform size drops were produced at 2000 rev/min, 500 ml/min.

The v.m.d. of the spray produced under these conditions was 230 um.

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## ADDENDUM

Due to a misunderstanding on the part of the Authors, the work reported here was carried out with the disc rotating in the opposite direction to that recommended by the manufacturer. The Authors apologise for the inconvenience caused.

A REVISED VERSION OF THIS PAPER WILL BE INCLUDED IN VOLUME 3 OF THESE PROCEEDINGS.

Fig. 1. 2000 rev/min, 500 ml/min

Fig. 2. 2000 rev/min, 1000 ml/min

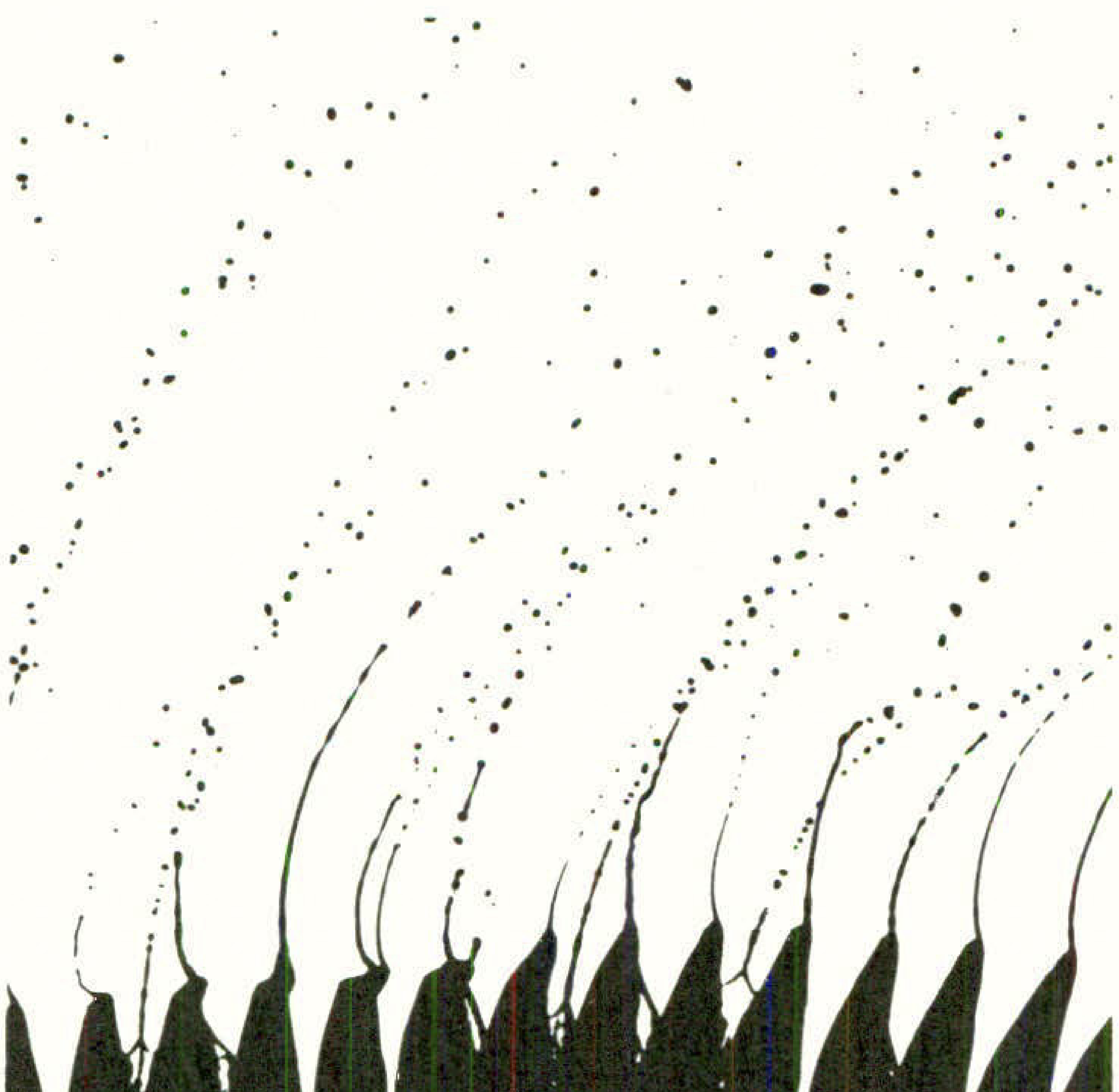
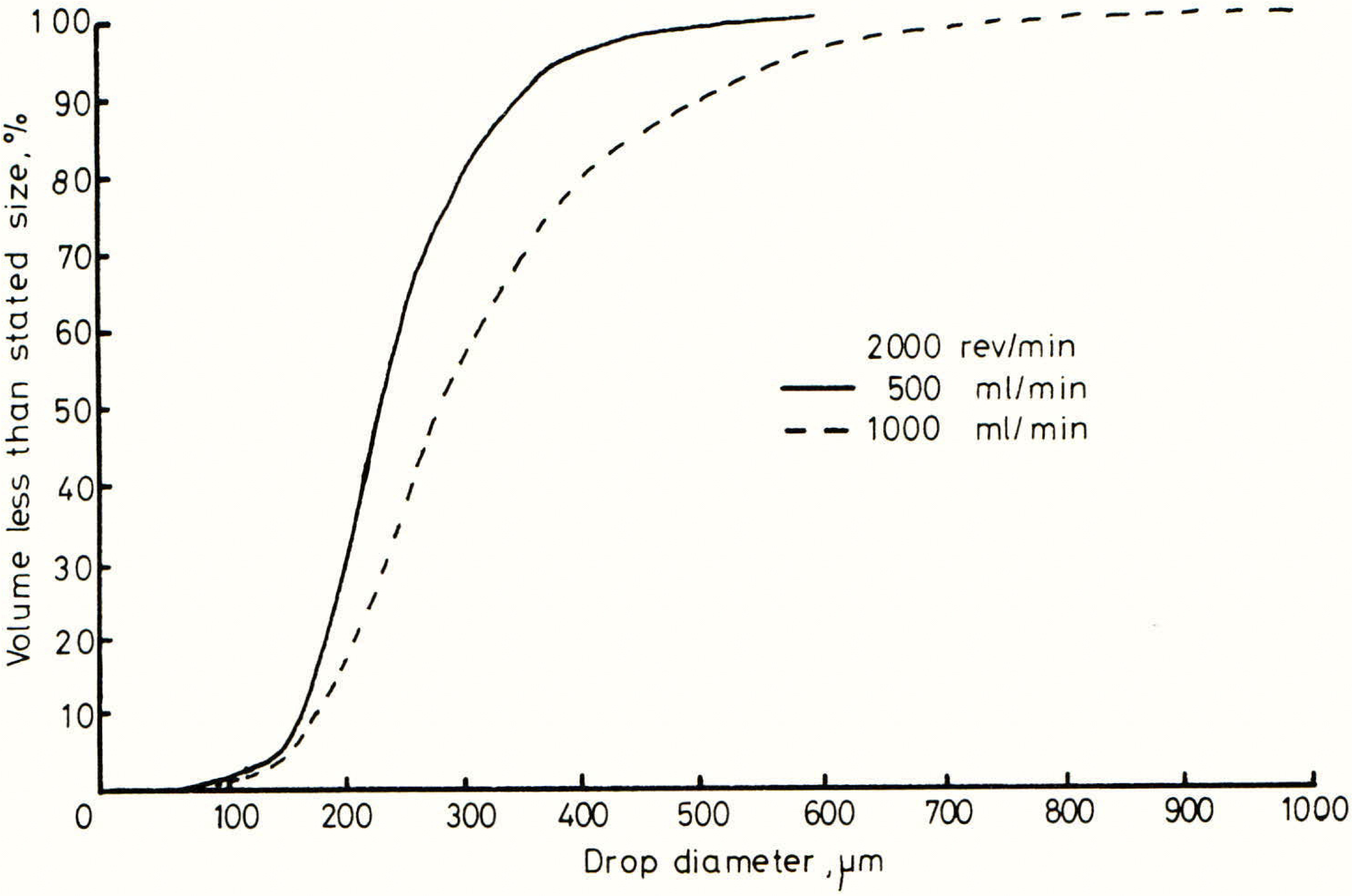


Fig. 3. 3000 rev/min, 500 ml/min

Fig. 4. 3000 rev/min, 1000 ml/min



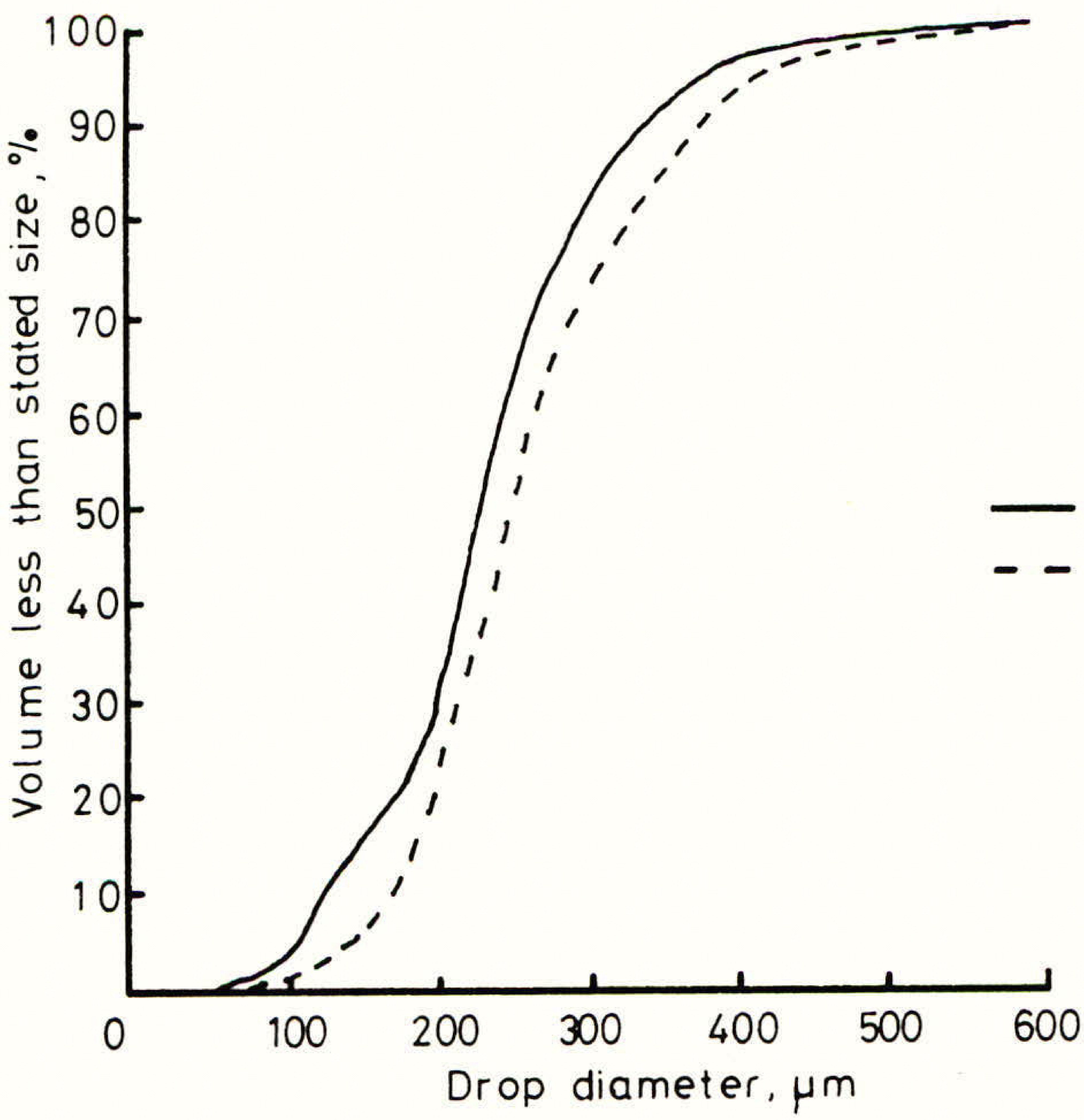




Fig. 5 Drop size spectra

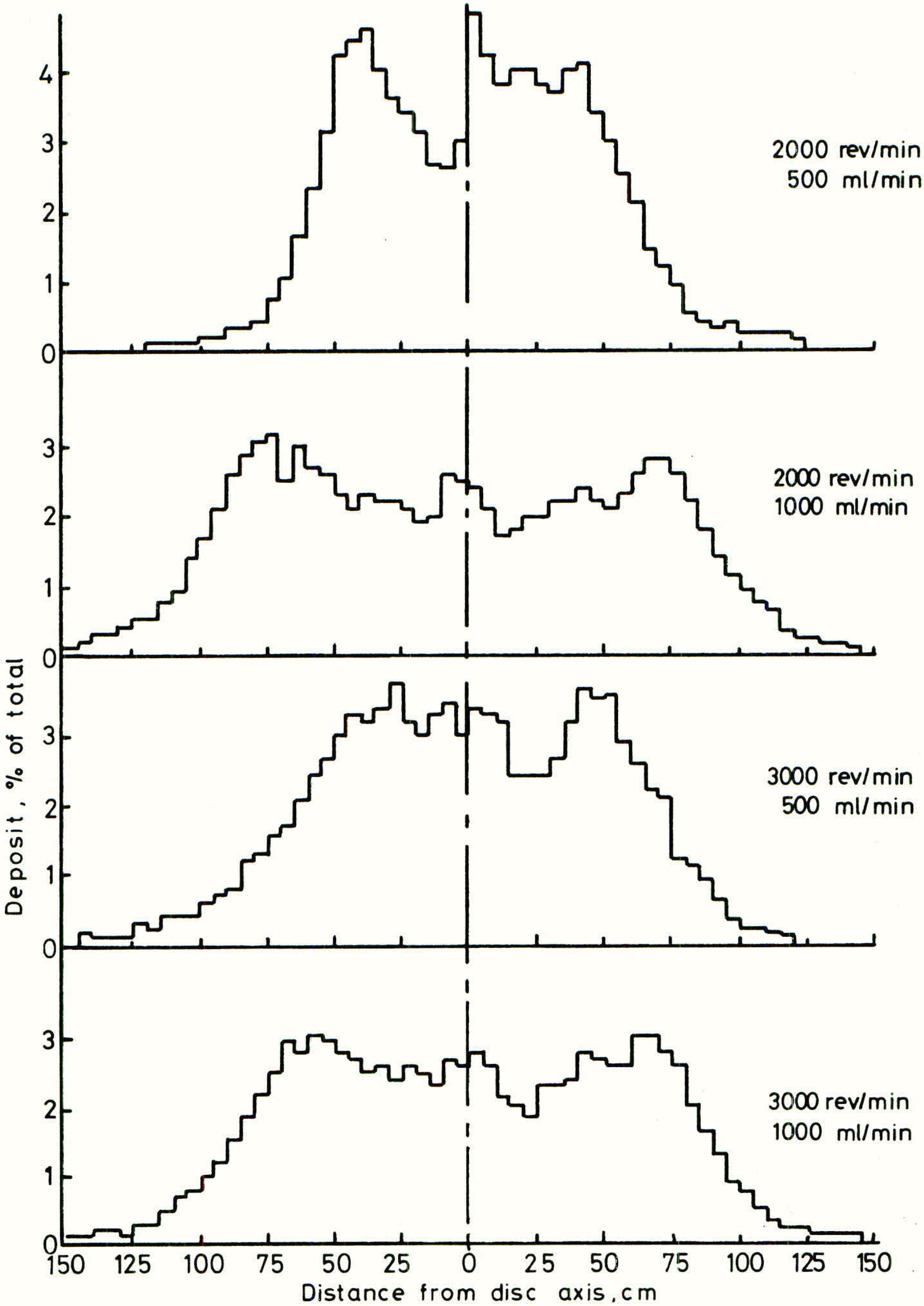



Fig. 6 Spray distributions

# A STUDY OF THE EFFECTS OF DISC SPEED AND FLOW RATE ON THE PERFORMANCE OF THE MICRON 'BATTLESHIP'

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Summary The performance of a cup-shaped centrifugal nozzle, known as the Micron 'Battleship', designed for use on a tractor-mounted CDA sprayer, was studied to determine spray distribution and drop size over a range of flow rates and disc speeds. The 'Battleship' produced a narrow drop spectrum, the v.m.d. of which can be varied, over a range of 70um to 250um. The swath width ranged from 1.38m for 94um drops to 2.08m for the 250um drops in still conditions with an acceptably uniform distribution across the swath.

## INTRODUCTION

Spinning discs have been used mainly on hand-held CDA sprayers as they are suitable for low flow rates and slow forward speeds, but as a nozzle capable of higher flow rates to match faster forward speeds is needed with tractor-mounted equipment, the performance of a large capacity spinning cup, known as the Micron 'Battleship' (Bals, 1978) was investigated.

This large spinning cup measuring 120mm in diameter and 75mm deep, has 180 channels which individually feed each of the teeth on the periphery of the cup. The grooves are deep enough to avoid spillage of liquid between grooves and provide lane separation between ligaments, thus allowing higher flow rates to be applied without over feeding.

For these experiments the cup was driven directly by a 12v DC electric motor and the speed controlled by altering the voltage. The liquid feed system onto the cup was altered for the different experiments. Initially the cup was fed through a single orifice, but after tests with four jets to provide a more uniform distribution of liquid to the grooves, an inner cone 'funnel' was added. This cone was subsequently fed through two orifices for drop size analysis.

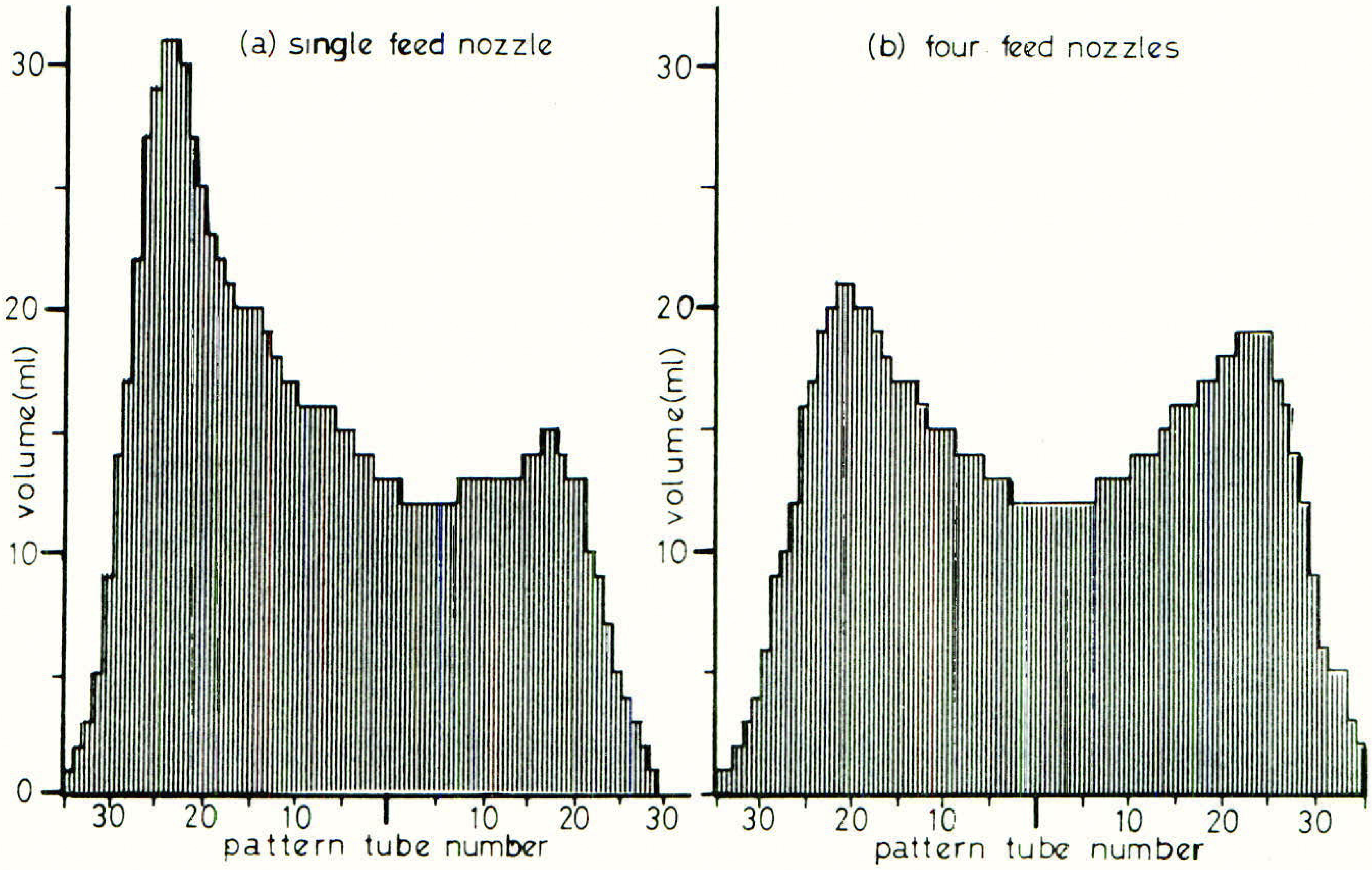
## SWATH DISTRIBUTION

A 3m x 3m patternator, with 98 channels of 32mm from peak to peak, was used. For each flow rate and disc speed studied, one litre of water plus 0.1% teepol was sprayed at a height of 300mm above the middle of the patternator.

A single feed to the base of the cup gave an asymmetrical distribution (Fig 1a), but when four jets were positioned symmetrically around the base of the

'Battleship', it produced a more regular distribution on either side of the centre line (Fig 2).

Fig.1 Swath distribution from Battleship at 2000 rev/min and 800 ml/min.




The effects of flow rates between 200 and 1200 ml/min, and disc speeds between 2000 and 6000 rev/min were studied. The swath widths given in Table 1 were measured from the point at which two swaths would overlap to give the most even overall distribution. The standard deviations were also calculated from the same points.

Swath width increased as the flow rate increased, but at low flow rates there was little effect from different disc speeds. However, at higher flow rates increased disc speeds caused a reduction in swath width.

## DROP SIZE ANALYSIS

The drop spectra were measured, at different flow rates and disc speeds, using the Malvern Instruments' 'Droplet and Particle Analyser Type 1800'. With this instrument diffraction patterns produced by drops passing through a laser beam are detected by a series of concentric semi-circular light sensitive cells linked to a computer. The energy distribution across the light sensitive cells is related to a Rosin-Rammler curve from which the drop distribution is calculated, (Swithenbank et al). The detector was fitted with a 300mm lens.

The disc was fitted with the 'cone feed' during these experiments, so that the liquid flowed down the funnel and spread out to feed more evenly round the

Table 1

Results showing the effects of flow rate and disc speed on swath distribution using disc fed with four symmetrical nozzles

| Disc Speed rev/min | Flow Rate ml/min | Swath Width m | ml/channel Mean | ml/channel % Coef. Var. |
|---|---|---|---|---|
| 2000 | 200 | 1.44 | 22.2 | 22.8 |
| | 400 | 1.63 | 19.6 | 16.5 |
| | 600 | 1.89 | 17.0 | 20.1 |
| | 800 | 1.95 | 16.4 | 18.5 |
| | 1000 | 2.08 | 15.4 | 23.0 |
| | 1200 | 2.14 | 15.2 | 26.0 |
| | 1400 | 2.21 | 14.4 | 23.8 |
| 3000 | 200 | 1.44 | 22.2 | 21.2 |
| | 400 | 1.63 | 19.6 | 17.7 |
| | 600 | 1.83 | 17.5 | 20.6 |
| | 800 | 1.89 | 16.9 | 20.0 |
| | 1000 | 1.95 | 16.4 | 16.5 |
| | 1200 | 2.14 | 14.9 | 16.8 |
| | 1400 | 2.27 | 14.1 | 20.0 |
| 4000 | 200 | 1.38 | 23.3 | 16.7 |
| | 400 | 1.63 | 19.6 | 20.0 |
| | 600 | 1.83 | 17.5 | 22.0 |
| | 800 | 1.83 | 17.5 | 18.6 |
| | 1000 | 1.95 | 16.4 | 15.8 |
| | 1200 | 2.08 | 15.4 | 22.4 |
| | 1400 | 2.14 | 14.9 | 20.4 |
| 5000 | 200 | 1.38 | 23.3 | 14.9 |
| | 400 | 1.57 | 20.4 | 16.7 |
| | 600 | 1.70 | 18.9 | 14.3 |
| | 800 | 1.83 | 17.6 | 14.9 |
| | 1000 | 1.89 | 17.0 | 16.4 |
| | 1200 | 1.89 | 17.0 | 13.3 |
| | 1400 | 1.95 | 16.4 | 16.1 |
| 6000 | 200 | 1.38 | 23.3 | 17.7 |
| | 400 | 1.57 | 20.4 | 14.5 |
| | 600 | 1.70 | 18.9 | 15.5 |
| | 800 | 1.76 | 18.2 | 13.3 |
| | 1000 | 1.82 | 17.5 | 13.4 |
| | 1200 | 1.89 | 17.0 | 14.5 |
| | 1400 | 1.89 | 17.0 | 12.7 |

base. Measurements were taken on three occasions for each flow rate between 50 and 1400 ml/min and disc speed between 1000 and 6000 rev/min.

Changes in volume mean diameter (v.m.d.) are shown in Fig 2, with v.m.d./n.m.d. ratios in Fig 3. For example, at 1000 rev/min as flow rate increased from 50 to 300 ml/min, the v.m.d. was reduced from 328um to 273um but above 300 ml/min the v.m.d. increased to 389um at 1400 ml/min. The reading at 100 ml/min, namely 416um, may be unreliable for two reasons: firstly, the standard deviation over three replicates was much higher than the others at $\pm$ 80 and secondly, the drop spectrum produced by the disc was at the upper limits of the detector using a 300mm lens; a more accurate answer would be obtained by using a 1000 lens, giving a drop size range of 19um to 1874um.

At 6000 rev/min, there was an increase in v.m.d. from 76um at 50 ml/min to 104um at 400 ml/min with a slight increase to 119um at 1400 ml/min. The disc speeds between 1000 and 6000 rev/min show the transitional phases between these two curves.

The v.m.d./n.m.d. ratios (Fig 3) show similar patterns to the v.m.d.'s (Fig 2) but at 1000 rev/min where the ratios for flow rates from 50 to 1000 ml/min (excluding 250 ml/min) are all 1.1 and 250 ml/min is 1.2.

## DISCUSSION

The swath width and v.m.d. are both altered by changing flow rate or disc speed. In relation to CDA spraying, however, the v.m.d./n.m.d. ratio deteriorates at certain combinations of disc speed and flow rate. Johnstone (1978) suggested that for an acceptable spectrum the ratio should not exceed 1.4 but he referred to a spectrum measured using manual techniques using MgO or Kromekote slides. With the Malvern Instrument, which is very sensitive to aerosol drops as small as 5um, the v.m.d./n.m.d. ratio may be increased. For example, when the spectrum from the 'Battleship' was analysed at 3000 rev/min and 1000 rev/min the v.m.d. was found to be 185um on MgO slides and 192um on the Malvern Instrument. The v.m.d./n.m.d. ratios were however 1.23 for the MgO and 3.9 for the Malvern. This indicates that when quoting the v.m.d./n.m.d. ratio the method of spectrum analysis must be stated. It may also be valid to raise the limit to, say, 1.6 when using the Malvern or other apparatus of equal sensitivity.

In relation to controlled drop application, for CDA 250, a 250um drop is produced with a flow rate of 1000 ml/min and a disc speed of 2000 rev/min but when a smaller drop is required a higher disc speed and lower flow rate enable the appropriate size to be selected. The smallest v.m.d. obtained was 76um with a n.m.d. of 63um, being produced at 6000 rev/min and 50 ml/min.

A swath width of 2.08m was produced with a 250um drop in contrast to 1.2m for the Micron 'Herbi'. This means that at a forward speed of 2 m/s a pesticide could be applied at the rate of 40 l/ha from the 'Battleship' or 4 l/ha from the 'Herbi'. The swath width was decreased to 1.38m when the drop size was 94um under still conditions although with a cross wind a wider swath would be produced.

The spray distribution across the swath from the 'Battleship' was more even than that obtained with the 'Herbi' disc by Lake (1976). The WRO stacked disc was developed to overcome the distribution problem with the 'Herbi' (Taylor et al, 1976). However, with the stacked disc, each disc must be fed accurately with the correct flow of 60 ml/min otherwise by increasing the flow rate the

Fig.2 A graph to show the vmd at different flow rates and disc speeds.

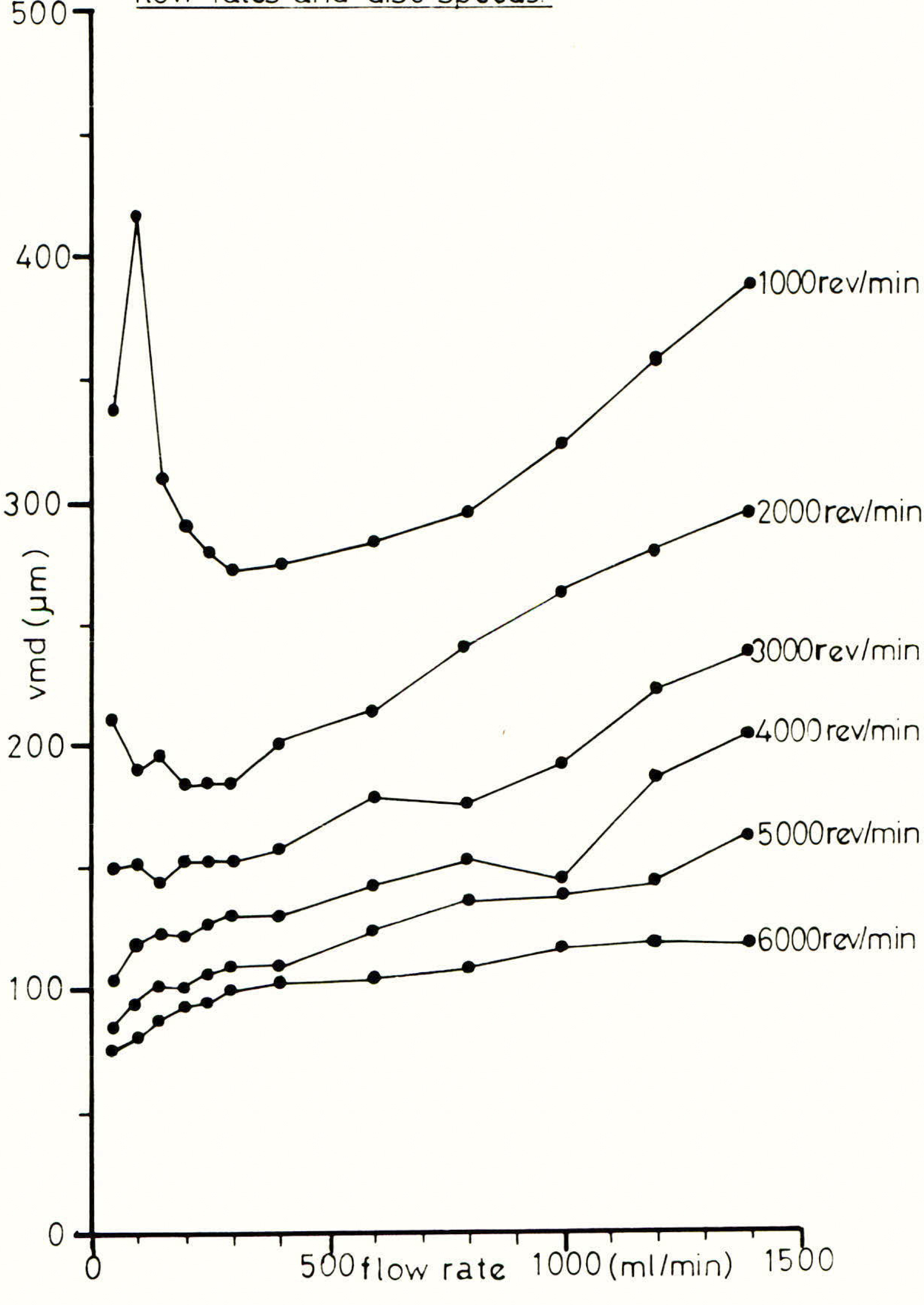
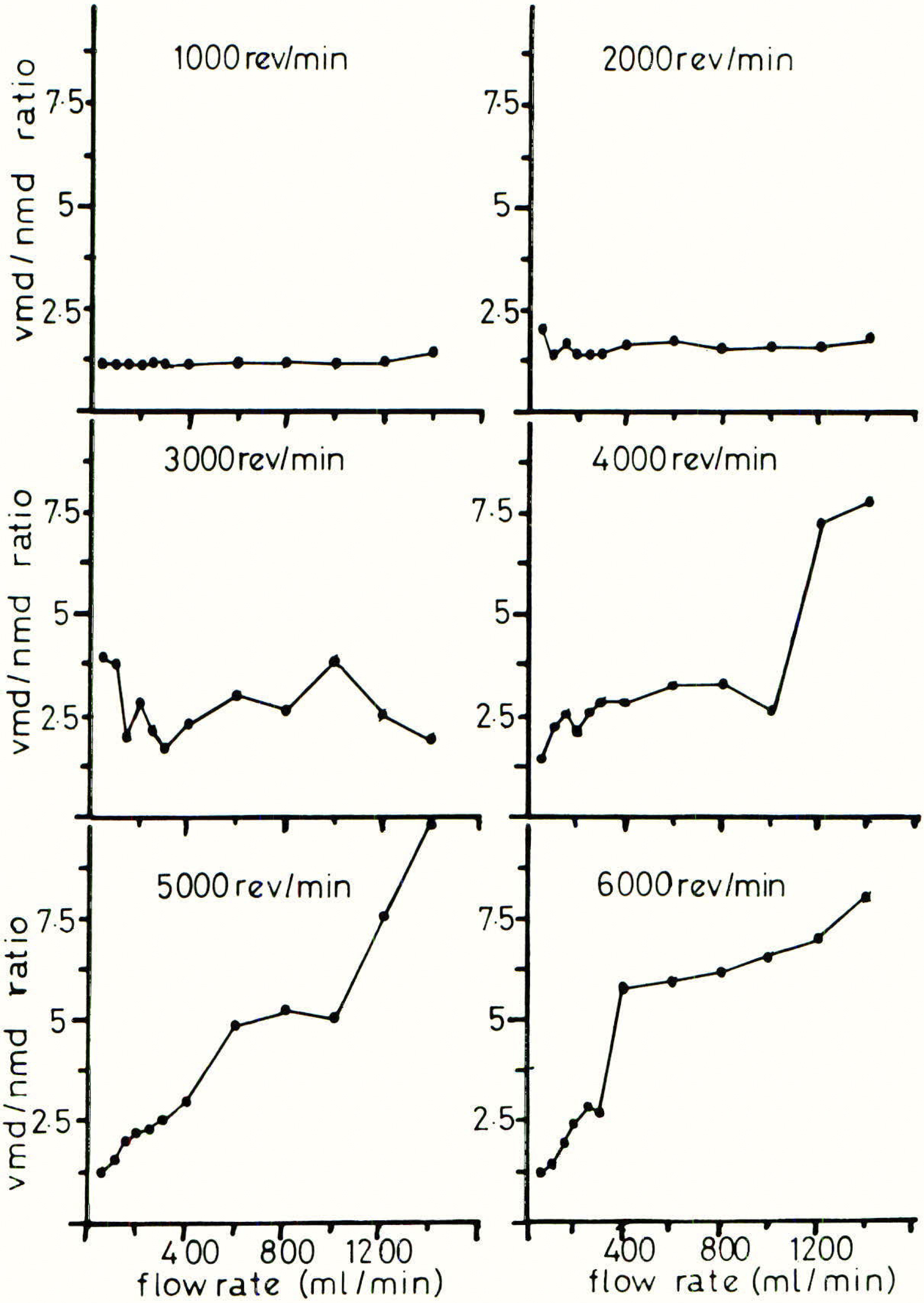


Fig.3 The effect of flow rate and disc speed on the vmd/nmd ratio



the v.m.d./n.m.d. ratio deteriorates (Johnstone et al, 1977). So due to the limitation of flow rate drop density is low and to increase application rate the forward speed must be reduced, sometimes below practical levels.

## CONCLUSION

The 'Battleship' spinning cup is suited to providing a narrow range of drop sizes from 70um to 250um when fitted to a CDA sprayer provided with suitable controls for disc speed, flow rate and swath width. Such a sprayer will be capable of applying pesticide at reduced volumes with the appropriate drop size in relation to the pesticide, formulation and crop. Nozzles mounted on a horizontal boom are essential for placement application and even with the smaller drops below 125um, drift will be minimal due to the relatively short distance between the nozzle and the crop.

The most important advantage of the 'Battleship' is that higher flow rates than the 'Herbi', namely up to 1400 ml/min, can be sprayed, which allows faster forward speeds.


## Acknowledgements

I wish to thank Mr. E.J. Bals of Micron Sprayers Ltd. for his co-operation and for the use of the 'Battleship' prototypes for this work. Thanks are also due to O.D.M. for supplying the Malvern analyser on Project No. R3337.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# DRIFT FROM AN ULVAMAST SPRAYER

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Summary Drift over cereals from an Ulvamast sprayer was measured. Deposits were collected at distances up to 50 m from the sprayer and showed that the spray diffused resulting in deposits several metres above the height of emission.

## INTRODUCTION

The Ulvamast sprayer, Fig. 1, uses a multi-disc aerial atomising head designed to produce drops of 60 µm diameter. The manufacturers of the Ulvamast intend the equipment to be used to apply a limited range of insecticide and fungicides to crops at between 1 and 5 l./ha using a bout width of 10 to 40 m depending on wind speed and atomiser height.

Discussion at the BCPC Symposium on Controlled Drop Application (BCPC 1978) showed that there was no published data available on the amount of drift from the sprayer although measurements have been made of the drift of spray from hand-held disc units. (Johnstone & Huntington, 1976). Some data is, however, available on the amount of drift from hydraulic pressure nozzles. (Byass & Lake, 1977)

This note records measurements made during the summer of 1978 of the drift of spray from an Ulvamast sprayer used in a cereal crop about 1 m high.

## METHOD AND MATERIALS

The sprayer was modified to enable small volumes of spray liquid to be fed at a constant pressure to the atomiser. The spray liquid was a mixture of Shellsol A+ and Risella 33++, in the ratio by volume of 7:3 and 0.4% by weight of Waxoline Red "O"+++.

The layout of the experiment is shown in Fig. 2. Masts 8 to 10 m high were used to support lengths of 2.5 mm diameter plastic electrical sleeving. The masts were positioned 1, 5, 10, 20, 50 and 100 m from the atomiser.

For each run the sprayer made successive passes of the row of masts over periods of several minutes with the atomising head fixed at a height of 2.4 m above ground level. The tractor speed was 2 m/s. Mean wind speed was recorded 2 m above ground level using a cup anemometer.

At the end of a run a spectrophotometer was used to determine the amount of spray deposited on each 1 m length of sleeving. The dye was extracted by washing the sleeving in 10 ml of a mixture of Shellsol A and Rissella 33 (7:3).

Details of the two runs are given in Table 1.

Table 1

Details of runs

| Run No. | Flow rate l./min | No. of passes | Mean wind speed, m/s | Wind direction |
|---|---|---|---|---|
| 1* | 0.3 | 20 | 1.5 | NNW |
| 2 | 0.6 | 12 | 4.8 | SW |

*Wind direction outside the manufacturers recommended limits (Lockinge Farm Enterprises, 1978)

## RESULTS AND DISCUSSIONS

Histograms showing the deposits on the first lengths of sleeving 1 m from the path of the sprayer are shown in Fig. 3. In Run 1 deposits were obtained on the highest length of sleeving 6 to 7 m above ground level while in Run 2 when the wind speed was higher no deposits were obtained above 4 m. In both runs most of the deposit was below the emission point.

Deposits on the other lengths of sleeving are shown in Figs. 4a and 4b as percentages of the total deposit on the sleeving attached to the first mast 1 m from the path of the sprayer. No deposits were obtained in Run 1 on the sleeving at 50 m and 100 m and in Run 2 on the sleeving at 100 m. This is as expected because of the wind direction.

In Run 1 55% of the spray was deposited on the sleeving 5 m from the path of the sprayer and 10% at 10 m. In both cases deposits were obtained on the highest sleeving 8 to 9 m above ground level. In Run 2 when the wind speed across the direction of travel was higher, deposits on the sleeving were 68% at 5 m, 22% at 10 m, 11% at 20 m and 2% at 50 m. At 5 m deposits were obtained 4 to 5 m above ground level and this increased to 5 to 6 m at 10 and 7 to 8 m (the highest point) at 20 m. It may be assumed that the spray not collected at the 5 and 10 m masts was deposited on the crop. This means that 32% of the spray was deposited within the first 5 m and 46% between 5 and 10 m. Deposits would have been too low to measure at 50 m if the spray continued to diffuse.

## CONCLUSIONS

In Run 1 diffusion of spray resulted in deposits being collected at heights which increased with increasing distance downwind. In Run 2 deposits were collected at the maximum height (8 to 9 m) at all three masts.

## Acknowledgement

We would like to thank Mr. J. Haigh, Lockinge Farm Enterprises Ltd. for the loan of the Ulvamast sprayer.

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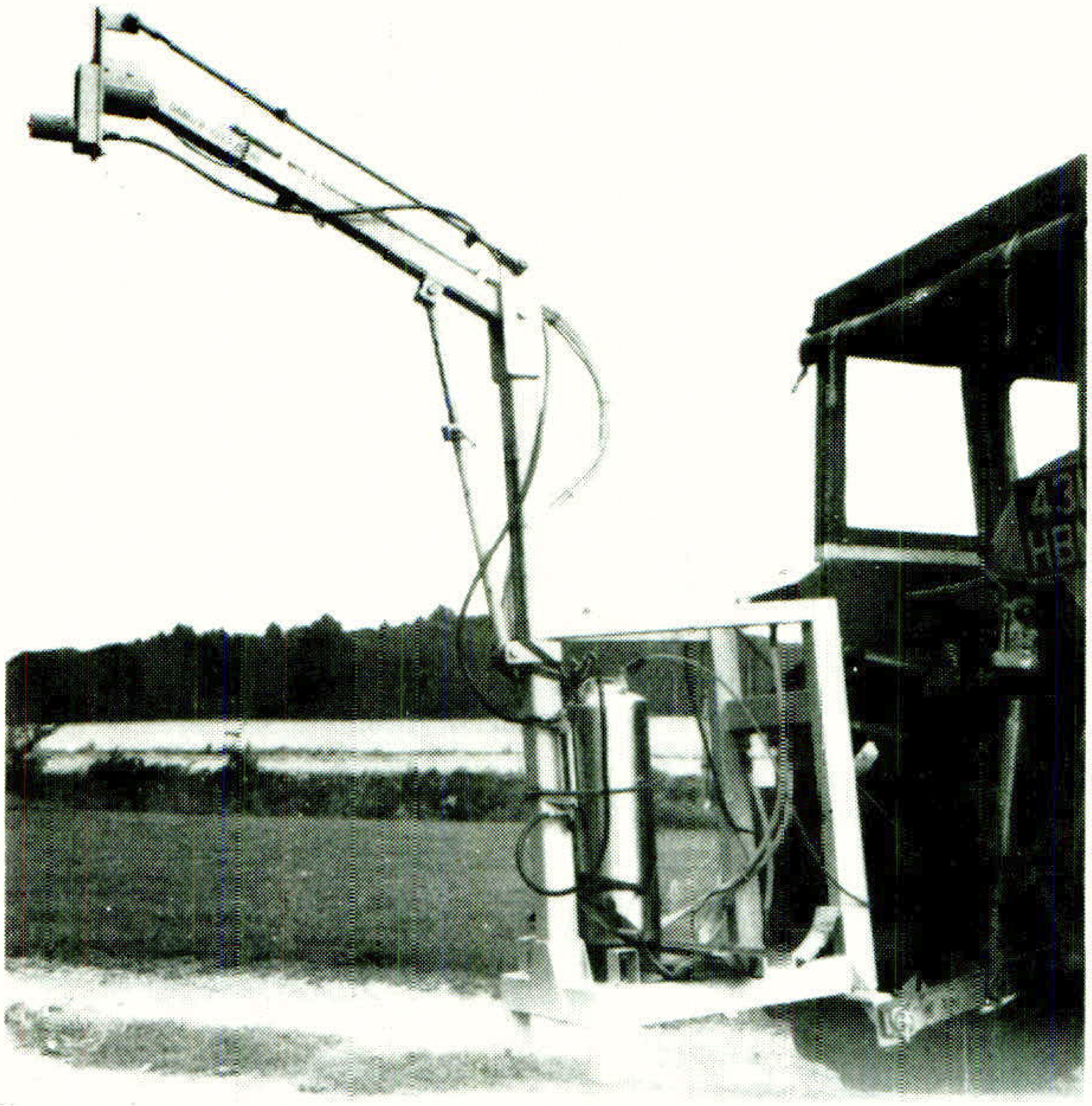


Fig. 1 Modified Ulvamast sprayer

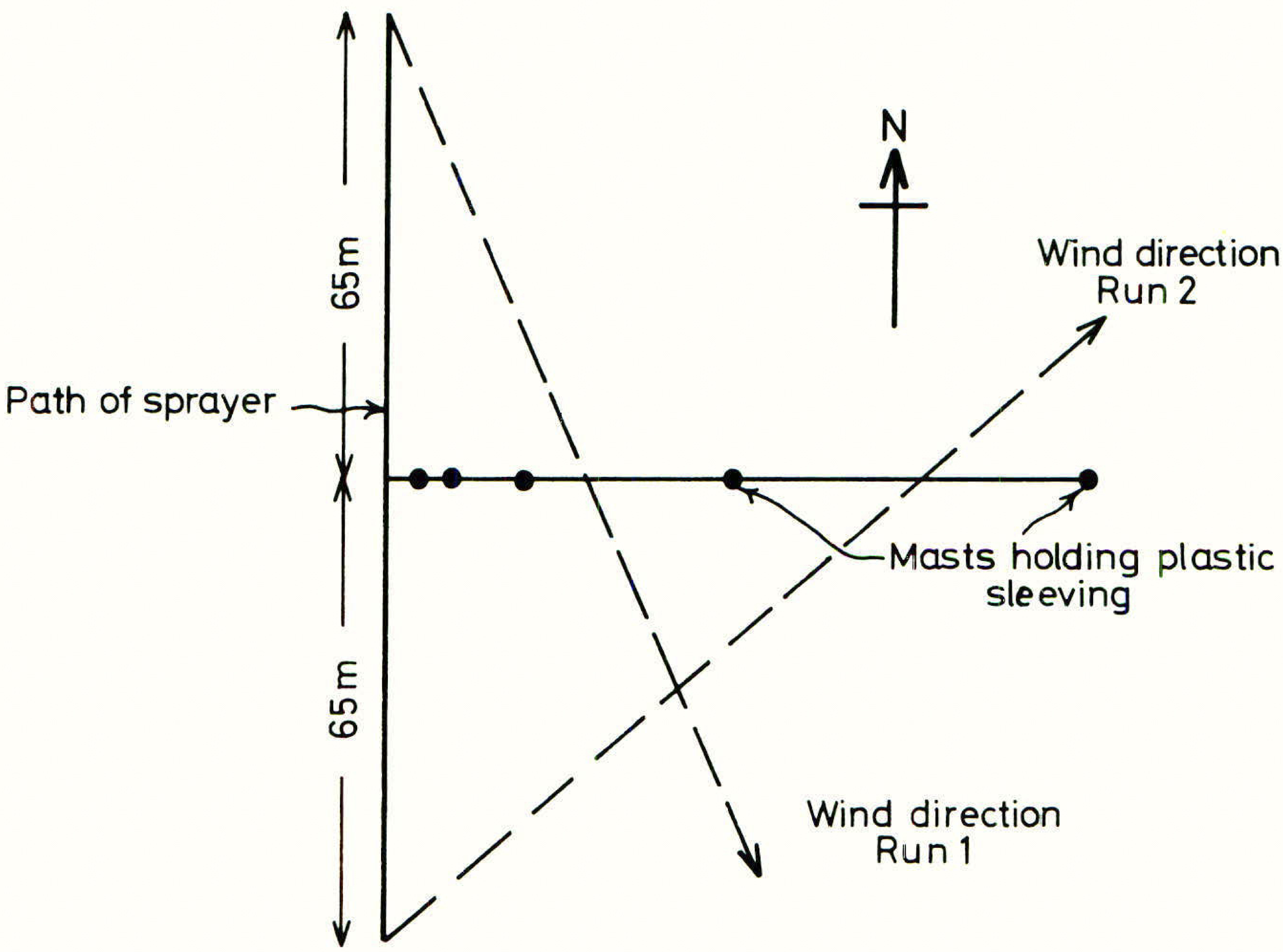


Fig. 2 Layout of experiment

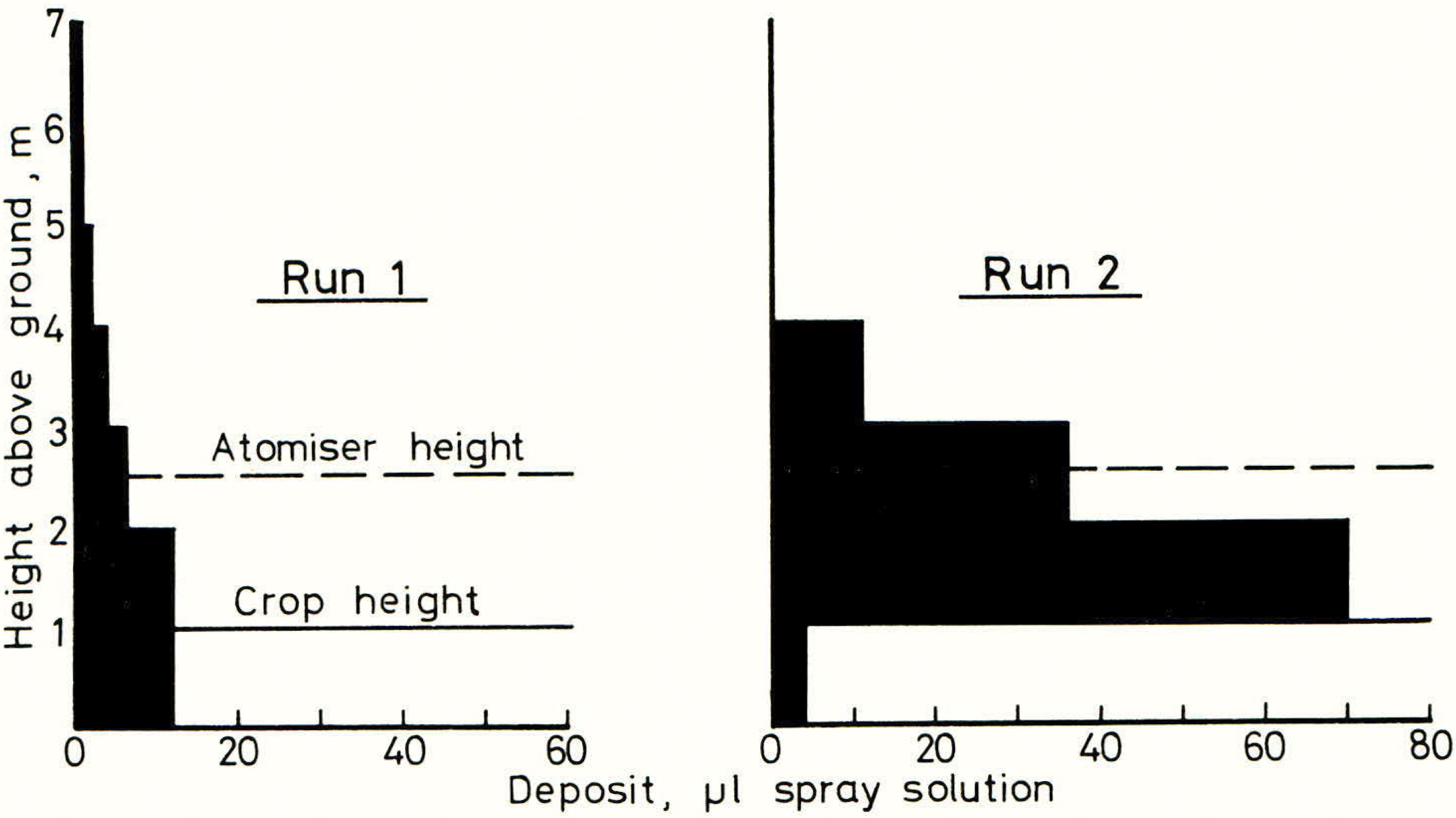


Fig. 3 Deposits at 1m mast

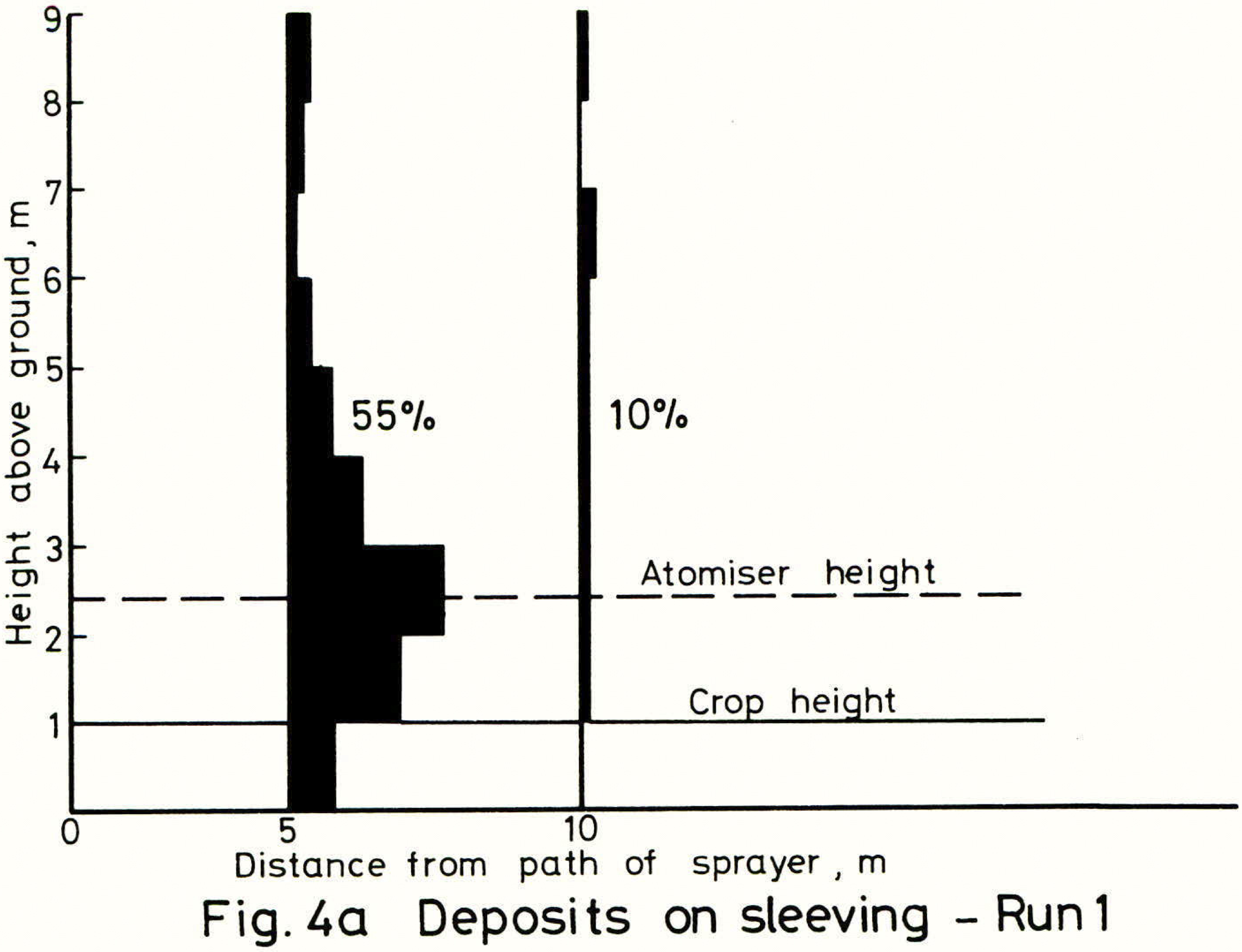


Fig. 4a Deposits on sleeving - Run 1

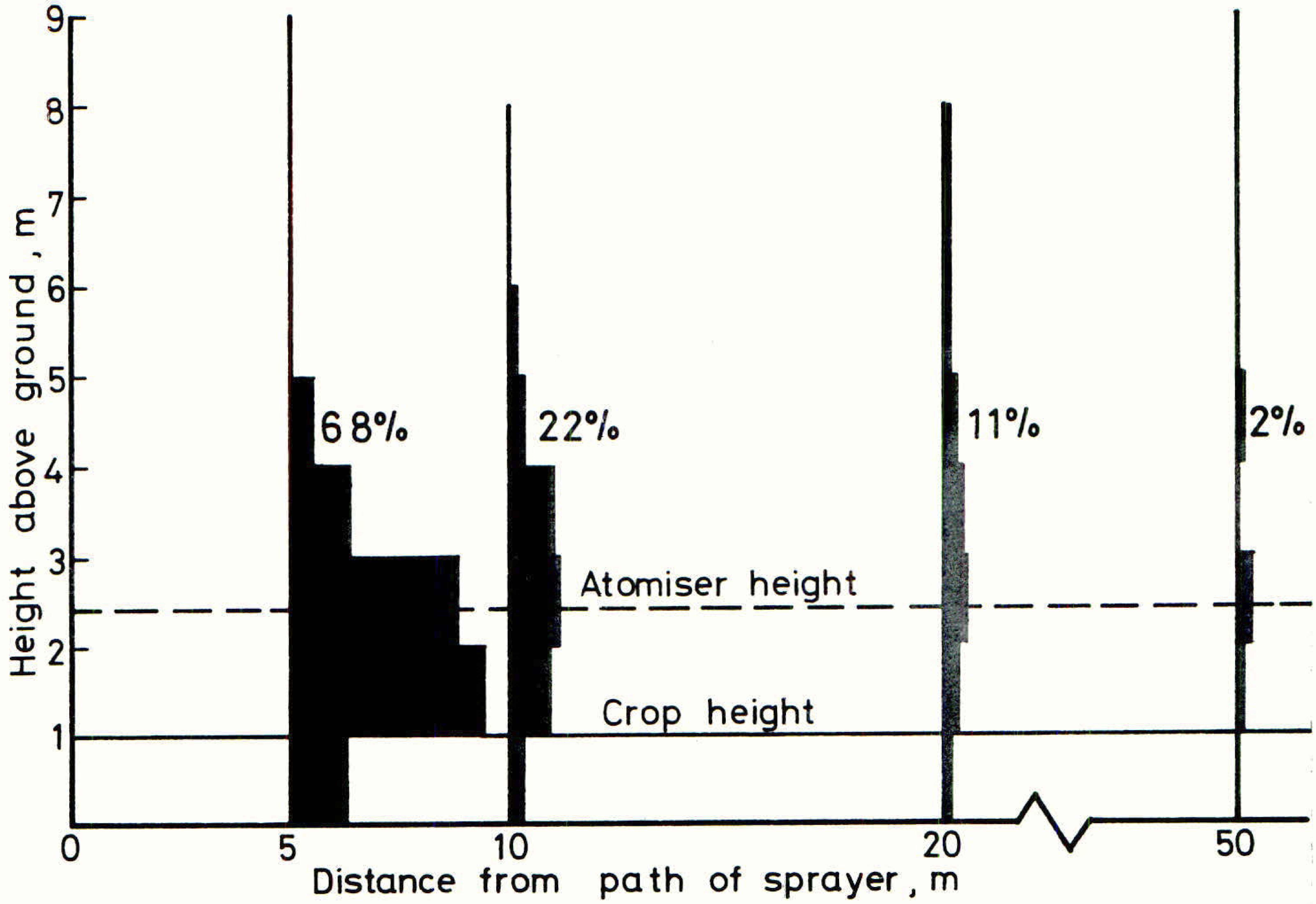


Fig. 4b Deposits on sleeving - Run 2