SPRAY DISTRIBUTION FROM AEROPLANES

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SUMMARY

METHODS are described for measuring the distribution of spray from aeroplanes. Some measurements, based on chemical estimation, are given for three types of spraying aeroplane. It has been found that the pattern of spread is much influenced by propeller slipstream, crosswind, flying height, and droplet size.

Note: Positions of sampling spray are described as right of centre if they are on the pilot's right.

VISUAL METHODS OF ESTIMATION

The pattern of spray from aeroplanes is commonly assessed by observing it on a suitable surface. The spray may be dyed and inspected on a white sheet. Alternatively, spray may be collected on absorbent paper with powdered soluble dye rubbed into it. This method was used by Little in his studies of spray penetration of gorse. It does not require any additive to the spray.

Visual methods give an indication of the size of droplets at different parts of the swath, and are able to reveal any serious weaknesses in the spread. These methods are, however, not accurate. Weak parts of the spray consist largely of fine droplets, which tend to be given greater emphasis than large droplets owing to their greater covering power. Visual methods make the spread appear more uniform than it really is, and make the effective swath width appear greater than it is.

Provided these limitations are recognised, visual methods are very useful.

QUANTITATIVE METHODS OF ESTIMATION

A much more accurate estimate of spray distribution is possible by laying out hollow vessels or flat plates, and estimating the quantity of spray collected by each. A large number of measurements must be made for even the simplest investigations, and it is essential that the method used to estimate the deposit should be quick. The method should also be accurate, but very high accuracy is not needed, because it is not possible to avoid statistical errors of sampling.

The total weight of the spray cannot be used because of evaporation. Even if evaporation losses could be adequately allowed for, this means would still not be accurate enough, especially at low volume per acre.

It is therefore necessary to add some material to the spray which does not evaporate or decompose and which can be estimated quickly and accurately. Such a material must be truly soluble in the spray and free from surface active properties. Materials which lower surface tension are concentrated in the surface layers and are liable to become disproportionately represented in the fine droplets.

It is usual for a water medium to be used in these tests, but it is possible also to use an oil medium.

SANDERS COLORIMETRIC METHOD

A strong solution of dye, perhaps 2 lb in the aeroplane spray tank, is sprayed over flat ground on which are laid 6 in. × 3 in. rectangular plates of stainless steel. The dye is washed off these with 50 cc (approx. 2 oz) of distilled water and estimated in a electrophotometer. The Sanders method has been adopted as a standard method in the U.S.A. The dyes used are selected for light stability, but even so the samples must be collected quickly and stored in the dark.

CHEMICAL METHODS

Numerous methods of estimating deposits chemically are available, but those requiring chemicals to be spread in trace amounts are best avoided because they are liable to error from impurities picked up. Investigators

naturally tend to choose methods in which they are experienced, and for which they are equipped.

The author has usually used magnesium sulphate spread at 10 to 20 lb hydrated weight per acre. The spray is collected in short screw-top jars with an opening of 7 sq. in. The sample is washed out with distilled water and titrated against sodium ethylene diamine tetraacetate (EDTA), using Eriochrome Black T dye as an indicator, buffered to pH10. This method of estimation has a degree of accuracy rather better than required and can be made very quickly with the use of small self-zeroing burettes. This method is unaffected by impurities likely to be picked up, including the alkali released from new glass on its first wash.

Since titration with EDTA is still not well known, the author has investigated the spraying of sodium carbonate, which can be titrated against standard acid. Twenty pounds (hydrated weight) per acre will allow the maximum accuracy of this method to be attained. Carbon dioxide is released during the titration and the end point is likely to vary with the amount of shaking, unless the slow procedure of boiling during titration is used. Methyl red indicator has been found best, since it almost avoids the effect of variable amounts of carbon dioxide. It takes a lot of care to ensure accuracy to 3 per cent of the average which is desirable in these investigations. The magnesium estimation is more accurate; with it errors can be kept below 3 per cent without difficulty.

AIRFLOW AROUND AEROPLANES

Spray released from an aeroplane is influenced inevitably by air currents generated by the aeroplane as it moves through the air. The aeroplane, being supported entirely by the air, must impart downward momentum to the air at a rate equal to its weight. An aeroplane flying high and of the size commonly used for spraying will leave the air behind descending at something like 6 ft per second.

If the aeroplane is flying low, the air beneath it is constrained in its downward movement by the ground and is forced to move outward. The outward movement continues long after the aeroplane has passed, carrying spray with it.

Near the wingtips, air beneath the wing tends to be drawn upward into an area of lower pressure above the wing. This movement also continues long after the aeroplane has passed, giving rise to the well known wingtip vortices.

The existence of outwash and wingtip vortices has long been proven. More recently these effects have been forcibly demonstrated by Arkesson, using helium filled balloons (5).

In addition there are important effects due to propeller slipstream of fixed wing aeroplanes or to rotor rotation in helicopters.

IRREGULARITIES OF SPRAY PATTERN

Outwash from the aeroplane has two benefits: it makes the swath wider, and it makes a gradual fall-off at the edge so that lapping is not critical. On the other hand it tends to make the spray deposit uneven.

WEAK CENTRE

Owing to outward movement of air carrying spray with it, the spray tends to be light at the centre. It might be thought that very low flying would prevent the weakening of the deposit at the centre by causing the spray to fall before it has time to be carried far sideways by the outwash. However reasonable this might seem, it is a wrong assumption. Work in the U.S.A. has always shown an aggravation of the weak centre with decreasing flying height. This has been confirmed by the author for two types of machine not reported on by the Americans.

It would appear that even very low flying permits appreciable side movement of large droplets, but prevents filling in of the weak parts by finer drops falling well behind the aeroplane (6).

PROPELLER SLIPSTREAM

In tests by the author the weakest point of spray deposit is shifted

from 3 to 6 ft to one side as a result of rotating propeller slipstream. The inner half of the spray pattern is rendered uneven. Spraying aeroplanes have been given asymmetric nozzle arrangements in recognition of this problem, but nowhere sufficiently to compensate for the effects of the propeller. Asymmetric slipstream effects are probably the worst feature of spray patterns from aeroplanes (and helicopters) at present, and have proved very difficult to correct. Attempts to overcome these difficulties by modifying the aeroplanes rather than the spraying gear have met with no success. Clearly, contra-rotating propellers are very desirable.

EFFECT OF WIND

Headwind and tailwind have been found by the author to have no measurable effect on the spread provided the wind is steady and the aeroplane is flying directly into wind or downwind.

On the other hand sidewinds, even of low velocity, have a big effect on the pattern of spread. The most important effect of a light crosswind is to reduce the washout of air beneath the wing on the windward side, but to help the washout on the lee side. When crosswind is less than 5 m.p.h. only the smaller droplets are much affected. These smaller droplets, however, form a large proportion of the spray going outward beyond the wingspan. A light crosswind reduces the throw on the windward side, and carries it far out on the lee side, but the spread inside the wingspan is not greatly affected.

Above about 5 m.p.h. even large droplets cannot be thrown outward against the wind. The spray which normally goes outward from under the wing on the windward side is made to fall under the wing, giving a heavy deposit a little short of the wingtip. The edge of the spray deposit is very sharp on the windward side, a heavy deposit falling just out from the wingtip, but none only 2 ft further out. On the lee side the spray falls off very gradually beyond the wingtip.

Above about 5 m.p.h. crosswind speed the spread is thus very asymmetric and it is not possible to achieve a good overall spread by correct lapping.

DROPLET SIZE

The sinking speed of drops in calm air decreases rapidly with size. The smaller drops are much more likely to be carried off by wind and be deposited well away from the flying path. Small drops are also liable to be picked up in the turbulent air behind the aeroplane and to fall in a broad strip some time after the aeroplane has passed. The effect of these slow settling small drops is to make the overall spread more even by filling in to some extent the weak gaps formed by the heavier drops. American investigators consider some fine drops beneficial; they should be generated near the centre of the swath and should be kept out of the region of the wingtips (6).

In calm air fine drops usually give the most uniform spread. In wind coarse drops are better.

The size of drops will be reduced by adding wetting agents to the spray. On several occasions the author attempted to find a different pattern of spread from the addition of wetting agent, but was unable to find a real difference. It is concluded that the effect of wetting agents on spray pattern probably exists, but is very small in comparison with the more important factors of flying height, crosswind, and volume of spray per acre.

Spray patterns cannot be reproduced in full detail, even under good conditions, and minor changes in the pattern are difficult to demonstrate.

HEIGHT

Swath width increases with flying height, but to a less extent than might be supposed. In the author's tests an increased width of swath of only about 10 ft was found between very low flying and the greatest practicable flying heights (20 to 40 ft). Increased height gives a better spread in calm air, but increases the effect of wind and may make lapping less accurate. The optimum height for best spread varies with the machine. It is greater in high volume, that is large droplet spraying than in low

volume, that is fine droplet spraying. The optimum height for one machine spraying at high volume was found to be as high as 35 ft.

Measurements by the author are in good agreement with those published. The author feels justified therefore in advising against spraying from less than 15 ft unless some definite advantage is known to result from flying lower. Wind might provide a sufficient justification for low flying, but this has not been proven. An interesting advantage in very low flying has been found in spraying against aphides with contact insecticides (6). Really low flying is able to get more insecticide under leaves and give a better kill, even though the spread over a flat surface is not so good.

ERRORS OF SAMPLING

There are errors in sampling spray arising from the chance interception of droplets, particularly the larger ones which are relatively few but account for a large part of the weight. It is obvious that the amount of spray collected is liable to variation according to whether a few large drops falling at the edge of the collector are intercepted or fall free of the collecting area.

Error of sampling is reduced by using a larger collecting area, or by averaging a group of samples taken from approximately the same place. Since the error falls off slowly with collecting area (error is inversely proportional to the square root of the area), it would be necessary to collect spray over an inconveniently large area of several square feet in order to reduce the statistical error of sampling to negligible size.

In addition to these statistical errors there are also sampling errors arising from real variations of the spray pattern over short distances. These variations occur especially under conditions of high turbulence at ground level as caused for instance by gusty winds.

Under good spraying conditions variations in deposit are usually quite gradual, and sampling at 5 ft intervals is satisfactory, though not so good as at 2 ft intervals as has been done in the U.S.A.

To assess sampling error the author has usually put out 3 or 4 jars at each sampling point, and used the variation among the samples as a criterion of sampling error. The average value of the samples is used in plotting the curves for spread shown.

	First Run cc standard HC1			Second run cc standard HC1			Third run cc standard E.D.T.A.		
Flying height ----	20 ft			20 ft			35 ft		
Volume of spray	100 gal./acre			40 gal./acre			100 gal./acre		
Wind speed ----	3 m.p.h. steady			9 m.p.h. steady			25-31 m.p.h. gusty		
<i>Feet left of centre</i>									
35 ----	0.2	0.2	0.3	0.3	0.2	—	3.9	2.4	2.1
30 ----	0.5	0.4	0.5	0.2	0.3	—	3.8	3.8	3.2
25 ----	0.5	0.4	0.5	0.4	0.3	0.3	3.9	6.5	4.4
20 ----	0.9	1.0	0.9	0.4	0.3	0.3	6.1	5.6	7.4
15 ----	2.5	2.4	2.4	0.8	0.7	0.7	4.2	7.8	6.8
10 ----	1.5	1.6	1.6	2.3	2.3	2.4	5.6	7.4	5.7
5 ----	2.1	2.1	1.9	3.3	3.1	3.0	5.0	5.7	4.8
Centre ----	1.9	2.0	—	2.1	2.3	2.4	4.7	4.7	4.4
<i>Feet right of centre</i>									
5 ----	2.6	2.4	2.7	2.6	2.6	2.8	6.9	8.1	6.9
10 ----	2.3	2.9	2.9	3.1	2.8	2.8	5.1	4.4	4.4
15 ----	2.4	2.3	2.2	3.7	3.7	3.9	0.7	0.6	0.6
20 ----	1.4	1.7	1.5	1.3	1.4	1.6	0.0	0.0	0.0
25 ----	0.7	0.6	0.6	0.7	0.9	0.8	—	—	—
30 ----	0.4	0.6	0.5	0.5	0.5	0.5	—	—	—
35 ----	0.7	0.3	0.4	0.4	0.3	0.3	—	—	—

Individual samples from three independent runs by Fletcher aeroplane fitted with Swathmaster, showing good agreement among samples from

the same point in the first two runs, but poorer agreement in the third run which was measured under gusty conditions.

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The top curve shows an exceptionally fine spread, very fine droplets being used. The aeroplane was flown skilfully downwind in a steady 5 m.p.h. wind. The nozzles were then changed and the two lower curves obtained $\frac{1}{2}$ hour later. The wind had then risen to 8 m.p.h. and had become less steady in direction. Spraying was done downwind, but it is clear from the curves that there was some drift to the left from sidewind. A somewhat more even spread would no doubt have been obtained in calmer weather. There can be no doubt, however, that on this machine the finer nozzles allow not only a more uniform spread than the larger nozzles, but also a wider effective swathe.

Three measurements made of spray from the Swathmaster fitted to Fletcher aeroplane. At low flying height the spread is characterised by a very weak centre. The pattern of spread is greatly improved by going from 8 feet to 20 feet. The author recommends that spraying with this machine should never be done below 15 feet. High volume (100 imp. gallons per acre) spraying is best done as high as 35 feet, provided this does not give rise to appreciable side-drift of spray from wind.

Three spreads, done in quick succession. These are of special interest because the wind remained perfectly steady in velocity and direction during the test, viz. 3 m.p.h. from the left, 50 ft above ground level, and about 2 m.p.h. near the ground. Note how the wind has greater effect with greater flying height. Note also how the weak centre in the top curve is improved somewhat by flying at 15 ft.

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A motorised knapsack sprayer.

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Automatic spot spraying boom which gives mechanical selectivity.

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