Symposium on Controlled Drop Application - April 1978

THE INFLUENCE OF PHYSICAL AND METEOROLOGICAL FACTORS ON THE DEPOSITION AND DRIFT OF SPRAY DROPLETS OF CONTROLLED SIZE

D.R.Johnstone[a]

Centre for Overseas Pest Research, College House, Wrights Lane, London W8 5SJ

Summary The movement of pesticide sprays from source to target is discussed in relation to the aerodynamic characteristics of small droplets and other relevant physical and meteorological factors. Some consideration is given to the droplet size requirements for specific control tasks, using controlled droplet application techniques.

INTRODUCTION

The term 'controlled drop application', abbreviated to CDA, was put forward by John Fryer of the ARC Weed Research Organisation in 1975 when discussing the application of herbicides at very low volume rates, specifically with rotary atomisers governed in such a way as to produce a narrow range of droplet size centred about a diameter of 250 µm. Since then, this restricted usage has found some limited acceptance in application terminology.

However, it seems more logical that any application which is made in accordance with the principle of choosing an optimum spray droplet size - on a variety of appropriate criteria - then subsequently employing equipment which will produce the chosen droplet size, or at least a fairly narrow range of droplets about the optimum size, should be referred to as controlled droplet application. The principle should not apply exclusively to the use of rotary atomisation, nor to ultra-low or very low volume application. If this is accepted, then traditional and controlled droplet application may be contrasted as follows:-

Traditional application	Controlled droplet application
Empirical development from high volume, through medium, to low volume application. Droplet size usually incidental to volume application rate and determined in part by the required delivery through hydraulic pressure nozzles.	Primary criterion that of optimum droplet size determined by the nature of the target and other relevant application considerations. Use of minimum volume rate at chosen droplet size which will effect control.

It is apparent that controlled droplet application should also be controlled volume application, and will tend towards low, very low or ultra-low volume application, as arbitrarily defined in Table 1. There may still remain a few occasions when total wetting and high volume application appear necessary, but, even in these exceptional cases, the use of a controlled droplet size, and in particular smaller rather than larger droplets, should reduce the volume required to achieve the desired result, avoiding the onset of early wasteful run-off before all the target surfaces have been sufficiently wetted.

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[a] Centre for Overseas Pest Research, Division of Chemical Control, Porton Down, Salisbury, Wilts. SP4 0JQ.

Droplet size remains the key factor in the travel and deposition of pesticide sprays, and the purpose of this paper is to re-examine, in the context of controlled droplet application, the effect of droplet size on the movement of spray droplets from source to target and to indicate how variations in microclimate and the nature of the target can influence this movement and the efficiency of deposition.

PHYSICAL CHARACTERISTICS OF SMALL DROPLET BEHAVIOUR

Droplet inertia, stop distance, relaxation time, fall velocity and drift

In still air, the rate at which a small droplet falls is determined by the balance of gravitational and viscous forces in such a way that a steady fall velocity (v_s) is attained more or less rapidly, depending on the droplet's size, or more correctly, it's inertia. The effect of the droplet's inertia can be characterised by a stop distance (d_s), defined as the displacement over which the horizontal component of droplet velocity falls to zero following horizontal projection into still air with a given velocity (v_0). The ratio of stop distance to projection velocity (d_s/v_0) remains constant for a given droplet size, and has been called the relaxation time (τ), which is in effect, the time the droplet requires to adapt itself to the applied force (Davies, 1966).

For viscous resistance, $\tau = m/3\pi d\eta = d^2\rho/18\eta$ ....(1)
where m is the mass of the droplet, ρ it's density, d it's diameter and η the viscosity of the air. Stoke's law for terminal velocity takes the form

$$v_s = \tau g(\rho - \rho_a)/\rho \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where g is the gravitational constant and ρ_a is the density of air.

Table 2, adapted from Davies, p394, displays fall velocities, relaxation times, and stop distances corresponding to a projection velocity of 1 m/s, for droplets of unit density in the size range 1 - 1000 µm.

The movement of spray droplets in the wake of the sprayer is rendered more complex by the manner in which they originate, particularly by their efflux direction and velocity and also, in the case of aircraft spraying, by the local disturbance in the wind flow caused by the passage of the sprayer. The stop distances give some indication of the range over which efflux velocities can exert an over-riding influence on the band width and travel of spray droplets as they leave the nozzle. This is most significant for coarse or medium sprays, so that such droplets can be directed onto the target from short range, e.g., for 200 µm diameter droplets emitted from an 8 cm diameter disc rotating at 2000 rev/min, the stop distance is calculated as 0.6 m and the same distance is calculated for 500 µm diameter drops emitted from a hydraulic nozzle with 3 m/s efflux velocity. Efflux velocity has proportionately less effect on the travel and deposition of finer sprays and, unless these are supported and directed by airblast, the fall velocity assumes increasing importance.

If such droplets are released from above the target their wind-borne travel may be considered, very approximately, with the aid of some simplifying assumptions; namely that:-

a) droplets issue from a line source, downwards, at terminal velocity,
b) air disturbance is negligible,
c) droplet movement takes place in stable, isothermal air, over flat ground, with zero wind shear.

With these assumptions the movement of spray droplets released from a given height (H) becomes a simple function of wind speed (u) and fall velocity. Since the time (t) taken to fall vertically through a height (H) at velocity (v_s) is H/v_s, the distance ($S = ut$) travelled horizontally in that time in a wind speed (u) is

$$S = Hu/v_s \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

By adjusting the height inversely with change in wind speed it is possible to keep the product Hu constant, so that droplets of any given size should always travel the same fixed distances downwind of the source. This reasoning provided the basis for the 'Porton' method of locust spraying described by Gunn (1948) and Sawyer (1950).

If the droplet size distribution is known, a graphical method may be used to predict the deposition curve (Johnstone, 1972). Fig. 1 shows four such curves, illustrating % by volume deposited versus distance travelled downwind for various values of Hu (in m^2/s) for droplet spectra having v.m.d.'s of 35, 70, 140 and 280 µm, with coefficient of variation (c.v.)[d] of 50%.

In interpreting the curves the limitations imposed by the simplifying assumptions must be borne constantly in mind, in particular the effect of turbulence on the spray. For quiet, stable conditions, which generally imply light winds of of under 2 m/s, Hu may be about 1 or 2 m^2/s for a source height of 1 m when using portable sprayers, or about 2 - 3 m^2/s for the equivalent aircraft crop spraying operation. At 280 µm v.m.d. it is predicted that 50% of the spray would deposit with less than 5 m lateral displacement from the line of the aircraft source for Hu = 5 m^2/s, and with less than 2 m displacement from a portable sprayer for which Hu = 2 m^2/s. Equivalent displacements for 140, 70 and 35 µm droplets from aircraft/portable sprayer sources for Hu values of 5 and 2 respectively, are shown as 11m / 4m, 37 m / 15 m, and 135 m / 54 m, indicating the marked effect of wind displacement anticipated for droplets of less than 50 µm in diameter.

Whether or not turbulence modifies droplet behaviour in this situation will depend on the ratio of the stop distances to the scale of the turbulence present. Thus if d_s is large compared with the eddy size the droplets will be little affected. By contrast, large eddies tend to pick up those droplets having only small stop distances and the droplets then participate in the turbulent motion of the airstream and become diffused by eddy processes (Pasquill, 1961; Yeo, 1974). The effect of instability is normally to increase the band width predicted by the simplified approach, some droplets being deposited nearer to the source, while some travel much greater distances. In field trials over mature cotton, Threadgill and Smith (1975) measured vertical air currents averaging about 3 cm/s (range -2 to 10 cm/s) which could markedly modify the travel of droplets having diameters of 70 µm and below. Bache and Sayer (1975) have suggested that the aircraft spraying height should be increased when operating in turbulent conditions to maintain the position of peak deposition at the same distance from the aircraft track, but give no estimate of the magnitude of change in recovery incurred due to increasing elevation.

However, once small droplets come within striking range of the target, be it a crop canopy, or resting or flying insect, deposition takes place by a combination of gravitational settlement and inertial impaction (provided no droplet bounce or blow-off occurs) either in the natural air currents or in supplementary airstreams specially generated by the dispersal equipment, e.g., mistblowers.

Sedimentation and inertial impaction

The relative importance of these two deposition processes can be roughly gauged by the ratio v_s/u (where u is here the airstream velocity), but more precisely, in the absence of appreciable atmospheric turbulence, the ratio is given by:-

$$\frac{\text{sedimentation}}{\text{impaction}} = \left(\frac{A_1}{A_2}\right)\cdot\left(\frac{v_s}{u}\right)\cdot\left(\frac{1}{E}\right) \quad ....(4) \qquad \text{(Yeo, 1974)}$$

where A_1 = projected area of target in the horizontal plane

A_2 = projected area of the target normal to the wind

E = efficiency of collection by impaction on the given target.

The impaction or collection efficiency of a target interposed in an airstream laden with small droplets (defined as the ratio of the number of droplets striking the obstacle to the number which would strike it if the streamlines were not deflected) varies with the airstream velocity and relative size of the target and

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[d] C.v. = $(d_{84} - d_{16})/d_{50}$, where d_{84}, d_{50} and d_{16} are respectively the droplet sizes below which 84, 50 and 16% by volume of the spray is contained. (A c.v. of 50% corresponds to a geometric standard deviation ($\sigma_g = d_{84}/d_{50} = d_{50}/d_{16}$) of 1.28 for a log-normal distribution, and a ratio of volume median to number median diameter (v.m.d./n.m.d.) of 1.21).

spray droplets in a somewhat complex way (Richardson, 1960; Dorman, 1966). However it is possible to determine the theoretical collection efficiency as a function of a dimensionless inertia parameter (P) which links the relevant physical variables in a relatively simple mathematical expression:-

$$P = \tau u/d = \left(\frac{v_s}{g}\right)\cdot\left(\frac{u}{D}\right)\cdot\left(\frac{\rho}{\rho-\rho_a}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

where D = effective width of the target normal to the flow.

The functional relationship between collection efficiency (E) and P is best shown graphically (Fig. 2). The upper and lower limits of E are found with potential and viscous flow (i.e. high and low Reynolds number (Re) = $18\tau u/d$) respectively. May and Clifford's experimental determination of E versus P for ribbon collectors is shown as the broken line in the figure. As an example, Fig. 3 illustrates the derived values of the theoretical collection efficiency versus droplet diameter for 1.3 and 0.13 cm wide ribbon targets at given airstream velocities (Johnstone et al.,1977a) using May and Clifford's (1967) experimental relation for E v. P, in conjunction with equation 5.

In studying the deposition of spray droplets in the field it is observed that as the droplet size falls below the rather arbitrary value of 100 µm (at which size the fall velocity is about 0.25 m/s) inertial (wind-induced) collection becomes increasingly evident, and below a droplet size of 50 µm (fall velocity 0.07 m/s) inertial impaction is usually the dominant process of deposition, sedimentation only being more effective under unusually still or sheltered conditions. The airstream from a mistblower nozzle merely augments the natural wind to a greater or lesser extent. However, at a droplet size of 30 µm for example, inertial collection efficiency can vary from as much as 88% (or higher) for a ribbon target of 1 mm width (or narrower) in a moderate airstream of 3 m/s, to virtually zero for a ribbon of 10 mm width in a light airstream of 0.5 m/s. These values give some indication of the transient variations which may be encountered in deposition on various natural obstacles (including leaves, stems and other plant structures) when working in the coarse aerosol droplet size range at ambient wind speeds (the wind invariably being attenuated within the structure or canopy of a crop). This highlights the problem of designing a simple artificial sampling system based solely on inertial or sedimentary deposition to monitor such small droplets consistently during airborne movement over and within a crop target (Johnstone et al., 1977).

EFFECT OF WEATHER AND MICROCLIMATE ON THE DRIFT AND DEPOSITION OF SMALL DROPLETS

The foregoing has outlined in a simplified way how droplet deposition can be affected by the prevailing weather and some of the transient features of the microclimate. High volume application techniques in which the droplets are directed onto a crop at close range by hydraulic or pneumatic pressure are much less susceptible to such weather variations than those very low or ultra-low volume techniques which utilise very fine sprays, the droplets of which are carried to the target primarily by the prevailing wind and its accompanying eddies, as well as being subject to evaporation in transit. The latter effects require more detailed examination.

Temperature, humidity and evaporation

The rate of evaporation of non-aqueous carrier in small droplets moving with an airstream is primarily a function of ambient air temperature, but for aqueous formulations the saturation deficit, measured by the relative humidity, is an additional factor which regulates evaporation. Amsden's data (1962) has been used to plot the variation in lifetime of water droplets, subject to evaporation at 30°C, 50% r.h., also at 20°C, 80% r.h., with initial droplet size, over the range 30 - 200 µm, as shown by the broken lines in Fig. 4 (Johnstone, 1972). On the same graph the variation in fall time from several heights (H) with droplet size, derived from equation 3, has been shown as a family of curves (full lines). The points of intersection of the full and broken lines define critical droplet sizes for given heights of fall and ambient conditions, which will just reach the ground before evaporating. Under moderately severe conditions of 30°C and 50% r.h. the critical sizes from release heights of 0.5, 1, 2, 5 and 10 m are approximately 60, 70, 85, 110 and 130 µm respectively. The use of water as carrier therefore requires special care, the hottest and driest times of the day being best avoided. In the special case of fungicide application the presence of dew on the crop may fulfil an important role in the redistribution of the spray (Hislop, 1970), so that spraying should normally be carried out as soon as possible after sunrise before the dew has evaporated. However, until there is evidence that this redistribution, which involves dilution, is also of benefit when using concentrated insecticides, it would appear better to delay their application until the dew has evaporated from the top layers of the canopy. An alternative would be the last hour before sundown when falling temperature can increase the humidity appreciably (Johnstone and Huntington, 1977a).

Frictional and convective turbulence; Richardson number

The turbulence we have to consider arises in two ways: (1) as frictional or forced convection due to roughness of terrain or vegetation creating resistance or drag on the airflow; (2) as free convection due to the buoyancy of the boundary layer air.

Laminar or viscous flow is encountered only under very stable or inversion conditions - those calm, or near calm conditions of clear evenings, night time or early mornings - when radiation from the ground causes the surface to cool below the temperature of the adjacent air so that buoyancy is eliminated. Strong sunlight, on the other hand, warms the soil surface and/or vegetation cover and with it the neighbouring air, setting free convection in motion. Hot spots and thermal plumes develop, especially in conditions of very light wind, when the air movement is observed as a series of gusts and lulls. One effect of increasing wind is to reduce the magnitude of these thermal effects, the resulting frictional mixing of the boundary layer air neutralising any marked temperature gradients which might otherwise develop. Thus while periods of light wind, associated with stable lapse rate or inversion conditions, will favour deposition onto horizontal collecting surfaces, such as the upper surfaces of those leaves so disposed, e.g., cotton, stronger winds will enhance collection by vertical surfaces, in particular the sides of stems and narrow upright leaves, such as those of certain graminaceous crops, e.g., rice, which face towards the drifting spray. Small amounts of lee side deposition can occur by impaction in the turbulent wake of large obstacles if the droplets are sufficiently small (Hadaway and Barlow, 1965). Convective turbulence associated with moderate to high super-adiabatic lapse rates in morning and early afternoon can result in rising air currents of sufficient velocity to overcome sedimentation of very small droplets, and may carry these aloft (Johnstone et al., 1977b).

One function recognised as a criterion for stability is the dimensionless Richardson number (Ri), (Richardson, 1920), which can be used to express the ratio of buoyancy to frictional kinetic energies associated with a parcel of air in the boundary layer. A simplified definition of Ri may be taken as:-

$$Ri = (g/\theta)(\Delta\theta.\Delta z)/\Delta u)^2$$

where g = gravitational constant; θ = temperature (°K); $\Delta\theta$ and Δu are respectively temperature and velocity differences over the height interval Δz.

Provided temperature and wind gradients close to the ground can be suitably measured, a characteristic Richardson number may then be determined. Values of Ri range from +1 or greater for marked stability with temperature inversion, through zero and very small negative values (~0.005) for neutral stability, to negative values of about -1 for very marked instability associated with high super-adiabatic lapse rates. The selection of appropriate sensors for determination of Ri has been discussed elsewhere (Huntington and Johnstone, 1973; Johnstone et al., 1974).

Correlation with drift and deposition of very fine sprays

Nearly two decades ago Yeo et al., (1959) demonstrated a correlation between recoveries by sedimentation of coarse aerosol sprays emitted from an aircraft and a stability factor which was essentially equivalent to Richardson number. More recently, correlation of positive Ri with sedimentation and the inverse correlation with inertial collection has been demonstrated for the application of insecticides as very fine sprays to cotton by portable rotary atomisers (Johnstone and Huntington, 1977). The latter's results for sedimentation are summarised in Fig. 5, in which recoveries (R_s), estimated volumetrically for three different formulations, have been compared under five different conditions (tests A - E). The component diagrams illustrate the magnitudes of the individual variables Ri, θ, r.h., u and the divergence in time of day from the noon datum ($|T|$). Highest recoveries have been obtained in early morning and late evening. It is apparent that factors other than Ri can influence drift and deposition strongly, especially if the formulation is volatile, and the recovery of the two aqueous formulations (1 and 2) is markedly affected by the two inversely correlated variables r.h., and θ (c.f. applications D and E). The effect of wind speed is less marked in this example.

When the formulation is volatile, volumetric recoveries can seriously underestimate mass recoveries of the involatile components of the spray. Table 3, condensed from Johnstone and Watts (1970), compares volume and mass recoveries and the inferred evaporation losses sustained by the depositing spray, when applying an oil formulation of DDT in a carrier with boiling range 217 - 285 °C by aeroplane for control of cotton insect pests. The measurements indicated losses of 18 - 64% by volume, depending on droplet size and the conditions at the time of spraying. Waterless formulations should be checked for volatility if evaporation problems are suspected (Johnstone and Johnstone, 1977). Some recent measurements from Thailand in which total mass recoveries (R_T) of very fine spray were determined colorimetrically from individual and groups of plants during application of insecticides onto cotton by portable sprayers are recorded in Table 4 (Johnstone, 1977a; Johnstone et al., 1977a). In these tests, mass recoveries on plants generally exceeded 70% for droplet spectra with v.m.d.'s ranging from 60 to 90 µm, provided wind speed remained under about 3 m/s. The lower recovery in application R is accounted for by the combination of instability and moderate wind, a combination which also explains the significantly lower mass recoveries when the droplet size was reduced to 42 µm v.m.d. (S). Good recovery was obtained at small droplet size using a mistblower (T).

CHOICE OF OPTIMUM DROPLET SIZE FOR SPECIFIC TASKS

With present knowledge and experience it is debateable whether one chosen droplet size can fit all conditions surrounding even one particular pest. nevertheless for a specific pest control problem the optimum droplet size range may be predicted by the sort of theoretical considerations summarised in this paper, supported, if necessary, by some appraisal in laboratory wind tunnel tests (Hadaway and Barlow, 1965). The final choice for field application should always be made with reference to the interaction of pest, crop, formulation and environment.

A broad guide to the appropriate choice is indicated in Table 5, adapted from an outline published by EPPO (1972) for ULV aerial application. Specific situations should allow closer definition. The narrowest droplet spectra currently available for field use are provided by rotary atomisers, which can give a ratio of v.m.d./n.m.d. of about 1.3 (c.v. 53%, $\sigma_g \sim 1.3$), compared with a ratio in excess of 2.0 (c.v. 100-150%. σ_g 1.7-2.0) for hydraulic pressure nozzles. Until novel ways of effecting comparable or better homogeneity in atomisation are developed, rotary atomisers are likely to remain the preferred equipment for CDA.

EPILOGUE

All the above considerations indicate that the performance of different spray machines can only be critically evaluated if the relevant meteorological conditions are known, and that if valid comparisons of performance are to be made, particularly for applications in the very fine spray or aerosol category, tests should ideally be carried out simultaneously, using appropriate assessment techniques (Johnstone, 1977 a, b). Furthermore, if consistent results are to be achieved in applying sprays of this nature, some guidelines regarding modification of operating procedures for variations in weather conditions will generally be required, accompanied by an acceptance of limitations on spraying under weather conditions which are unsuitable (Johnstone, 1977c).

We are improving our control of droplet size; we can achieve understanding of drift and deposition processes, but not control of the weather. How far can we use this understanding, together with choice and control of droplet size to give us truly controlled application?

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Table 1

Classification of sprays by droplet size and volume application rate

A. By droplet size

Description	Range of v.m.d.[b] (µm)
Coarse spray	>500
Medium spray	200 - 500
Fine spray	100 - 200
Very fine spray / mist	30 - 100
Aerosol	<30

[b] Volume median diameter.

B. By volume application rate

Description	Application rate (l/ha) Field crops	Bushes and trees
High volume (HV)	>600	>1000
Medium volume (MV)	100 - 600	300 - 1000
Low volume (LV)	20 - 100	50 - 300
Very low volume (VLV)	5 - 20	20 - 50
Ultra-low volume (ULV)[c]	<5	<20

[c] Essentially waterless formulation.

Note: Definitions are necessarily arbitrary, but the above seems to be a rational description of current usage with reference to ground machines and portable sprayers when applying insecticides and fungicides. (For herbicides LV is taken as 50 - 200 and VLV as 5 - 50 l/ha respectively). Aerial spraying must normally fall in the LV, VLV or ULV categories. The boundaries can be considered slightly flexible, e.g., a very fine spray with v.m.d. of 40 - 50 µm has many of the features of, and in certain instances may be justifiably described as a coarse aerosol.

Table 2

Terminal fall velocities (v_s), relaxation times (τ) and stop distances (d_s) for projection velocity of 1 m/s, for droplets of diameter (d) in the size range 1 - 1000 µm having unit density

d (µm)	v_s (cm/s)	τ (s)	d_s (cm)
1000	385	3.925×10^{-1}	39.2
500	200	2.040×10^{-1}	20.4
300	115	1.172×10^{-1}	11.7
200	70	7.135×10^{-2}	7.14
150	46	4.690×10^{-2}	4.69
100	25	2.548×10^{-2}	2.55
50	7.2	7.340×10^{-3}	0.734
30	2.7	2.752×10^{-3}	0.275
20	1.2	1.223×10^{-3}	0.122
10	0.30	3.057×10^{-4}	0.0306
5	0.078	7.950×10^{-5}	0.00795
1	0.0035	3.570×10^{-6}	0.00036

Table 3

Volume and mass recoveries (R_v and R_m) of sprays onto cotton by aeroplane determined from samples sedimenting onto horizontal artificial targets above the top of the crop

Application	Droplet size v.m.d.	H	R_v	R_m	Evaporation $(R_m-R_v)/R_m$	T (GMT)	u	θ	Cloud
	µm	m	%	%	%	h	m/s	°C	oktas
F	120	6.2	10	19	47	1415	0.72	81	0
G	110	5.2	15	42	64	0915	1.7	78	5
H	120	4.0	18	39	54	0830	1.4	76	4
I	125	3.7	22	46	52	0755	0.9	75	1
J	120	3.7	23	28	18	ca.0800	1.8	74	2-4
K	125	3.7	28	42	33	0810	0.62	75	3-6
L	140	2.5	34	48	29	0810	0.72	70	3-4
M	140	3.1	42	62	32	0810	0.9	69	3

Applications made from a Beaver aircraft equipped with two Micronair AU 2000 atomisers, applying a formulation of 20% DDT in heavy aromatic naphtha.

Table 4

Total mass recoveries (R_T) of sprays on cotton plants by portable atomisers under different meteorological conditions

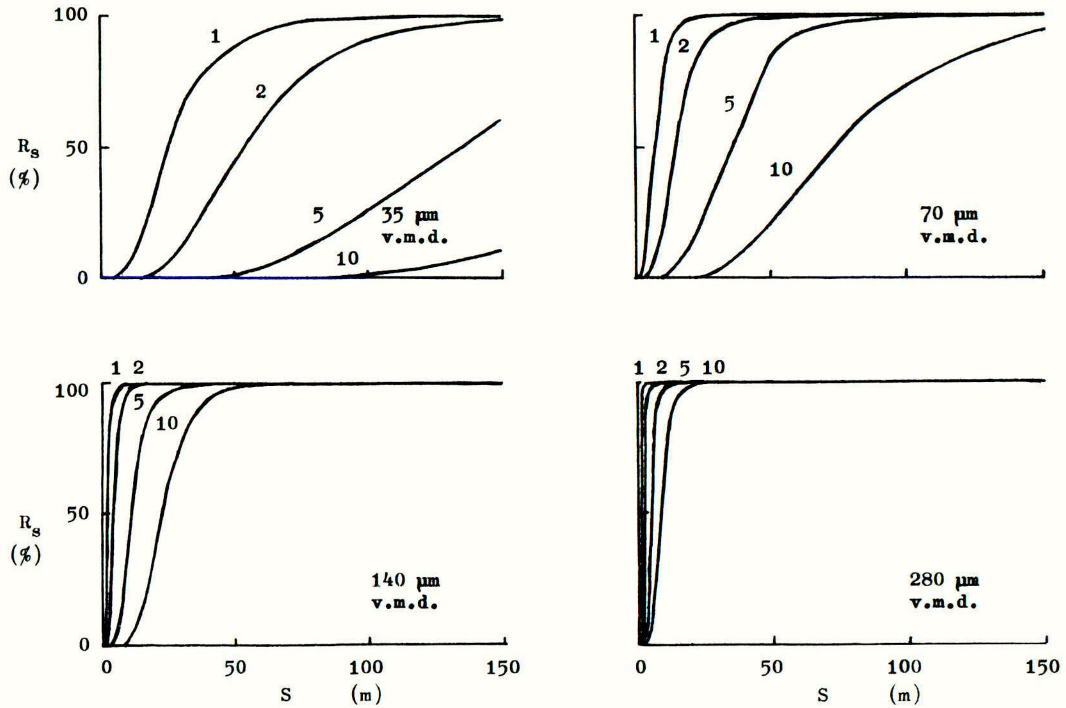
Application	Droplet size n.m.d./v.m.d.	R_T	T (GMT)	u	Ri	θ
	µm	%	h	m/s	-	°C
N	65/90	89	1015	0.6	-0.40	30
O	34/60	74	1100	0.3	-0.90	30
P	43/86	67	0855	3.0	-0.017	28
Q	44/80	73	1000	1.2	-0.021	31.5
R	44/80	48	1120	1.7	-0.047	31
S	26/42	19	1120	1.7	-0.047	31
T	27/59	74	1000	1.2	-0.021	31.5

All applications were made with portable rotary atomisers, except T (motorised mistblower). Applications P - T were 15% solution of triazophos in 70% vegetable oil, 15% other solvents; application O was 25 % triazophos in xylene; application N, dyed water only.

Table 5

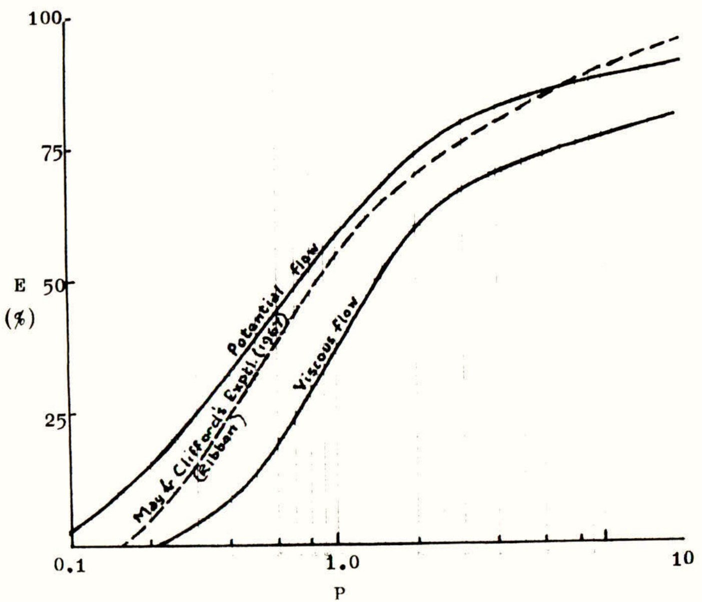
Guide to choice of spray droplet size in controlled droplet application

Approximate v.m.d. (µm)	Use	Remarks
>500	Herbicide application from the air when avoidance of drift a critical consideration.	Only suitable for slow flying aircraft, in particular, the helicopter.
200-500	Larvicide application against public health pests and bait spraying against mobile pests (ULV). Crop spraying with residual sprays against most pests and diseases (MV/LV).	Suitable for spot placement. Useful with aqueous sprays in conditions of high temperature and low relative humidity, particularly in aerial application.
125-250	Crop spraying using contact and residual sprays against most pests and diseases (LV/VLV).	Good deposition, but possible loss of cover density at VLV rates.
60-120	Crop spraying with contact and residual sprays against most pests and diseases (VLV/ULV).	Good canopy penetration. Check volatility of formulation, especially in aerial application.
30-60	Contact action sprays against flying or resting adult insects, e.g., tsetse flies, mosquitos (ULV)	Poor deposition on large obstacles; prone to drift. Evening or night-time application, or within 1 h after sunrise best.
<30	Contact sprays against adult mosquitos (ULV).	Little, if any, lasting effect. Best application conditions as for 30-60 µm.



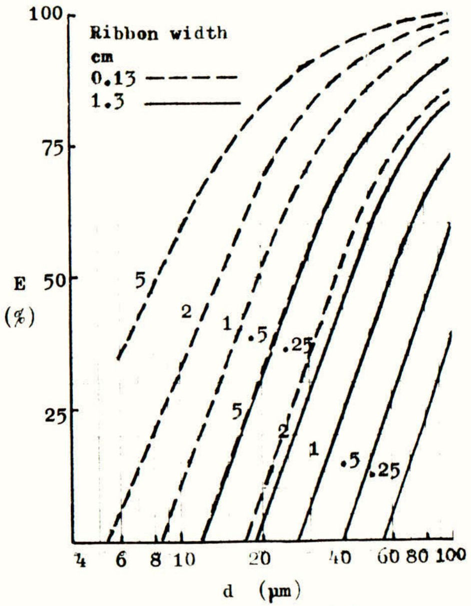
Recovery by sedimentation (R_s) versus distance travelled downwind (S) for droplet spectra with v.m.d.'s of 35, 70, 140 and 280 µm at Hu values of 1, 2, 5 and 10 m^2/s under conditions specified in the text

Figure 1



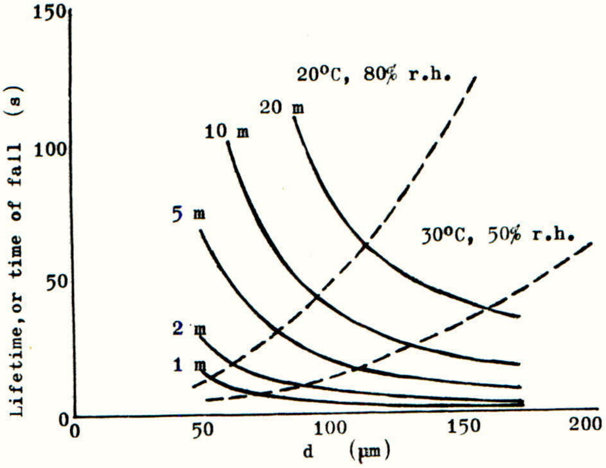
Collection efficiency (E) v. inertia parameter (P)

Figure 2



Collection efficiency (E) v. droplet diameter (d) for 0.13 and 1.3 cm wide ribbon target at 0.25, 0.5, 1, 2 and 5 m/s airstream velocities

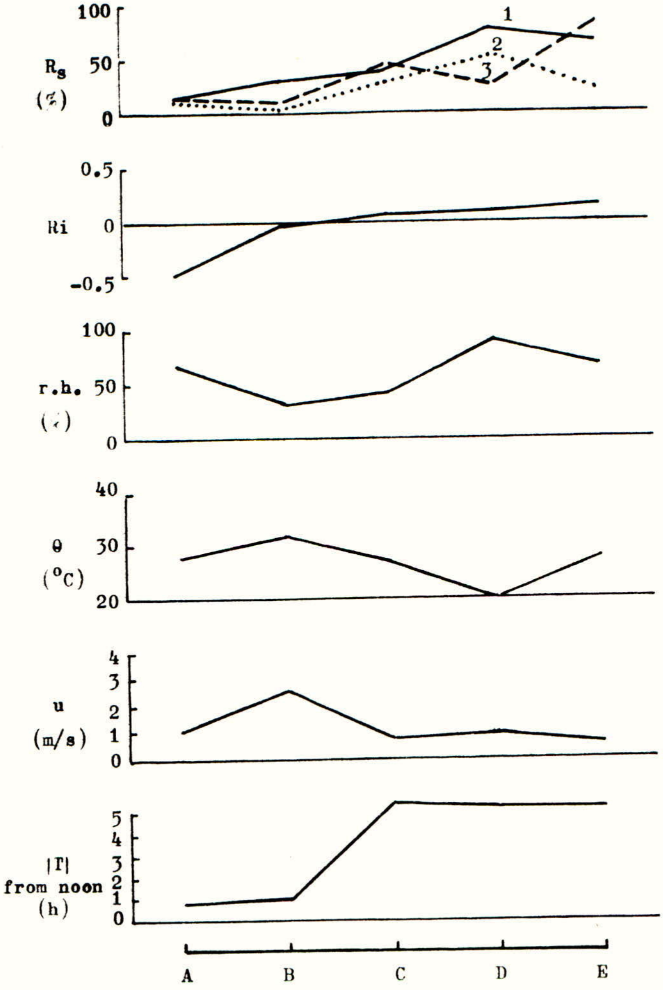
Figure 3



Lifetime of water droplets (broken lines) for two ambient conditions; and fall times from indicated heights (full lines), plotted against droplet diameter

Figure 4

Figure 5



Recoveries by sedimentation (R_s) of carbaryl sprays, measured volumetrically, for three formulations (1, 2 and 3), and the corresponding meteorological parameters, in five tests A - E

1. VLV aqueous formulation; n.m.d./v.m.d. 102/128 µm
2. VLV aqueous formulation with 18% molasses; n.m.d./v.m.d. 75/98 µm
3. ULV formulation in isophorone; n.m.d./v.m.d. 68/83 µm