# A SHROUDED SPINNING DISC FOR THE PRODUCTION OF HOMOGENEOUS SPRAYS

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## INTRODUCTION

Particle size is a critical factor in determining the behaviour of pesticide sprays in the atmosphere. The size of a spray droplet affects its terminal velocity, its rate of evaporation and whether it will deposit in the target area or drift out of it (1). Particle size also determines whether a given drop will deposit on the upper layers of the plant canopy or flow around the leaves, penetrate the crop, and impact upon insects within it (4).

All spraying machines now commercially available produce a wide spectrum of droplet sizes. This is largely due to the methods of atomization used (3) and is the source of a number of problems. To prevent the drift of herbicides, for example, the spray should not contain any droplets smaller than 200 microns in diameter. However, for insect control, in situations where drift is not a problem, it might be preferable if most of the spray were in much smaller drops. Himel (5, 6, 7) showed that only drops of 50 microns or less, constituting 1% of the spray volume, actually impacted on the Spruce Budworm larvae which were the target. This suggests that if all the spray had been in drops of 50 microns or less the amount of insecticide released into the environment could have been reduced one hundredfold.

It is apparent, therefore, that for any given pest/crop combination there might only be one drop or a narrow range of droplet sizes which is optimal and that droplets of any other size present in the spray might be more or less wasted. Unfortunately we cannot investigate this possibility directly at the moment since equipment which will produce homogeneous sprays of any chosen droplet size is not available. Thus there is an urgent need for laboratory and field sprayers which will produce uniform spray droplets of any chosen size. Walton and Prewett (11) showed that spinning disc sprayers at low flow rates produced sprays of almost uniform dropsize in the range 3 mm to 15 microns. The spray so formed also contains appreciable numbers of small satellite droplets and May (10) published a description of an improved spinning top where airflow was used to remove or winnow-out these satellites. Jarman (8) has reviewed a variety of rotary atomizers and discusses their performance. Burt (2) described a field sprayer, based on the spinning disc, for the production of sprays with narrow drop spectra. This paper describes an alternative design based on May's (10)

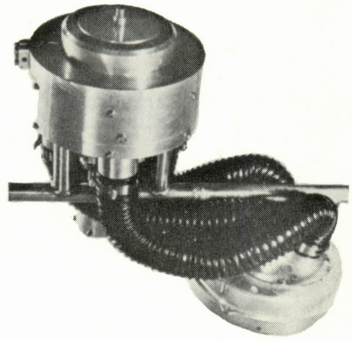

**Figure 1** A shrouded spinning disc for the production of homogeneous sprays.

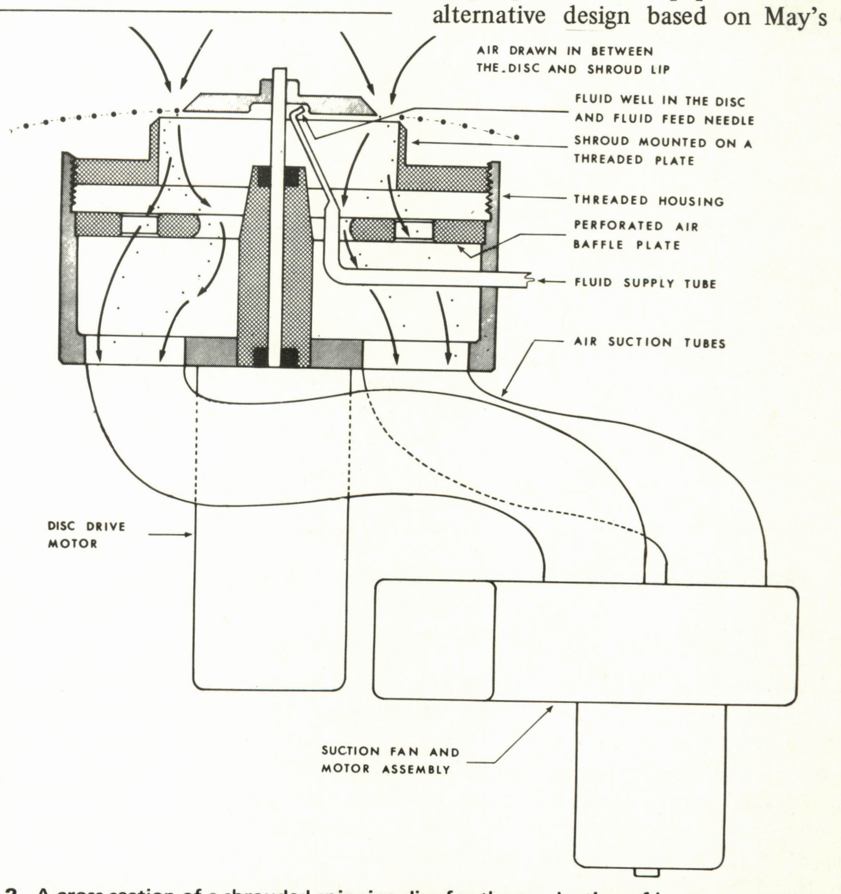


**Figure 2** A cross section of a shrouded spinning disc for the production of homogeneous sprays.

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spinning top but adapted to field use at flow rates high enough for normal pest control operations. A preliminary account of this design was given by McKinlay (9).

## Equipment and Materials

The essential parts of the equipment used in these studies (Figures 1 and 2) consist of a 10 cm diameter matte-surfaced brass disc revolving in the centre of a shroud of 12.7 cm inside diameter. The shroud is mounted on a threaded plate screwed into the top of a threaded housing so that the shroud lip can be set at any desired distance below the level of the disc. The housing was made large enough to accommodate shrouds larger than the 12.7 cm diameter one used in these tests. When desired, air can be drawn in through the gap between the disc and shroud at approximately 2,100 litres per minute by a motor-driven suction fan. To equalize the winnowing airflow around the periphery of the disc, a perforated air baffle plate was placed in the housing between the air suction tubes and the shroud. Originally the spray fluid was fed to the centre of the disc through a hollow shaft. However, leakage at the shaft seal was a serious problem and would have necessitated major changes in design. Therefore, an external fluid-feed to the disc (Figure 2) was accepted as a temporary solution. Currently liquid is fed to a small well around the disc shaft by an externally mounted needle.

A spray solution of 5% Butanol and 2% Uranine was used for all tests reported here. Droplets were collected either on fixed, glossy photographic paper or in dishes containing a 3 : 1 vaseline/paraffin mixture. Measurements were made with a Fleming Particle Analyser and a shearing eyepiece.

## RESULTS AND DISCUSSION

When the shrouded, spinning disc is operating, the main drop-size is determined by the speed of rotation of the disc. As the droplets cross the gap between the edge of the disc and the shroud the drops are deflected by the stream of air drawn in through the gap between disc and shroud. If the height of the shroud has been properly adjusted the small, satellite droplets, being deflected more than the larger, main droplets, are trapped within the shroud. The larger

TABLE I PERCENTAGE OF VOLUME IN DROPS OF DIFFERENT SIZES AT FOUR FLOW RATES AND TWO DISC SPEEDS*

| | Flow rate | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 15 ml/min | | 30 ml/min | | 50 ml/min | | 100 ml/min | | |
| Microns | No winnowing | With winnowing | No winnowing | With winnowing | No winnowing | With winnowing | No winnowing | With winnowing | |
| Below 20 | | | | | | | | | 4300 rpm |
| 20-40 | 2 | | 3 | | 6 | | 13 | | |
| 40-60 | 8 | | 7 | | 3 | | 18 | | |
| 60-80 | 5 | 3 | 1 | | 5 | | 20 | 3 | |
| 80-100 | 59 | 71 | 15 | 4 | 3 | 1 | 18 | 8 | |
| 100-120 | 15 | 17 | 50 | 88 | 9 | 95 | 20 | 80 | |
| 120-140 | 11 | 9 | 24 | 3 | 61 | 4 | 11 | 9 | |
| 140-160 | | | | 5 | 12 | | | | |
| 160-180 | | | | | 1 | | | | |
| Below 20 | 1 | | 2 | | 2 | | 1 | | 9300 rpm |
| 20-40 | 13 | | 26 | | 32 | | 31 | | |
| 40-60 | 78 | | 70 | | 55 | | 30 | | |
| 60-80 | 8 | | 2 | | 11 | | 33 | | |
| 80-100 | | | | | | | 5 | | |

*The spray solution consisted of 2% Uranine and 5% Butanol in water.

Shroud 3 mm below the level of the disc.

droplets escape as a more or less homogeneous spray. The settings to be used for any desired drop-size and degree of homogeneity will depend to a large degree upon such factors as the density, viscosity and surface tension of the particular liquid being used. Therefore, the performance data given in this paper can only be regarded as indicative of the types of results that might be obtained.

Preliminary tests confirmed the need for the disc to be thoroughly wetted by the spray solution if homogeneous sprays were to be produced. It was also found that this was more difficult with aqueous sprays than with oil solutions. High speed photographs showed that, even where the surface tension of water had been reduced to 30.3 dynes per square centimeter by the addition of 5% butanol, wetting was not easy. If this solution is run onto the surface of a dry, rotating disc it does not wet but runs out over the surface of the disc as thin, rolling filaments. Matting the surface of the disc improved wetting but the best results were obtained by rubbing the disc with spray solution immediately before spraying. This was done in the tests described below.

Once the disc is thoroughly wetted the homogeneity of the spray depends upon the rate at which the spray fluid is fed to the disc. As the flow rate is increased from 15 to 100 ml per minute, at either 4,300 to 9,200 rpm, the spray produced by the disc becomes progressively less

TABLE II DROP-SPECTRA OF HERBICIDE SPRAYS PRODUCED BY A HYDRAULIC NOZZLE (SPRAYING SYSTEMS, 650067) AND THE SHROUDED-SPINNING-DISC*

| Drop-size | Hydraulic Nozzle | Shrouded-spinning-disc | | | |
|---|---|---|---|---|---|
| | | 4000 rpm | | 8000 rpm | |
| | | No winnowing | With winnowing | No winnowing | With winnowing |
| Microns | % Vol. | % Vol. | % Vol. | % Vol. | % Vol. |
| Below 11 | | 0.0005 | | 0.0008 | |
| 11-16 | 0.0007 | 0.01 | | 0.02 | |
| 16-22 | 0.006 | 0.2 | | 0.04 | |
| 22-32 | 0.09 | 0.2 | | 0.2 | |
| 32-44 | 0.4 | - | | 3.9 | |
| 44-64 | 0.5 | 1.2 | | 4.8 | 0.2 |
| 64-88 | 2.7 | 1.4 | 0.1 | 0.3 | 2.8 |
| 88-125 | 3.7 | 1.6 | - | 49.0 | 71.3 |
| 125-177 | 17.2 | 13.4 | 13.3 | 15.5 | 25.7 |
| 177-250 | 55.8 | 82.1 | 86.6 | 26.1 | |
| 250-354 | 19.7 | | | | |

*The hydraulic nozzle was spraying the equivalent of 4 ounces of 2,4-D in 4 gallons of water per acre and at 40 psi. The feed rate for the spinning disc was 60 ml/minute to apply the equivalent of 4 ounces 2,4-D in 1 gallon per acre, and the shroud was set 1 mm below the level of the spinning disc.

homogeneous with the most marked change taking place between 50 and 100 ml per minute (Table I). However, at all feed rates the homogeneity of the emitted spray was greatly improved by winnowing with an air stream drawn in between disc and shroud. For example, at 100 ml per minute and 4,300 rpm 10 to 20% of the spray actually produced by the disc was in each of six size ranges between 20 and 140 microns. When this spray was winnowed with the lip of the shroud set 3 mm below the level of the disc 80% of the final spray volume was between 100 and 120 microns and 100% between 60 and 140 microns.

Results which might be expected when applying a herbicide at field rates with this nozzle and with a standard hydraulic nozzle (Spraying Systems, TeeJet 650067) at 2.8 $kg/cm^2$ are indicated in Table II. It is apparent that the hydraulic nozzle produces droplets in a wide range of sizes, many of which would be prone to drift. The spinning disc alone produces a more uniform drop spectrum and this, in turn, can be much improved by winnowing. At 4,300 rpm and a feed-rate of 60 ml per minute the shrouded-spinning-disc, with winnowing, produced a spray where 99.9% of the spray volume was made up of droplets between 177 and 250 microns.

The sprays produced by this shrouded-spinning-disc are not as homogeneous as those produced by May's spinning top which was operated at much lower feed rates. However, these results do suggest that a field sprayer with an output adequate for pesticide applications in the field could be based on this nozzle design. If the nozzles were spaced 1.22 meters apart the flow-rate of 100 ml per minute to each disc would give 29 liters/hectare at a tractor speed of 1.6 kph. This is a little lower than might be desirable but should be adequate for field studies on the relationship between volume per acre, dosage and drop-size.

## SUMMARY

Droplet size is one of the critical factors in determining the performance of agricultural sprays but, owing to the lack of suitable equipment, the relationship between droplet-size and biological effect is very difficult to measure under field conditions.

This paper describes a nozzle for the production of sprays consisting of uniform droplets of any chosen size. Droplets produced by a spinning disc are winnowed by a stream of air drawn between the disc and a surrounding shroud. Small satellite droplets are winnowed out and trapped whilst the relatively uniform main droplets escape. The size of the main droplet is determined by the speed of the spinning disc.

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## REFERENCES

1. Akesson, N.B. and W.E. Yates. 1964. Problems relating to the application of agricultural chemicals and resulting drift residues. Ann. Rev. Ent. 9: 285-318.
2. Burt, E.C., E.P. Lloyd, D.B. Smith, W.P. Scott, J.R. McCoy and F.C. Tingle. 1970. Boll Weevil control with insecticide applied in sprays with narrow spectrum droplet sizes. J. Econ. Entomol. 63(2): 365-370.
3. Fraser, R.P. 1957. The mechanics of producing sprays of different characteristics. Proceedings of Second International Plant Protection Conference, Fernhurst, England. Butterworths Scientific Publications, London, England.
4. Hadaway, A.B. and F. Barlow. 1964. Studies on the deposition of oil drops. Ann. Appl. Biol. 55: 267-274.
5. Himel, C.M. 1969. The fluorescent particle spray droplet tracer method. J. Econ. Entomol. 62(4): 912-916.
6. Himel, C.M. and A.D. Moore. 1969. Spray droplet size in the control of Spruce Budworm, Bollworm and Cabbage Looper. J. Econ. Entomol. 62(4): 916-919.
7. Himel, C.M. 1969. The optimum size for insecticide spray droplets. J. Econ. Entomol. 62(4): 919-925.
8. Jarman, R.T. 1957. Rotary atomizers. C.I.R.U./Porton. Report No. 127.
9. McKinlay, K.S. 1969. Spectrum control by droplet selection. IVth International Congress of Agricultural Aviation, Kingston, Ont., August.
10. May, K.R. 1949. An improved spinning top homogeneous spray apparatus. J. Appl. Phys. 20: 932-938.
11. Walton, W.H. and W.C. Prewett. 1949. The production of sprays and mists of uniform drop size by means of spinning disc type sprayers. Proc. Phys. Soc. (Section B) 62(6): 341-350.