THE DESIGN AND CONSTRUCTION OF A MACHINE TO COMPARE CDA AND HYDRAULIC NOZZLES ON A FIELD SCALE

I Rutherford

ADAS Liaison Unit, Wrest Park, Silsoe, Bedford MK45 4HS

Summary A sprayer with three booms, one of which is fitted with spinning disc nozzles, was designed to facilitate comparison of application techniques on an ADAS Experimental Husbandry Farm.

INTRODUCTION

In 1975 several cereal farmers expressed interest in the Micron Herbi as a means of applying herbicide on cereals. It was felt that there was a need for a larger scale test rig to complement work at WRO and other ADAS trials using the hand held Micron Herbi. The work was carried out at the ADAS Bridget's Experimental Husbandry Farm, Winchester.

OBJECTIVES

The objectives of constructing the rig may be summarised as follows:

1. To evaluate distribution from unshrouded discs under dynamic field conditions.

2. To increase the area covered in each experiment.

3. To compare the effect of the same volume applied by discs and conventional hydraulic nozzles.

4. To develop a machine capable of applying pesticides on commercial acreages of the farm.

DESIGN FEATURES

Using the experience of the previous year, the sprayer was designed to incorporate the following features:

1. The machine should be capable of applying pesticides by CDA and 'conventional' hydraulic nozzles, the latter at the same volume per unit area or higher volumes.

2. To facilitate multi-factorial experimentation, changes from one treatment to another will involve the minimum of delay.

3. Pressure control should be independent of tractor engine and forward speed.

4. Flow rate should be individually controlled and monitored to each CDA head.

5. The speed of each disc should be individually controlled and monitcred.

6. The CDA lines should incorporate a method of washing with clean water to minimise disc contamination.

THE SPRAYER

Design and Construction

A schematic layout of the experimental rig is shown in Fig 1. The chassis, tank and pump were those of an Allman 80 mounted sprayer. A rectangular frame, constructed of square section tubes, supported two conventional hydraulic booms in addition to a boom with the Micron Herbi discs (CDA heads). Each boom could be operated independently by selecting the appropriate combination of valves.

The eighteen 80° angle nozzles were spaced at 0.33 m following work suggesting that this was the optimum (Andrews R and Byass J, 1977). Similar studies indicated that the optimum spacing for the Herbi heads was 0.6 m (Lake J et al, 1976), and ten were fitted in line on the rear boom.

Wherever possible, other components were selected from those available 'off the shelf'.

Pressure Control

Pressure control and adjustment is a critical factor which influences the design of the machine. With the possible need to spray some treatments at different forward speeds, the pressure regulating system was independent of both engine and pto, and consisted of a pneumatic diaphragm. When an air reservoir on one side of the diaphragm was pressurised the spray liquid maintained a constant pressure irrespective of the flow rate to the booms.

CDA Flow Control

The flow of liquid to each CDA head was metered through an orifice plate at the end of each spray line. A suitable flow to each disc was achieved by adjusting the combination of size of orifice and operating pressure. Another pressurised diaphragm prevented drips from the heads.

Monitoring the Flow to each Head

A bank of flow indicators, one for each line, was fitted, so that the driver could see whether a ball had lifted off the seating or not if there was a blockage.

Monitoring Disc Speeds

Each motor was wired to a warning lamp in the driver's cab. If a fault developed, and the motor slowed or stopped, the light indicated which motor required. attention.

Filtration

The smallest conventional nozzles and the CDA heads were protected by a 100 mesh filter in addition to the normal filtering arrangements. An additional pressure gauge downstream of the filter warned the driver of any blockage.

Tank Agitation

Agitation was provided by recirculation of the spray liquid via the diaphragm back to the main tank.

Flushing the System

A 25 litre tank was provided to enable the CDA discs to be flushed with clean water between experiments, to avoid residues and build up on the discs.

These components were all available as standard units from Ramsey Engineering and were normally used in their liquid fertiliser equipment.

OPERATION

For the herbicide and fungicide experiments at Bridget's Experimental Husbandry Farm the machine was mounted on a Massey Ferguson 135 fitted with an accurate tachometer.

A calibration chart (Fig 2) indicated the correct speed to be selected to give the desired application rate for each boom and nozzle combination. The air pressure in the centre diaphragm was applied and the application rate selected by operating the appropriate valves. The machine enabled large and complicated experimental application treatments to be sprayed with the minimum of fuss and delay.

Acknowledgement

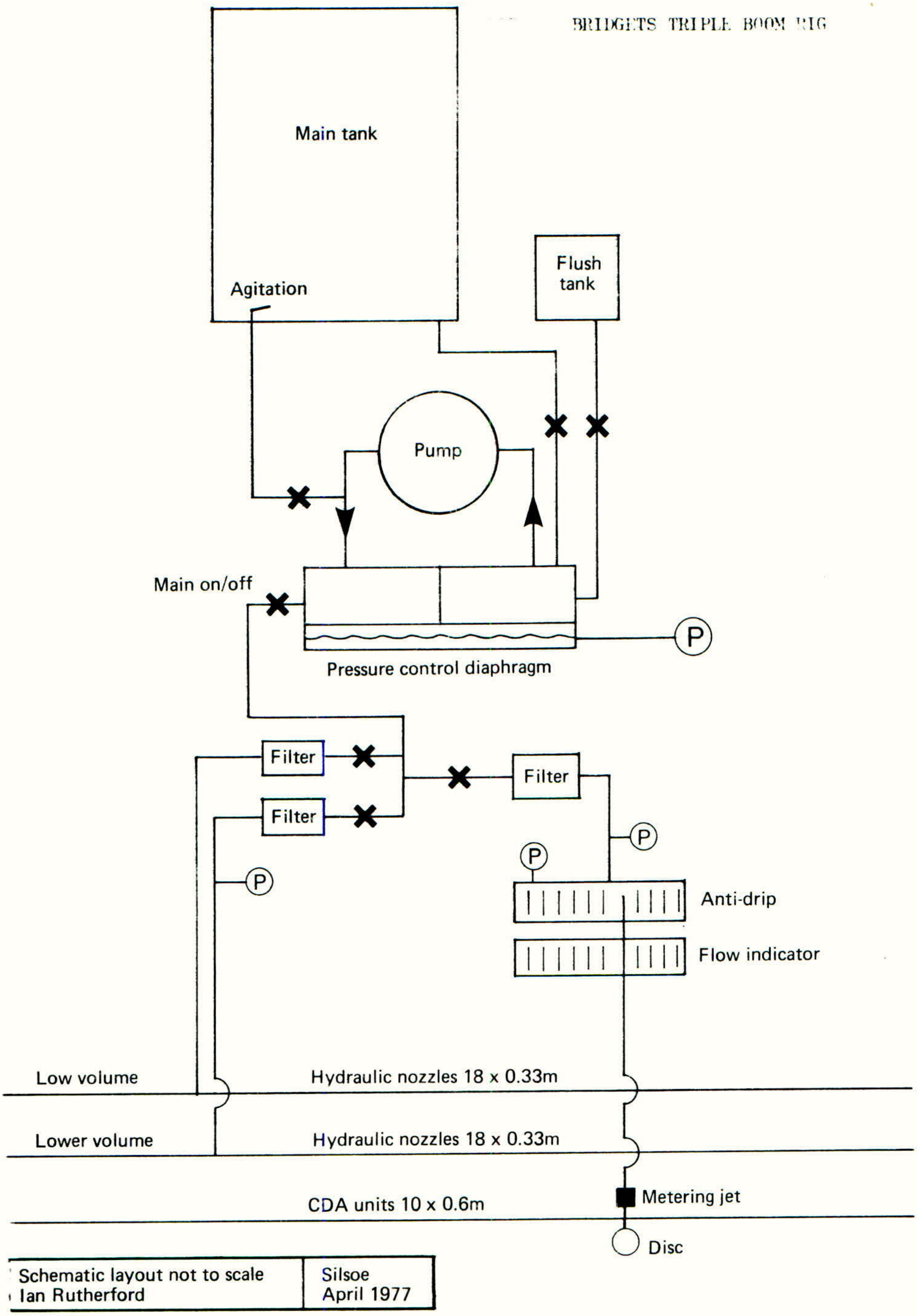
I would like to thank the NIAE Spraying Department for advice and practical help in the design and the staff at Bridget's Experimental Husbandry Farm, particularly the mechanic, Mr Steve Ashfield, for the actual assembly and construction.

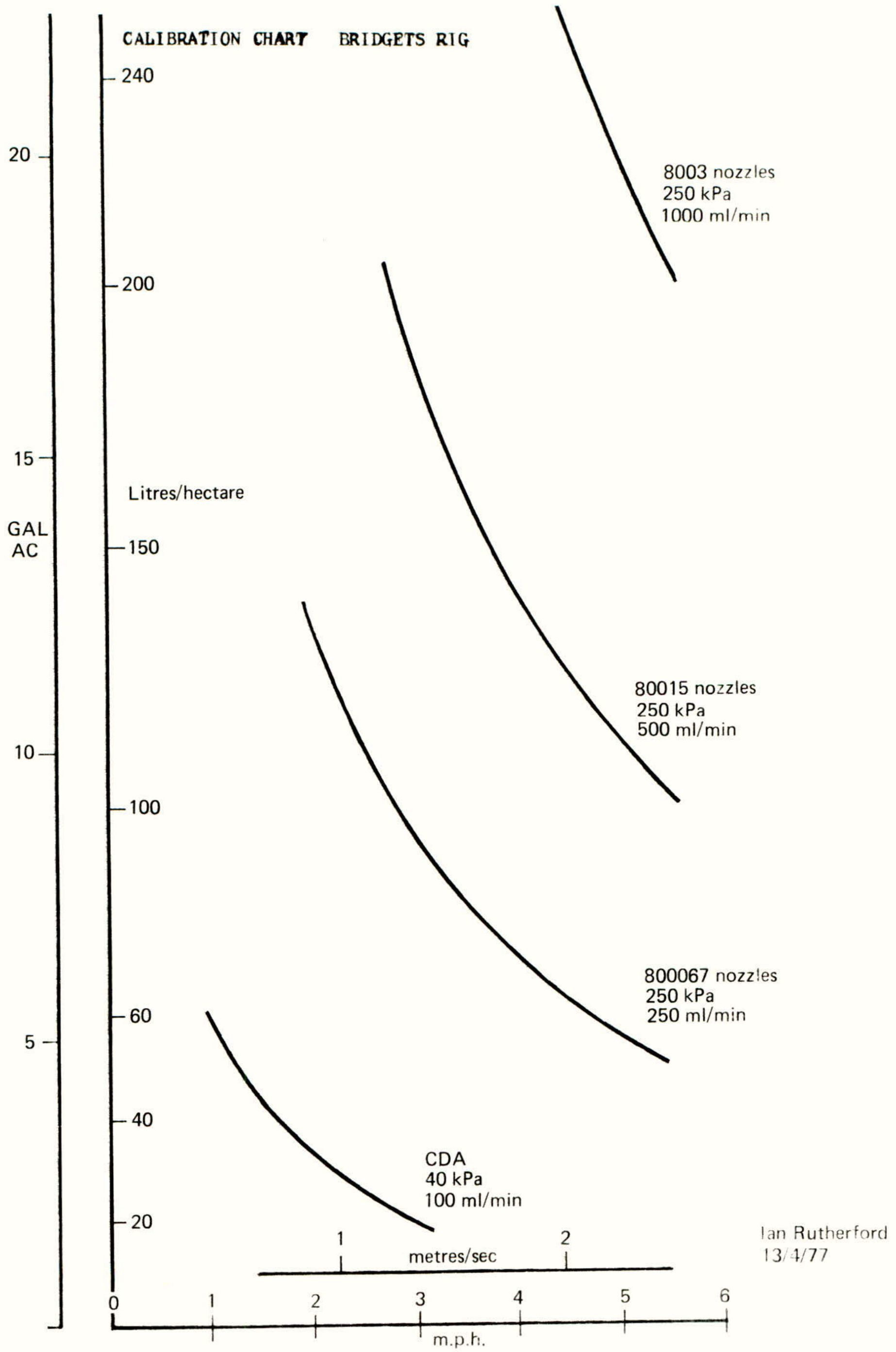
References

ANDREWS, R. and BYASS, J. (1977) Choice and use of nozzles for cereal spraying at conventional application rates. Proceedings of NIAE Subject Day - Spraying on Large Cereal Farms. Paper III NIAE Report 25.

LAKE, J., FROST, A. R. and GREEN, R. (1976) Measurements of drop size and spray distribution from the Micron Herbi disc. Proceedings 1976 British Crop Protection Conference - Weeds. 399-405

BRIDGETS TRIPLE BOOM RIG




CALIBRATION CHART BRIDGETS RIG
20
15
10
5
GAL
AC
240
200
150
100
60
40
20
Litres/hectare
8003 nozzles
250 kPa
1000 ml/min
80015 nozzles
250 kPa
500 ml/min
800067 nozzles
250 kPa
250 ml/min
CDA
40 kPa
100 ml/min
1
2
metres/sec
0
1
2
3
4
5
6
m.p.h.
Ian Rutherford
13/4/77

THE RICHMOND GIBSON CONTROLLED DROP APPLICATION TRIALS SPRAYER

N. J. Hind

Richmond Gibson Ltd., Downton, Salisbury, Wiltshire

Summary This sprayer, developed initially in response to a request by the WRO and ADAS for a machine capable of being used for research work, has been designed for small plot replicate work, applying drops of given size in the range 150 to 350 µm diameter. It is a two-man hand-held sprayer giving a swath of 2.4 metres using rotary atomizers.

INTRODUCTION

The Richmond Gibson CDA Trials Sprayer has been designed to offer Research Stations and Commercial Companies a reliable tool for accurate assessment of the behaviour of pesticides at different volume rates and different drop sizes. The drop size range of 150-350 µm is intended for soil application or for crops directly under the area covered by the spray heads. The size of drop is subject to minimal drift and is larger than the diameter normally associated with inhalation hazards to the operator.

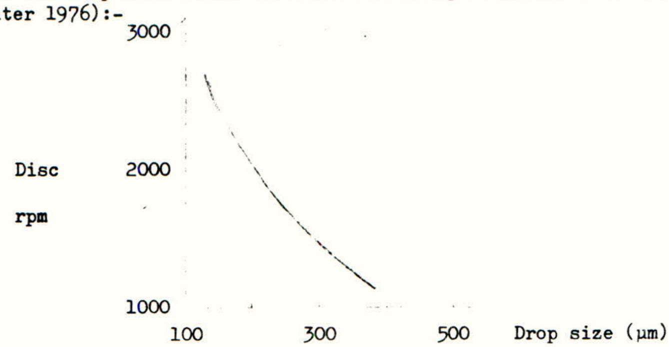
The method and efficiency with which a pesticide is applied, and other chemicals within its formulation such as the surfactants, clearly affect the material's performance. This area has perhaps been neglected, limited by the equipment available, but now that means of selecting drop size and numbers of drops are available, it is more important to be able to relate the physics of the applied material to biological performance.

CONSTRUCTION AND PERFORMANCE

The unit consists of a rectangular framework supported between two end sections which act as legs and optional windshields. The semi-permeable windshields and handles are adjustable to suit height of crop and operator. All frame parts are constructed from aluminium. Within the central framework are held the mountings for the two heads, the tank and the controls for monitoring the spray output.

The heads themselves are three 'Herbi' discs (Bals, 1975) mounted above each other on a drive shaft coupled to a 24 volt DC motor with built-in frequency tachogenerator. The top two discs are shrouded such that half the fluid input is dispersed by the disc and half is collected by the shroud and fed to the disc below. The bottom disc is unshrouded and the overall pattern obtained from the three discs is linear across the swath with a rapid cut-off at the edges. The two heads adjust horizontally for swath matching (the swath varies slightly with drop size and fluid viscosity) and vertically for optimum distance to target (minimum 30 cm). The discs and shrouds come apart swiftly and simply for cleaning.

The tachogenerator frequency is converted by an electronic 'package' to a dial read-out of motor rpm, which in turn is selected by the operator with a rotating knob control in the speed range 1100-2400 rpm. Power supply is from four lantern batteries to be found in most village stores within easy reach of the trial site. A form of voltage regulator is incorporated in the electronics such that when the batteries become drained the rpm will fall to zero rather than read low. Hence at all times disc speed and thus drop size are accurately monitored. The relationship between disc speed and drop size is for flow not exceeding 80 ml/min (Taylor, Merritt & Drinkwater 1976):-



The pesticide solution is contained in a 7 litre tank which slots onto the frame and is easily removed for emptying or cleaning out. It is pressurised by hand-pumping whereupon the fluid passes through a constant pressure control valve which may be adjusted and set to give a positive steady flow at any viscosity. On leaving this valve the fluid is split and is fed through a needle valve at the base of a flow meter before reaching each head. The needle valves allow fine tuning of flow rate and balancing between heads. A tap allows flow control to each head where the fluid enters a manifold for distribution to the discs. Thus flow rate is accurately measured and monitored throughout the experiment. Different pesticides may be calibrated by their viscosity.

It is important that a trials sprayer may be moved easily from site to site and this machine can be disassembled to fit into an ordinary car. The windshields and handles are removable, the heads may be detached or swung up under the frame, which itself can be broken in half.

In operation the machine is held comfortably in one hand by an operator at each end, total weight being only 25 kg. One operator is responsible for monitoring the fluid flow and the other observes disc rotation speed as the experiment is carried out.

CONCLUSION

The Richmond Gibson CDA trials sprayer is already in use with a number of organisations. It is aimed at those researchers and trialsmen investigating the suitability of pesticide formulations for controlled drop application and determine which factors affect the results obtainable from the pesticide.

Acknowledgements

The author wishes to thank the WRO and ADAS for their assistance in developing the equipment.

References

BALS, EJ (1975) The development of a CDA herbicide hand sprayer PANS 21 345-349.

TAYLOR W A, MERRITT C R, DRINKWATER J A, (1976) An experimental tractor-mounted, very low volume uniform drop size sprayer. Weed Research, 16 203-208.

Symposium on Controlled Drop Application - April 1978

PORTABLE MICRO-TIP NOZZLE ASSEMBLY FOR PRODUCING CONTROLLED MONOSIZE DROPLETS FOR USE IN FIELD MICRO-PLOT EXPERIMENTS

S. Uk

CIBA-GEIGY, Agricultural Aviation Research Unit,
c/o Cranfield Institute of Technology, Cranfield,
Bedford MK43 OAL

Summary A micro-tip nozzle capable of producing controlled monosize droplets from 15 to 200 µm has been constructed into a portable assembly for use in field micro-plot experiments on spray droplet activity. The equipment enables the application of measured micro-amounts of chemicals onto critical sites of natural targets in the field within the range of droplet sizes normally used in routine ULV spray operation. Such a capability provides a cheap and reliable method to realistic evaluation of field performance of a product and its target dose. It can also be used to determine the spread factor of droplets on collecting surfaces in the same location where spray experiments are conducted.

INTRODUCTION

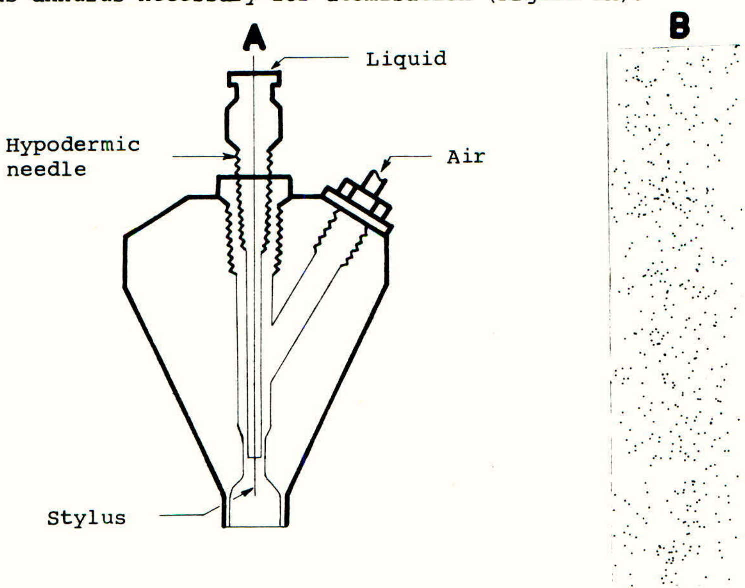
In pesticide spray research, controlled production of uniform sized droplets is required for many basic studies such as the capture efficiency of droplets by targets, droplet evaporation and dispersal, the toxicological properties of various droplet sizes, and the spread of droplets on collecting surfaces. Various types of devices have long been designed and perfected; they include laboratory spinning tops (Walton and Prewett 1949, and May 1966); vibrating tips or capillary tubings (Wolf 1961, Mason et al 1963 and Dabora 1967); vibrating perforated membranes (Berglund and Liu 1973 and Bouse et al 1974); airblast micro-capillary tips or styli (Ainsworth 1944, and McPhail 1960, Reil and Hallett 1969, Courshee 1975 and Haliburton 1975); and an harmonic electrical sprayer (Sample and Bollini 1972).

All these droplet generators, except that of Bouse et al (ibid) and the Courshee pipette (Courshee ibid), are for fixed laboratory set-up and cannot be conveniently used in agricultural field work, or in mobile laboratories which require intercontinental work displacement, often at short notice. Whereas Bouse's atomiser is designed for routine application of pesticides, the Courshee pipette is small and intended specifically for basic investigations into physical and toxicological properties of spray droplets. However, the latter requires special equipment to draw glass tubings to very fine capillary atomising tips which then becomes highly delicate to operate.

In order to further improve the efficiency of pesticide usage in agriculture, a lot more has yet to be learned about spray toxicology in the field, viz. mode of transfer of sprayed chemicals to the target pests, and dose/mortality relationships for each target stage which may depend on types of formulation, route of entry, etc. Attempts to evaluate this aspect of toxicology from large scale aerial spray as well as small plot experiments have not been satisfactory and a re-examination of procedures and instrumentation has let to the design of the present micro-tip nozzle assembly.

ATOMISING NOZZLE

The nozzle is basically of the type described by Buckholz and McPhail (ibid) with the shape and attachment modified for convenient manufacturing and assembly. It consists of a No. 30 Gauge hypodermic needle (O.D. = 0.30 mm, I.D. = 0.15 mm), whose hub is threaded to fit into a brass housing which provides the pressurised gas annulus necessary for atomisation (Figure 1A).



The primary air supply tube can be as large as 1.0 mm diameter, but the exit tube surrounding the hypodermic needle tip is critically drilled to give a clearance of no more than 0.10 mm around the needle. Into the hypodermic tubing, which is cut square, is inserted a hard-drawn stainless steel stylus (diameter $\sim$0.13 mm) electrolytically sharpened to a fine point. The stylus constitutes the so-called zero-issuing point (Bals 1972) of liquid to be stripped off by the gas annulus so that small uniform sized droplets can be produced. The liquid held in the needle hub, is fed to the stylus tip by a combination of gravity and suction effect from the gas annulus. It is critical that the square end of the hypodermic tubing be drawn back about 1.0 mm into the gas annulus tube to obtain the venturi effect. On the other hand, the stylus must project about 1.0 mm outside the gas tube.

The 30 G needle model can produce only droplets of about 100 µm or smaller. In order to obtain larger droplets, the No. 25 or 27 G needle may be used with correspondingly larger stylus and gas annulus bore. An example of uniformity of size generated is illustrated in Figure 1B.

STYLUS SHARPENING

The stylus can be sharpened to a fine point with any desired tapering angle by skilful dipping of its tip as anode into chromic acid solution, across which a voltage of 6 or 9V from a dry cell is applied; a small crocodile clip, used to secure a 10-ml beaker containing the electrolyte to a holding bottle base to prevent its accidental over-turning, also acts as the cathode. With the help of a binocular microscope, the stylus can be sharpened in less than 30 seconds. Brief, repeated dips into the chromic acid result in a steep tapering angle with a relatively thick point, whereas slightly longer (about 5 seconds at a time) and deeper dips give a small tapering angle with a very sharp point.

ASSEMBLY AND OPERATION

A five litre stainless steel tank employed in the vending of soft drinks was adapted for use as compressed air container (Thornhill 1974). The inlet opening of the tank was re-threaded to fit a 10-bar pressure gauge[(1)] to indicate tank pressure which could be operated up to 8.0 bars. A small on/off toggle[(2)] valve was connected in series with a fine metering valve (Micromite 1600 series)[(2)] to a miniature filter/pressure regulator[(1)] which was in

---

(1) C. A. Norgren Limited, Shipton-on-Stow, Warwickshire

(2) Hoke International Limited, Barnet, Hertfordshire

turn attached to the modified tank outlet by means of Gyrolok[2] fittings. Air was pumped into the tank via a Schrader valve fitted to the tank lid. The connection between the toggle valve and the nozzle consisted of a short high-pressure copper tube (3 mm O.D.) and a high-vacuum rubber tube which provided easy manipulation. After the air pressure has been set by the regulator and the metering valve to produce the monosize droplets of desired diameter, it may be left undisturbed while the toggle valve is used to start and stop the spray.

To prevent droplets from being blown by wind in the field, the nozzle was inserted tightly into a tube of 4 cm in diameter and 6 cm long made of a cut polypropylene bottle.

The 30 G micro-tip is able to produce monosize droplets down to 15 µm whereas the 25 or 27 G cannot generate monosize droplets below 50 µm as too high a pressure causes a wide range of liquid break-up. Furthermore tip flooding also results in a polydisperse spray. Being gravity fed, the tip is prone to flooding which, however, can be avoided by leaving the toggle valve permanently open or in the case of pulse operation, by repeated brief pulses every 2 or 3 seconds. When sprays are not needed, they can be caught in disposable paper towels loosely wrapped around the polypropylene spray guide tube.

Since suitable liquid flow is so minute (e.g. 1 - 2 µl min^{-1}), the combination of gravity and venturi feed seems to be the practical solution for such a field equipment and irregular droplet size production may be best avoided by the above mentioned procedures.

The sizes of droplets produced may be calibrated by collecting them on magnesium oxide slides (May 1950) prior to use in an experiment as pre-settings of the pressure regulator and metering valve do not always produce the same droplet diameter due to the difference in temperature which in turn affects the gas flow rate. Furthermore, the variation in reading the pressure gauge caused by parallax may be sufficient to generate different diameters. To collect droplets smaller than 50 µm, PVC pipes of 10 cm diameter and 40 cm long may be used as settling chambers to shield the effects of ambient air movement. This arrangement may be employed to determine the spread factors of droplets on plant surfaces or artificial collectors in the same location where field sprays are being studied. Such information is more relevant than that obtained in distant laboratories.

RESULTS AND DISCUSSION

The size of droplets, their number and the quantity of active ingredient delivered by a pulse of the toggle valve for a given setting of the pressure regulator and metering valve, depends on the type of formulation and its viscosity at the time of atomisation, which in turn may vary significantly with ambient temperature. As an example, the following data refer to Nuvacron 40 SCW[3] tested in Sudan at $35^{o} \pm 3^{o}C$ (Table 1).

Table 1 Delivery of Nuvacron 40 SCW by a 27 G micro-tip nozzle operated at 20 PSIG and 300 ml min^{-1} of air onto flat collectors within the confines of the spray guide tube (droplet size of about 120 µm).

	No. droplets per quick pulse of toggle valve	Amount of Nuvacron 40 per pulse determined chemically
	33	29.3 nl
	32	27.8
	32	27.8
	26	25.6
	33	
	32	
	27	
	29	
mean	30.5	27.6
S.D.	2.6	1.4

When the toggle valve was left permanently open to allow continuous atomisation, the mean number of 120 µm droplets generated per second was 9.2 ± 1.1 (S.D.)

By holding the spray guide tube against the surface to be treated and quickly pressing and releasing the toggle valve, bursts of small droplets with known dosage rates may be delivered repeatedly to a single target as small as a plant bud or a leaf lobe.

The dose-toxicity relationship of a product under field conditions can thus be conveniently determined without complications

---

(3) SCW = Water soluble concentrate; a CIBA-GEIGY product containing 40% monocrotophos

caused by non-uniform pest distribution, vagaries of droplet deposition from aerial or ground sprayers normally encountered in conventional small plot experiments. The technique has been tried successfully in the Sudan Gezira to compare the effectiveness of a few chemicals on the whitefly juveniles.

The ability to apply the pesticides of known micro-quantities onto critical natural targets in the range of droplet sizes similar to those of normal field sprays, may provide cheap and reliable methods of evaluating the biological performance of a chemical as it is used in the field. The target dose of a product and the biological effect of droplet size may then be evaluated on a more realistic basis.

Acknowledgements

The skilful manufacturing of nozzles by Mr. R. Hussey, Instrumentation Section, Department of Electronic and Control Engineering, Cranfield Institute of Technology, is gratefully appreciated.

The author is indebted to CIBA-GEIGY Limited for permission to publish this work.

References

ABBERTON, L. G. (1960) A microburette producing very small uniformly sized droplets. Tropic. Pestic. Res. Unit, Porton, UK. Porton Tech. Pap. No. 713

AINSWORTH, M. (1944) The construction and use of apparatus for delivering a drop or drops of known size. Chem. Defence Exp. Estab. Porton, U.K., Porton Rep. No. 2651

BALS, E. J. (1972) Personal communication, Micron Sprayers Limited, Bromyard, Hereford, U.K.

BERGLUND, R. N. and LIU, B. Y. H. (1973) Generation of monodisperse aerosol standards, Environ. Sci. and Technol., 7 (2), 147 - 53

BOUSE, L. F., HAILE, D. G. and KUNZE, O. R. (1974) Cyclic disturbance of jets to control spray drop size, Trans. ASAE, 17 (2), 235 - 39

BUCKHOLZ, E. E. and McPHAIL, M. K. (1960) Apparatus for applying liquids in small droplets to animals, Rev. Sci. Instrum., 31, (2) 132 - 36

COURSHEE, R. J. (1975) Personal communication

DABORA, E. K. (1967) Production of monodisperse sprays, Rev. Sci. Instrum., 38 (4), 502 - 06

HALIBURTON, W. (1975) Personal communication, Chemical Control Rep. Inst. Ottawa, Canada

KING, W. J. and JOHNSTONE, D. R. (1971) A modified microburette for the production of very small liquid droplets, COPR Misc. Rep. No. 1

LANE, W. R., JAYARATNE, O. W. and WOODS, J. D. (1963) An improved vibrating capillary device for producing uniform water droplets of 15 - 500 um radius, J. Sci. Instrum., 40, 247 - 49

MAY, K. R. (1966) Spinning-top homogeneous aerosol generator with shockproof mounting, J. Sci. Instrum., 43, 841 - 42

REIL, K. and HALLETT, J. (1969) An apparatus for the production of uniform sized water drops, at desired time intervals, Rev. Sci. Instrum., 40 (4), 533 - 34

SAMPLE, S. B. and BOLLINI, R. (1972) Production of liquid aerosols by harmonic electrical spraying, J. Colloid and Interface Sci., 41 (2), 185 - 93

THORNHILL, E. W. (1974) The adaption of a stainless steel container for use as a compression sprayer, PANS, 20 (2), 241 - 45

WALTON, W. H. and PREWETT, W. C. (o949) The production of sprays and mists of uniform drop size by means of spinning disc type sprayers, Proc. Phys. Soc. B., 62 (6), 341 - 50

WOLF, W. R. (1961) Study of vibrating reed in the production of small droplets and solid particles of uniform size, Rev. Sci. Instrum., 30 (10), 1124 - 29