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PHYSICAL FACTORS AFFECTING THE RETENTION OF SPRAY DROPLETS ON LEAF SURFACES

R. T. Brunskill

Chesterford Park Research Station
Fisons Pest Control Limited

Summary

A series of experiments has been carried out with a view to assessing the effects of various physical factors on the retention of spray droplets on pea leaf surfaces. The factors under consideration were:-

(1) The surface tension and the viscosity of spray liquid.

(2) The size and velocity of the spray droplets.

(3) The angle of incidence of the droplets as they impinge on the leaf surface.

Results show that the retention of spray droplets on pea leaves increases with decreasing surface tension and decreasing droplet diameter, is relatively unaffected by viscous changes in the range of practical interest, and decreases as the angle of incidence increases.

With the technique used for accelerating the droplets an increase in retention was observed at the higher droplet velocities.

Introduction

The ability of certain leaves to reject liquids falling on them is well known, a particularly familiar example being the cabbage leaf in a rainstorm. Previous investigators in the field of leaf retention have largely studied the phenomenon from the purely practical point of view, i.e. the determination of the percentage retention of spray fluids under practical conditions. The low retention of certain leaves to certain sprays has, in the past, been considered as due to coagulation of droplets on the leaf surfaces with subsequent rolling off under gravity.

Whilst this phenomenon is undoubtedly important and with certain leaves the predominant factor causing low retention, with other leaves, in particular leaves normally accepted as notoriously unwettable e.g. peas and cereals, low retention is due almost exclusively to the complete reflection of the spray droplets from the surface of the leaf. In low volume spraying, it is probable that this latter effect is the only one causing low retention.

This paper is largely devoted to the study of the physical factors in so far as they affect this reflection phenomenon of spray droplets on pea leaf surfaces.

Extent of the investigation

The following physical factors have been investigated in so far as they affect the retention of spray liquid on pea leaves:-

(1) The surface tension of the spray liquid.

(2) The size of the incident droplets.

(3) The viscosity of the spray liquid.

(4) The velocity of the incident droplets.

(5) The mean angle of incidence of the spray on the leaf surface.

Reflection phenomenon

Various leaf and inanimate surfaces have been tested for "reflection" properties with spray droplets. Smooth surfaces which are wetted with difficulty e.g. silicone treated glass and wax slides, never produce reflection of water droplets. Conversely many surfaces do have this property e.g. carbon black and magnesium oxide deposited on glass slides and such leaves as pea and iris. All the reflection surfaces have a very high contact angle with water droplets. In the case of carbon black and magnesium oxide the reflection of droplets is caused by the micro-rough nature of the individual surfaces and it would appear likely that peas and iris leaves exhibit the same effect by reason of a similar micro-roughness caused by the surface exudate of granular wax.

In an attempt to eliminate, as far as possible, errors due to variations in the micro structure of the leaves, the pea leaves used in the experiments were taken from pea plants grown under greenhouse conditions which were at the three leaf stage. The second leaf was chosen for the experiments.

Ideally, in investigations of this type, one would prefer to keep all other factors constant whilst variations in any one factor were being considered. This has not always been possible, and in this respect it should be pointed out that it is difficult to isolate the effects of droplet size and droplet velocity. In assessing the effects of droplet size in so far as it affects retention, the droplets under investigation were allowed to impinge on the leaf surface at their natural terminal velocity. From the purely academic standpoint this is unfortunate, but the results quoted will have more practical significance.

Angle of incidence

In assessing the effect on retention due to variations in the angle of incidence of the spray, the leaves were allowed to lie naturally on a flat platform and the angles of incidence were referred to this platform. In all cases flatly disposed leaves were chosen for the experiments but some inaccuracies in the final results are bound to occur due to micro-undulations in the leaf surface. Alternatively, strips of leaf could have been rigidly secured to the platform but this would have resulted in some damage to the leaf surface and led to a set of artificial conditions.

Velocity of droplets

There are many experimental difficulties involved in accelerating droplets without introducing undue turbulence in the attendant air stream. In the investigations into the effects of droplet velocity on retention it was therefore decided to use an air blasting technique to accelerate the droplets. It should be noted that retention results will probably be markedly different in the two cases. Nevertheless the technique employed more closely approximates to standard spraying practice.

Experimental techniques

Droplet production

Constant size droplets for the retention experiments were produced using a vibrating blade and a spinning disc.

Spray droplets from the vibrating blade equipment were produced with each passage of a sharp vibrating blade through a pendant drop of the liquid under test. The equipment gives rise to a well controlled stream of droplets which are characterised by their pronounced uniformity of size and velocity. Droplets of diameters from 40 to 400μ can be produced by this method.

Leaf specimens were carried through the stream on a small meccano trolley.

Droplets were produced from the spinning disc by feeding the dyed liquid under test at the central axis of the disc. Droplets of uniform size and velocity are thrown from the periphery of the disc and fall in a circular annulus. All other conditions being fixed, the diameter of the droplets produced is inversely proportional to the disc speed. Kiton Red (British Colour Index No. 31) was used to colour the solutions under test and Whatman No. 50 paper was used as the background for the leaf specimens. Kiton Red was chosen for the experiments as it is light-stable and pH stable, does not effect the surface tension of the test solutions and is readily eluted from filter paper. Whatman No. 50 paper has the advantage of not shredding on elution and is therefore particularly useful for colorimetric work of this kind.

Measurement of droplet diameter

The diameters of the droplets produced by both the vibrating blade and the spinning disc were measured using a two liquid cell. Mixtures of carbon tetrachloride and petroleum ether of specific gravities 0.9 and 1.1 were used as the cell fluids. A small quantity of the lighter liquid was run into the cell initially, the heavier liquid being slowly run in from a pipette placed at the bottom of the cell. A diffuse interface develops between the liquids where samples of the droplets under test can be observed.

Diameters of a collected sample can be readily measured using a microscope with calibrated eye-piece. Some coagulation of the droplets in a given sample always occurs, but the smaller diameter measured is a true indication of the original droplet size.

Measurement of retention

With the vibrating blade unit the leaf samples were carried through the droplet stream on a sheet of filter paper pinned to a simple trolley running on a meccano railway. The upper surface of the trolley was rotatable about an axis parallel to the direction of travel to allow variation in the angle of incidence of the falling droplets on the leaf surface.

In any one experiment the retention of the droplets on the leaf surface was measured simply by counting the droplets retained by the leaf and those which were reflected from the surface and landed on the surrounding surface of filter paper. A small quantity of red dye was added to the solutions under test to facilitate these observations.

In the case of the spinning disc to measure the retention of droplets on the pea leaf surfaces a colorometric technique was adopted. The leaves under investigation were laid on a filter paper background and were on all occasions sprayed with the test solution which was coloured with Kiton Red. The measurement of retention of the spray was subsequently obtained by eluting the dye from the leaf surface and comparing with elutions from the filter paper background.

Results

Surface tension

In the vibrating blade experiments various concentrations of methanol in distilled water were used to obtain surface tension variations over the range considered.

In the spinning disc experiments mixtures of acetic acid in water were used in preference to the methanol solutions, as it was felt that evaporation losses might be significant in this case.

The variation in retention with surface tension can be seen respectively in Tables 1 and 2 and pictorially in Figures 1 and 2. The droplet diameters were maintained at about 250μ and 350μ respectively, the droplets falling in both cases at roughly normal incidence.

Table 1

Droplet diameter 250μ. Methanol in water solutions

% Methanol	0	5	10	25	50
Surface Tension (dynes/cm)	71.2	62.6	57.6	48.1	38.8
No. of droplets	187	125	104	158	166
% retention	3.7	3.2	4.0	30.4	100

Table 2

Droplet diameter 350μ. Acetic acid in water solutions

Acetic Acid	0	10	20	25	50
Surface Tension (dynes/cm)	72.0	55.3	46.5	45.0	42.5
% retention	5.4	12.0	38.0	86.5	95.3

Droplet size

Water and one methanol solution were used in the vibrating blade experiments in assessing the effects of droplet diameter on retention. Solutions of acetic acid were employed in the comparable experiments using the spinning disc.

The results, at the quoted surface tensions, are shown in Tables 3 and 4 and presented graphically in Figures 3 and 4.

Table 3

0% Methanol Surface Tension 72 dynes/cm	Droplet Diam. μ	95	118	178	243	267
	% retention	100	66.7	21.3	0	0.5
25% Methanol Surface Tension 45.1 dynes/cm	Droplet Diam. μ	130	170		240	280
	% retention	100	82.8		30.4	31.3

Table 4

0% Acetic Acid Surface Tension 72 DYNES/CM.	Droplet Diam. μ	80	110	125	175	210	325
	% retention	92.2	89.0	76.6	46.5	35.5	5.6
20% Acetic Acid Surface Tension 46.5 DYNES/CM.	Droplet Diam. μ	80	110	170	225	305	500
	% retention	81.8	85.6	85.4	79.5	51.0	19.6

Viscosity

In the investigations into the effects of viscosity on retention, solutions of glycerol in water were used in conjunction with the vibrating blade equipment. Glycerol in water solutions are ideal in an investigation of this character, since comparatively large variations in viscosity can be obtained with negligible variations in the surface tension.

Results quoted at three droplet sizes can be seen in Table 5.

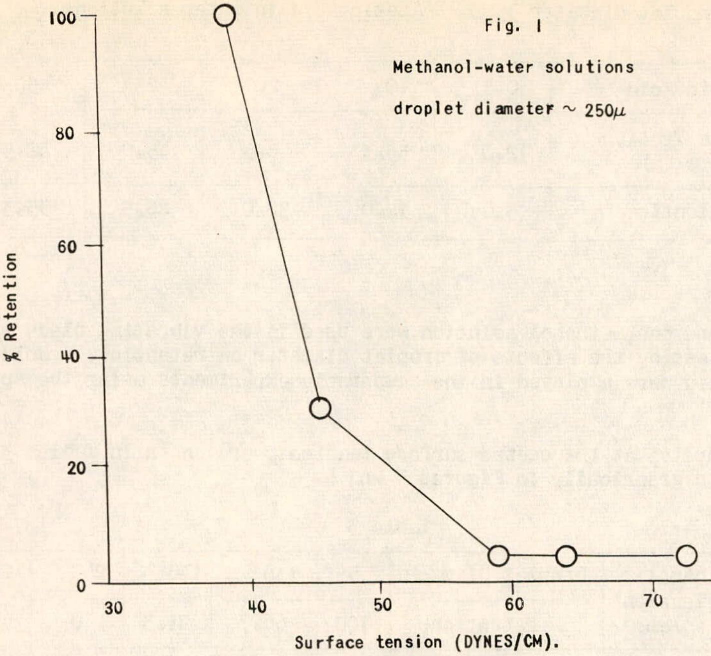

Fig. 1

Methanol-water solutions

droplet diameter ~ 250μ

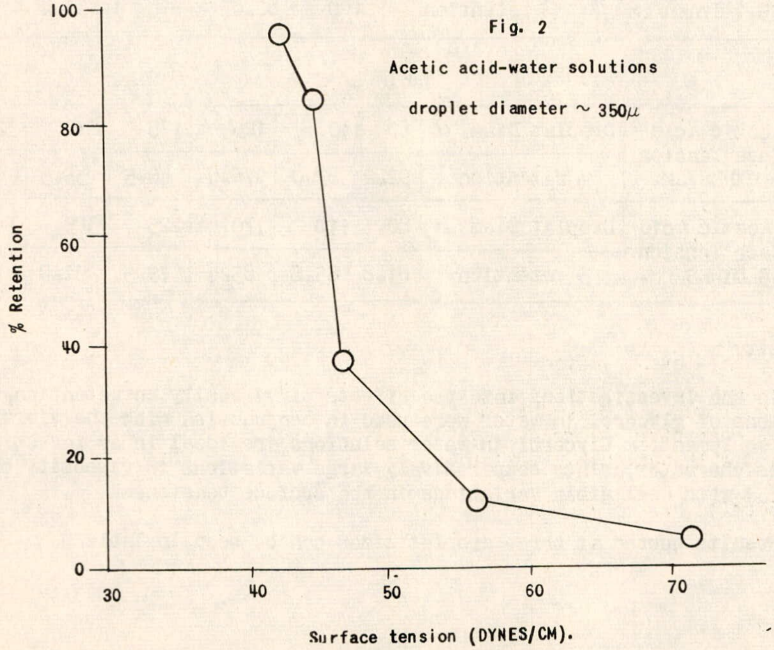

Fig. 2

Acetic acid-water solutions

droplet diameter ~ 350μ

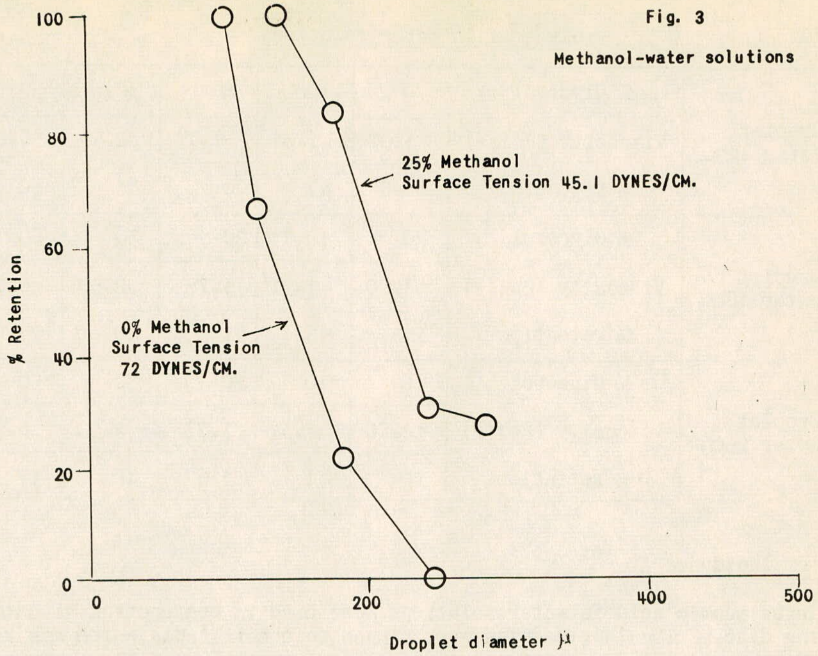

Fig. 3

Methanol-water solutions

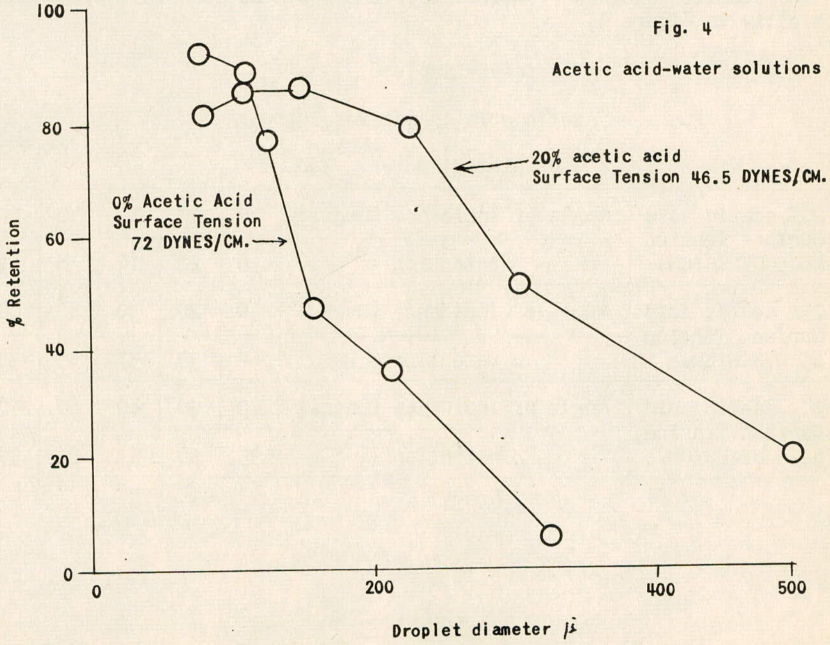

Fig. 4

Acetic acid-water solutions

Table 5

Glycerol in water solutions

Droplet Diameter 120μ	% Glycerol	0	10	20	30	50
	Viscosity (Poise)	1.00	1.31	1.77	2.50	6.05
	% retention	66.0	47	70	83	90
Droplet Diameter 180μ	% Glycerol	0	10	20	30	50
	Viscosity (Poise)	1.00	1.31	1.77	2.50	6.05
	% retention	21	15	51	20	77
Droplet Diameter 250μ	% Glycerol	0	10	20	30	50
	Viscosity (Poise)	1.00	1.31	1.77	2.50	6.05
	% retention	0	11	1.6	10	17

Angle of incidence

Three acetic acid in water solutions were used in conjunction with the spinning disc. The leaf samples were pinned to a cork table which was rotated as required and positioned in the circular annulus of the spray.

The results obtained from the experiments can be seen in Table 6 and graphically in Figure 5.

Table 6

Acetic acid in water solutions

Droplet diameter 380μ

20% acetic acid Surface Tension 46.5 DYNES/CM.	Angle of Incidence (Degs.)	0	20	30	40	60
	% retention	38	20	14	8	1.0
25% acetic acid Surface Tension 45 DYNES/CM.	Angle of Incidence (Degs.)	0	20	30	40	60
	% retention	62	59	57	53	34
30% acetic acid Surface Tension 42.5 DYNES/CM.	Angle of Incidence (Degs.)	0	20	40	60	70
	% retention	95	94	93	82	59

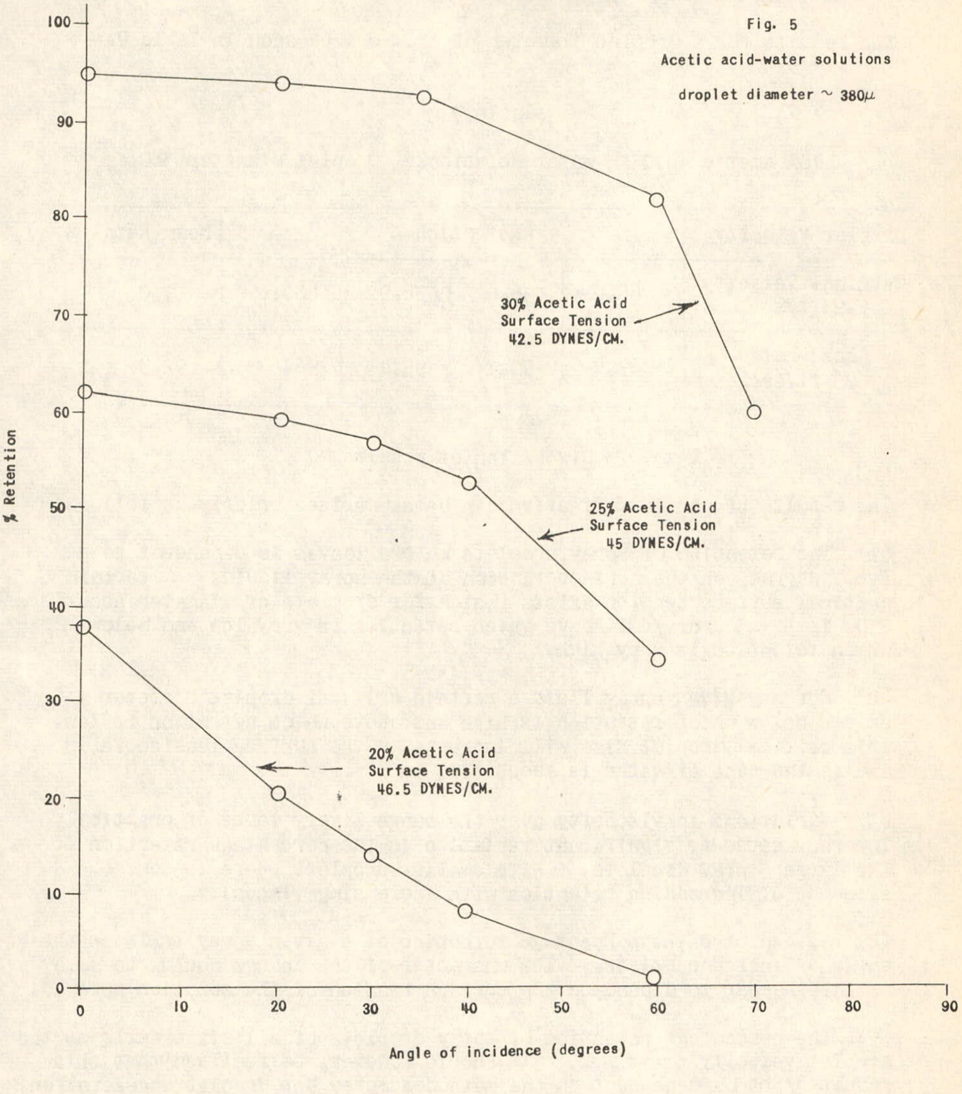
Fig. 5
Acetic acid-water solutions
droplet diameter ~ 380μ
30% Acetic Acid
Surface Tension
42.5 DYNES/CM.
25% Acetic Acid
Surface Tension
45 DYNES/CM.
20% Acetic Acid
Surface Tension
46.5 DYNES/CM.
% Retention
Angle of incidence (degrees)
0
10
20
30
40
50
60
70
80
90
100

Droplet velocity

Only a limited number of observations were taken of the effects of velocity on retention. The spinning disc was used for droplet production the spray falling into a vertical wind tunnel through which air was blown from a blower motor. The droplet velocity was assumed to be that of the air stream as it struck the leaf samples.

The results for a droplet diameter of 380μ can be seen in Table 7.

Table 7

10% Acetic acid in water solution. Droplet diameter 380μ

Droplet Velocity	Retention %				Mean Retn. %
Terminal Velocity 5.2 ft/sec.	66.6	56.4	58.9	46.1	57.0
Accelerated 25 ft/sec.	89.4	90.3	95.4	96.6	92.9

Discussion of results

The results of the investigation can be summarised briefly as follows:-

(1) The retention of spray droplets on pea leaves is dependent to a large degree, on the surface tension of the spray liquid. A certain critical surface tension exists (which for droplets of diameter about 250μ is 50-45 dynes/cm) above which retention is very low and below which retention is very high.

(2) For any given spray fluid a certain critical droplet diameter exists below which retention is high and above which retention is low. This critical droplet size will increase as the surface tension falls and in the case of water is about 100μ.

(3) Variations in viscosity over the range likely to be of practical interest cause no significant variation in the percentage retention of the larger spray droplets. With smaller droplets there is some evidence of increasing retention with increasing viscosity.

(4) As expected the percentage retention of a given spray falls as the angle of incidence rises. The character of the change would, to some extent, appear to depend on the surface tension of the solution sprayed.

(5) The percentage retention of spray droplets of all sizes falls as the droplet velocity decreases. It should however, be realised that this result might be dependent on the method adopted for droplet acceleration.

Theoretical considerations

Certain high speed photographs have been taken of the cycle of events which occur when drops fall on pea leaf surfaces and on surfaces carrying a thin deposit of granular carbon.

Both these surfaces exhibit the property of "droplet bounce". The photographs show that the droplets on striking the surface are flattened into an unstable state where the leaf area covered by the droplet is much greater than that covered by the equivalent stationary drop. After this point the droplet retracts from the surface and bounces away with a pronounced oscillation. The picture would appear to be a magnification of the effects seen when a soft rubber ball bounces from a hard surface.

It would appear therefore that the kinetic energy of the droplet is absorbed as surface energy of the deformed system, which retracts violently due to its instability, overshooting the normal stable configuration with final detachment from the surface as a free droplet in air. If this picture of the cycle of events is accurate it will be apparent that there exist an upper and lower limit of droplet size between which limits "complete bouncing" occurs. Droplets smaller than this lower limit, falling at terminal velocity, will not have sufficient kinetic energy to overcome the surface energy and viscous changes which occur in the cycle.

Conversely droplets of larger diameter than the upper limit will have so much kinetic energy available that disruption of the droplet occurs.

For surfaces exhibiting "bounce" therefore, there will be for any given surface tension of the liquid, a critical range of droplet sizes over which, reflection of the complete droplet is possible.

It will also be apparent that over this range of sizes the velocity of the reflected droplet will increase with the diameter of the droplet.

The important criterion determining droplet bounce, for any spray-leaf combination would by the considerations above appear to be associated with the advancing and receding contact angles.

In this connection it should be noted that no bouncing of droplets has been observed from any surface where the advancing contact angle was less than about 140°. As such contact angles are never encountered with the normal range of spray liquids on any smooth surface, it can only be assumed that bouncing is associated with a certain roughness of the surface. In the case of pea leaves this roughness is caused by the fine waxy granular deposit on the leaf surface.

PERFORMANCE OF SPRAY NOZZLES

K. Holly

Agricultural Research Council Unit of Experimental Agronomy,
Oxford

Summary

Spray distribution across the width of the area sprayed by a fan nozzle was measured using laboratory equipment. New nozzles of the same type and size varied appreciably in performance. Considerable changes in distribution occurred when different types of solution were sprayed through the same nozzle.

Introduction

One of the major factors governing the accuracy of equipment used in herbicide spraying, both experimental and commercial, is the performance of the nozzles employed. The spray distribution of individual pieces of equipment has sometimes been studied in considerable detail, as in a most interesting recent study of an aircraft sprayer (2). Yet the behaviour of the nozzles themselves and the factors which influence it have attracted singularly little attention. The fundamental study of the production of sprays by nozzles conducted at the Imperial College of Science and Technology has indicated the importance of such variables of the spray solution as its surface tension, viscosity, density and the presence of solid particles (4). However, there seems to be no published information on the magnitude of the practical import of such work. A good general account of nozzle behaviour has originated from one of the foremost American firms manufacturing nozzles (6). A short paper from New Zealand has illustrated the types of distribution pattern obtained with individual nozzles (3) and from Germany has come a somewhat mathematical treatment of the relation between nozzle spacing on a boom and the performance of cone nozzles (5).

In view of this paucity of published information some preliminary data obtained on various aspects of spray nozzle performance is brought together in the present report.

Methods and apparatus

The laboratory apparatus used for the measurement of the transverse spray distribution given by a nozzle was a refined version of a method first used at Iowa Agricultural Experiment Station (1). The nozzle socket, adjustable in height, is suspended over a sloping tray composed of a series of one in. wide troughs. The nozzle, actuated by compressed air at controlled pressure, sprays onto the tray. The nozzle and tray are surrounded by draught screening. When the spray liquid is running freely out of the lower ends of the troughs a battery of graduated glass cylinders is moved under the outlets and the amount of liquid collected by each trough in a given time thus measured. This may be expressed conveniently as ml of spray deposited per minute per in. wide section along the selected axis of the spray fan or cone. Total delivery rate of a nozzle can be measured separately using a nozzle socket set in the base of a magnetic valve controlled by a timing unit. This nozzle can thus be discharged into a graduated cylinder for a preset time.

Other determinations of nozzle performance were made with the nozzle fitted in the laboratory pot spraying equipment in which the nozzle is moved at constant speed through an enclosed cabinet. The spray solution contains a dye (tartrazine or tri-iodo-fluorescein) and the spray deposit is collected on filter papers or in containers placed under accurately machined rectangular holes in a metal plate. The dye is dissolved or extracted and estimated quantitatively by means of a photoelectric absorptiometer. The spray deposit can then be calculated in gal/ac.

Results

The investigation has been concerned primarily wuth fan nozzles insofar as these are the type most commonly used for herbicide spraying at present. The apparatus was constructed in order to select better-than-average nozzles for use on experimental equipment out of batches supplied by manufacturers. A striking variation in performance among new nozzles of the same size and batch as supplied to us became apparent. Typical instances are shown in Fig. 1. These are randomly selected new nozzles, inspected visually for obstruction and run briefly before test to remove any metal particles or dust remaining after machining. The distance from the nozzle at which the distribution was measured was varied according to the angle of the fan so that approximately the same width was covered at the plane of interception. Nozzles 21-24 are fan nozzles with machined brass tips and nozzles 101-104 are ceramic tipped fan nozzles. Both types have approximately similar total delivery rates.

The most desirable form of the spray distribution histogram depends on the use to which the nozzle is to be put. If required for a piece of experimental equipment, such as a pot sprayer, embodying only one nozzle, or for band spraying, it is desirable to have as even a distribution over as wide a portion of the fan as possible, i.e. a histogram resembling a plateau with a steep drop at each side. Visual inspection of histograms reveals the larger differences but a simple calculation is helpful for the selection of the best nozzles from a large batch. A procedure similar to the statistical calculation of the standard deviation of a mean was used. This is not statistically valid as the individual measurements are not random estimates of a mean spray deposition rate, so the statistical terms should be read in inverted commas. The individual measurements from the middle section of the fan within which about 80% of the total delivery rate is deposited (11 in. in the present instance) are used to calculate a mean square of their deviation from their mean. The "standard deviation" is derived from the mean square. This, in turn, is expressed as a "coefficient of variation", which relates the figure obtained to the magnitude of the mean delivery rate. This "coefficient of variation" provides in one figure a measure of the variability of the spray distribution over the most important part of the fan and can be used for the comparison of individual nozzles of similar or different types and delivery rates. The data for the nozzles shown in Fig. 1 are given in Table 2, which shows nozzle 23 to be the most suitable for 'single nozzle' use.

For use in a spray boom it is still desirable that the distribution should be even in the middle portion but a more gradual falling off at the margins of the fan may be compensated for by spacing of the nozzles to allow some overlap. Asymmetry of distribution, which was not infrequent, is clearly undesirable in all instances.

The influence of a number of factors on spray distribution was investigated. Variations in spray pressure have of course an effect on the total delivery rate of a nozzle. As an example of the magnitude of this effect measurement with a brass-tipped fan nozzle over the range 30-50 p.s.i. showed the delivery rate to be increased by 1.5% of the rate at 30 p.s.i. for every pound rise in pressure. Study of the distribution obtained with the same type of nozzle in the range 26-40 p.s.i. showed that small increases in pressure had the effect of a small increase in spray deposition towards the outer margins of the fan, with a corresponding slight reduction in the central peak. The total width of the fan was not significantly altered. This gives a slight improvement in the uniformity of distribution across the fan at the highest pressure but under practical conditions this advantage would be offset by drawbacks such as an increased risk of spray drift.

Fan nozzles are generally used at 12-18 in. above the intercepting surface. Study of the effect of a small increase in height within this range shows the fan width still broadens and there is a decrease in the variability of the spray deposition across the fan. In the absence of other considerations such as those connected with drift, some advantage in uniformity of spray is gained by such an increase in distance between fan nozzle and target. It should be noted that decreases in deposition in the middle of the fan of the order of 15% frequently occur as a result of increasing the height from 12 to 15 in.

Some of the most interesting results were obtained from the comparison of the distribution obtained with different spray solutions. All the tests so far mentioned have been conducted with tap water (surface tension approximately 72 dynes/cm). A comparison of the results obtained with tap water and a 0.2% v/v solution of Teepol in tap water (surface tension approximately 34 dynes/cm) is shown in Fig. 2. The latter gave a slightly sharper and higher central peak but the total effect of the very large reduction in surface tension was not great. Higher concentrations of Teepol do not reduce surface tension much further but can have a considerably greater effect on spray distribution. In a test on the pot spraying equipment spray deposition was 40% greater in the middle 6 in. of the fan 15 in. below a brass-tipped fan nozzle when spraying a solution containing 1.0% v/v Teepol than when spraying a solution without surface-active agent.

Some herbicide applications are made in oil and nozzle behaviour with this type of spray liquid can be very different from its behaviour with water. Fig. 3 shows the distribution obtained with the same nozzle spraying tap water and diesel oil. With the latter a marked concentration of spray liquid occurs in the margins of the fan and the amount deposited in the central portion under the nozzle is considerably increased. The total delivery rate of the nozzle, however, remains the same with both liquids.

In experimental spraying acetone is often used to dissolve new compounds which are water insoluble. Fig. 4 shows a direct comparison of the distribution of a dye solution in water and in a 50 : 50 mixture by volume of acetone and water, when sprayed by the pot spraying equipment. In this instance, the spray fan was widened and the amount of spray falling in the middle portion of the fan was appreciably reduced with the mixture. The effective dose applied by this equipment was therefore reduced.

Discussion

Several points of practical importance are brought out by the initial results of this empirical investigation of nozzle performance.

Firstly, new nozzles of identical type and size, although they may be reasonably similar in total delivery rate, are likely to vary considerably in the distribution pattern they produce. This has been found with nozzles from a number of manufacturers. Selection of nozzles for use in experimental spraying equipment by individual measurement of their spray distribution pattern is most desirable.

Secondly, the changes in spray distribution caused by small fluctuations in pressure at the nozzle and small changes in the height of the nozzle above the target are by no means negligible. In all types of spraying, variation in these factors can cause appreciable inaccuracies in dose applied.

Thirdly, spray distribution from a nozzle can vary very considerably according to the nature of the spray solution. The data here presented show gross variation in distribution according as to whether water, water plus surface-active agent, diesel oil or an acetone-water mixture is sprayed. Other types of spray such as oil-water emulsions or suspensions of wettable powders have not yet been investigated but are also likely to differ. A variety of types of deviation from the distribution with water was obtained presumably because a number of variables of the spray solution, including surface tension, density and viscosity are all involved. These results indicate that experimental spray equipment should be calibrated for performance with each of the types of spray liquid which may be used, as otherwise considerable differences in the amount and uniformity of the dose applied may occur. In commercial applications the optimum boom height for maximum uniformity of spraying may vary according to the type of spray being applied.

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Figure 1

Transverse distribution of spray given by new fan nozzles.

Nozzles 21-24 are brass tipped, measured at 15 in. below nozzle; nozzles 101-104 are ceramic tipped, measured at 12 in. below nozzle. Liquid: tap water. Pressure: 30 p.s.i.

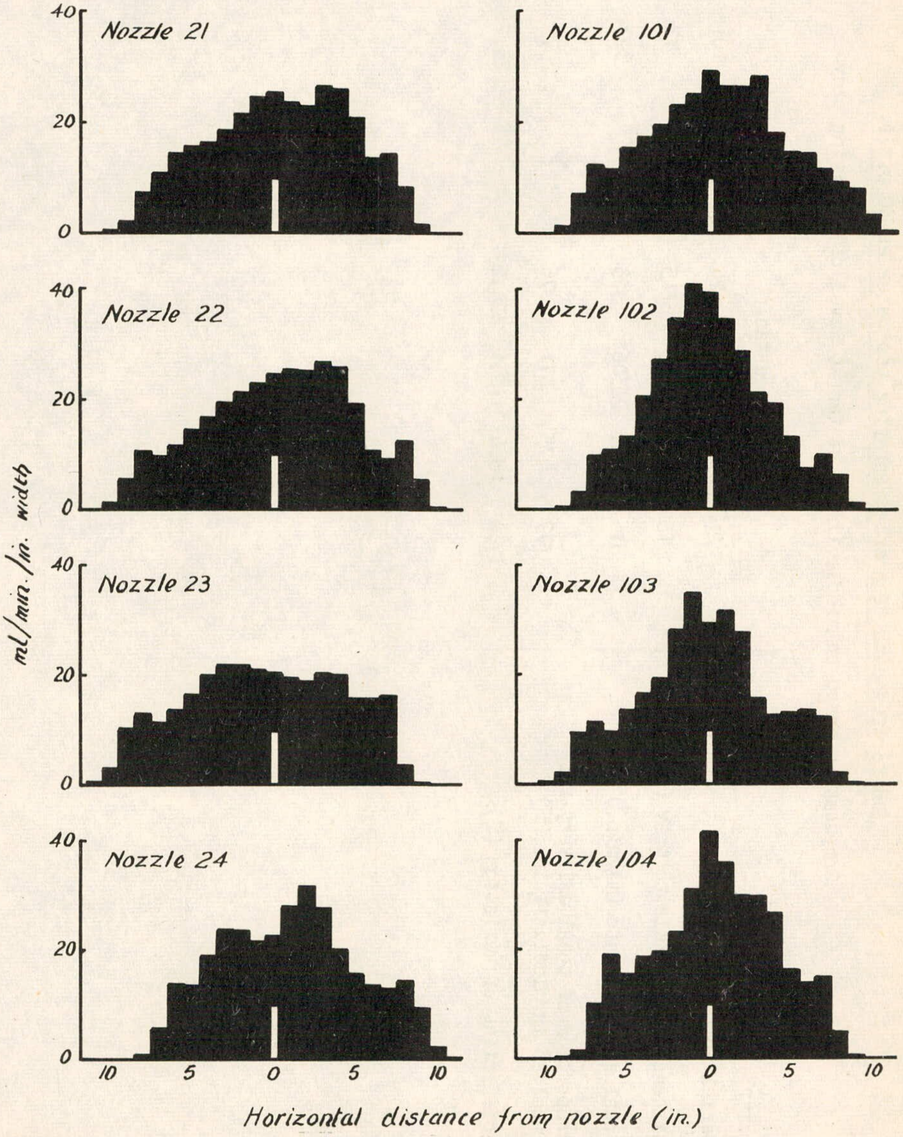


Table 1

Uniformity data of nozzles spraying tap water at 30 p.s.i.

Computation based on middle 11 in. of fan at level of receiving tray

Nozzle type	brass-tipped fan				ceramic-tipped fan			
Serial No. of nozzle	21	22	23	24	101	102	103	104
Distance from nozzle to tray (in.)	15	15	15	15	12	12	12	12
Total delivery rate (ml/min.)	316	322	306	323	327	344	306	352
Proportion of total delivery rate received in middle 11 in. (%)	77	75	71	76	75	85	80	81
Coefficient of variation (%)	17.0	18.4	10.1	24.2	23.7	36.9	37.6	32.3

Figure 2

The effect of change in surface tension on the Transverse distribution of spray.

Continuous line : tap water. Broken line: 0·2% v/v Teepol in tap water.

Nozzle: ceramic-tipped fan nozzle. Pressure: 30 p.s.i.
Distance below nozzle: 12 in.

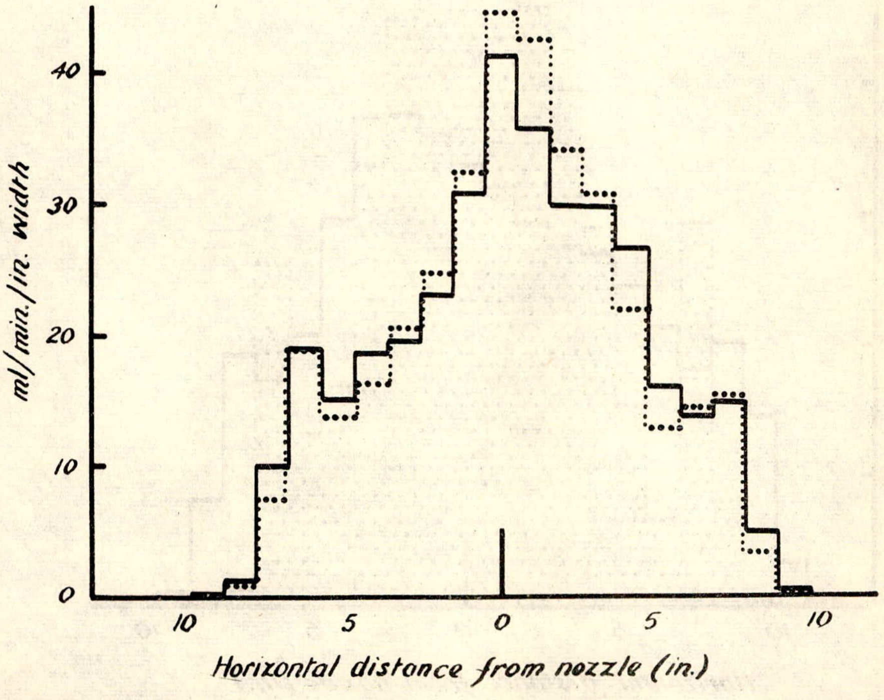


Figure 3

A comparison of nozzle performance when spraying oil or water. Continuous line: Tap water. Broken line enclosing stippled area; diesel oil.

Nozzle: brass-tipped fan nozzle. Pressure: 30 p.s.i.
Distance below nozzle: 15 in.

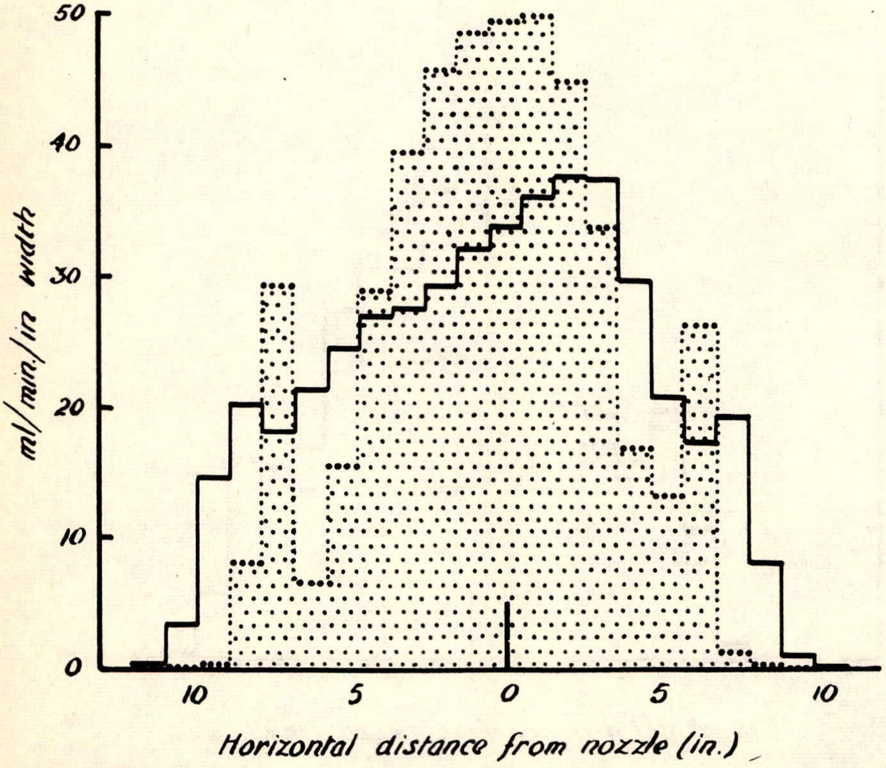
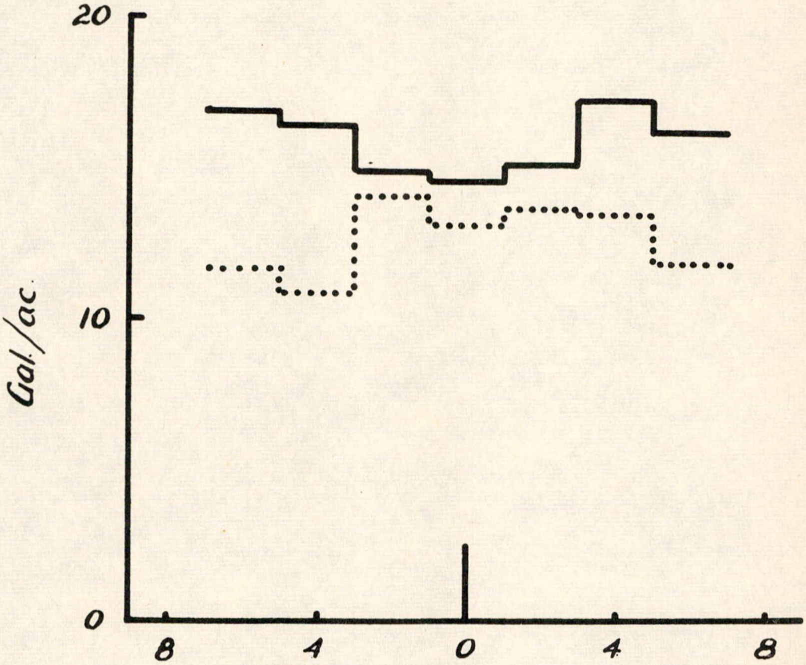


Figure 4

Spray deposition in the effective central portion of the fan when using different solvents in the pot spraying equipment.

Continuous line: distilled water. Broken line: 50:50 mixture by volume of acetone and water.

Nozzle: brass-tipped fan nozzle. Pressure: 30 p.s.i. Distance below nozzle: 15in.



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