# FACTORS CONCERNING THE PENETRATION AND DISTRIBUTION OF DROPS IN LOW GROWING CROPS

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Summary The results of an experimental and analytical study of spray distribution in low crops are given here. By varying the liquid pressure and the sprayer speed it is possible to obtain a considerable effect on penetration and deposition. To increase the efficiency in penetration of the spray liquid an aerofoil sprayer boom and additional air stream were used. With the help of high-speed cinematography qualitative and quantitative studies of the impaction of a spectrum of drops at different velocities were carried out.

## INTRODUCTION

Most ground sprayers for low growing crops are fitted with hydraulic nozzles which disintegrate the spray liquid into a spectrum of drops and direct them towards the ground. The nozzles are either cone or fan spray type for all types of commercially available pesticides, whether it is a herbicide, an insecticide or fungicide. The other types of atomizers, from the technical point of view, are not desired for ground sprayers used in field crops. For most applications of plant protection chemicals, selection of nozzle, sprayer speed and liquid pressure are chosen according to the application rate prescribed by the chemical manufacturers. Even though the dosage of the chemical, effective drop size and the target to be treated are discussed in recent papers by Ennis and Williamson (1963), Lake and Taylor (1974), and Walter et al (1977), no concern is shown for the practical field application. One could avoid the indiscriminate use of the chemical by applying the minimum necessary amount on the targets to be treated, which are very often in different regions of the crop. Invariably, during spraying a large bulk of water based spray liquid is used to cover the entire plant, even though a part of the chemical is enough to give the expected biological effect if the drops are directed to the targets to be treated. Only a fraction of the water acts as the solvent of the chemical and the rest acts as a carrier of the drops for better pentration and distribution.

A reduction in the application rate could be achieved by spraying the required amount of spray drops into an air stream directed towards the crop. Experimental and analytical investigations have been carried out to study the behaviour of spray liquid in field crops.

## EXPERIMENTAL PROCEDURE

### 1. Simulation of artificial crop

The experimental investigations placed emphasis on determining the penetration of the drops, as a function of the relevant spray parameters, with and without an additional air stream.

From the knowledge of fluid dynamics it is evident that the penetration and deposition of spray drops depends on the factors that characterise the size and shape of the obstacles in the path of the drops. Since the aim of this work is to study the penetration and distribution of spray drops in low-growing field crops, an artificial barley crop stand (4 m x 2 m) was set up in the laboratory to simulate field tests. The laboratory was large enough to avoid any wall effect. The artificial barley gave a fairly natural effect that was ideal for the simulation tests. The crop was of uniform height of 600 mm and uniform density. A sprayer boom attachment with five nozzles and driven by an electric motor, was used to simulate spraying with a ground sprayer.

### 2. Spray deposit and drop measurement

Water soluble fluorescent dye was used as a spray tracer to determine the amount of deposit at different heights within the crop. The same liquid was used to determine the drop spectrum using ultra violet flash photography. A sampling zone of 1 m x 1 m in the centre of the crop stand was used for the test.

### 3. Simulation of ground spraying

The spray deposits and drop spectra at different heights within the crop at three sprayer speeds, 5, 8 and 12 km/h, at three liquid pressures 1.5, 2.5 and 5 bar, and with and without additional air stream were studied using a complete factorial experimental design. The first series of experiments was run only with the conventional sprayer boom attachment. For the second series of experiments, ambient air was diverted into the artificial crop stand with the help of a windshield, in the form of an aerofoil, mounted on to the sprayer boom (Fig. 1). In the third series of experiments the additional air stream was achieved with a duct attached to the sprayer boom so that the drops were sprayed into the air stream. The air duct was fed from a stationary blower with the help of flexible plastic tubes.

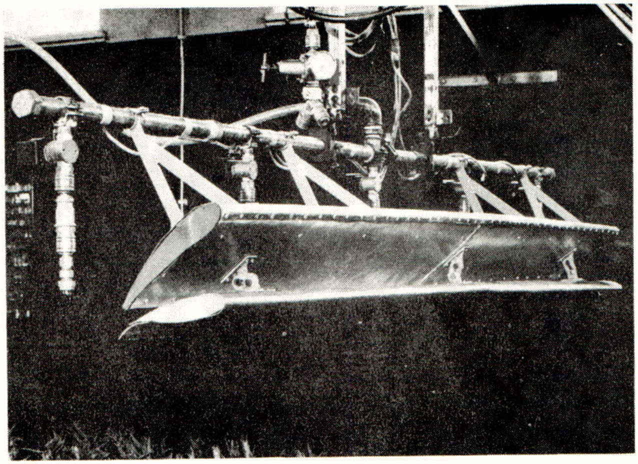

Fig. 1 Aerofoil sprayer boom

## RESULTS

### 1. Penetration and deposition of drops

The two principle variable factors, sprayer speed and liquid pressure, showed remarkable influence on penetration and coverage. An increase of sprayer speed decreased the penetration. At a sprayer speed of 12 km/h about 70% of spray liquid was recovered on the upper region of the artifical crop. At the lower speed of 5 km/h a uniform coverage was observed. An increase of pressure increased the penetration. This was mainly due to more drops due to the higher pressure. At the sprayer speed of 5 km/h and liquid pressure of 3 bar the penetration was uniform. This is mainly due to the extended duration of the air currents within the crop stand due to the lower sprayer speed and smaller drops with higher velocities (Table I).

## Table 1

### The percentage distribution of spray liquid at heights of 600, 300 and 100 mm from the bottom of the artificial barley crop

| | Runs No. | Application rate (l/ha) | Pressure (bar) | Sprayer speed (km/h) | Penetration;percentage | | Deposit | Total Deposit |
|---|---|---|---|---|---|---|---|---|
| | | | | | 600 mm | 300 mm | 100 mm | (ug/m$^2$) |
| Conventional sprayer | 1 | 400 | 2.5 | 3 | 48.5 | 34.7 | 16.8 | 3.9 |
| | 2 | 400 | 2.5 | 8 | 63.8 | 21.0 | 15.2 | 3.8 |
| | 3 | 400 | 2.5 | 12 | 72.0 | 21.8 | 6.2 | 3.5 |
| | 4 | 100 | 2.5 | 12 | 65.8 | 28.5 | 5.7 | 0.8 |
| Aerofoil sprayer | 5 | 400 | 2.5 | 3 | 55.2 | 28.9 | 15.9 | 4.1 |
| | 6 | 400 | 2.5 | 8 | 58.7 | 30.1 | 11.2 | 4.2 |
| | 7 | 400 | 2.5 | 12 | 56.8 | 29.5 | 13.7 | 4.5 |
| | 8 | 100 | 2.5 | 12 | 62.5 | 31.2 | 6.2 | 1.3 |

## 2. Effects of additional air

Investigation of the results with the additional air stream showed an increase in the number of smaller drops and better penetration. About 20% more coverage was observed while spraying with the aerofoil attachment at a sprayer speed of 12 km/h than with the conventional sprayer boom. A remarkable reduction in drop size spectrum was obtained with the air duct attachment (Table 2). Compared to conventional spraying an increase in deposit of up to 25% was measured in the lower region of the crop stand at a very low liquid pressure of 2.5 bar and at a sprayer speed of 12 km/h.

Due to the undesirable effects of the trailing edge of the aerofoil some further experimental studies are currently planned to optimise the location and positioning of the spray nozzle. So far satisfactory results have been achieved by locating the spray nozzle just in front of the trailing edge to deflect the drops into the crop. With this simple device the undesirable effects of air movement on the spray drops are eliminated to a certain extent by diverting air towards the ground for better penetration of the drops. Unlike the conventional sprayer this aerofoil sprayer gives better performance at higher sprayer speed.

Tests with an aerofoil combined with built in air ducts as one sprayer boom unit are also in progress.

### Table 2

### Drop size due to the filter effect of the artificial barley crop and additional air flow

| Fanjet nozzle (Teejet) | Pressure (bar) | Sprayer speed (km/h) | Run No. | Drop size (volume median diameter in µm) at various heights from the bottom of the crop | | |
|---|---|---|---|---|---|---|
| | | | | 600 mm | 300 mm | 100 mm |
| 110.02 | 3 | 5 | 1 | 246 | 247 | 211 |
| | | | 2 | 235 | 234 | 216 |
| | | | 3 | 213 | 210 | 185 |
| 110.04 | 4.5 | 16 | 4 | 311 | 303 | 274 |
| | | | 5 | 270 | 250 | 228 |
| | | | 6 | 249 | 232 | 232 |

Runs 1 and 4: crop spacing 180 mm
2 and 5: crop spacing 100 mm
3 and 6: crop spacing of 100 mm and with additional air flow.
Air velocity 4 m/s, and air volume 0.8 $m^3$/s.

Application rate: 180 l/ha, spray height: 500 mm

## AERODYNAMIC BEHAVIOUR OF DROPS FROM THE SPRAY NOZZLE TO THE IMPACT SURFACE

It is evident that with the combination of a suitable hydraulic pressure nozzle, liquid pressure, sprayer speed and the additional air stream it is possible to control the two **principal** factors, that is to say the final velocity of the spray drop and its size, for a desired penetration of the spray liquid into the crop stand. In the case of pressure nozzles the terminal velocity can be either more or less than the initial velocity, which ranges from 0 to 20 m/s. Since the minimum height of the sprayer boom is about 500 mm, most of the drops would attain their terminal velocity before reaching their targets. If the velocity is less than that of the cross winds and the turbulence above the crop they may drift away. The efficiency of penetration depends on initial velocity, drop size and the environmental conditions. Before conducting field spraying the environmental conditions are neither predictable nor measurable.

For efficient ground spraying it is essential to obtain more information on drop dynamics under natural environmental conditions. Previous work has covered this problem with the help of mathematical and computer simulation, and some aspects of it with experimental tests in wind tunnels, Heidt (1976), Williamson and Threadgill (1974) and Zaske (1973). Theoretical values of terminal velocities for drops with an initial velocity of 20 m/s, and final velocities after a vertical displacement of 500 mm from the nozzle tip, for various drop sizes calculated by Zaske (1973) are given in Table 3. Due to the complexity of the drop dynamics during spraying the influence of wind and turbulence generated by releasing the pressurized liquid and by sprayer movement have not been taken into account.

## Table 3

### Theoretical and experimental results of drop velocity

| Drop size<br>µm | Calculated terminal velocity, m/s | Assumed initial velocity, m/s | Calculated final vel. at 500 mm, m/s | Measured vel. at 500 mm, m/s |
|---|---|---|---|---|
| 100 | 0.272 | 20 | 0.7 | 4.0 |
| 200 | 0.672 | 20 | 1.9 | 4.5 |
| 500 | 2.02 | 20 | 12.0 | 8.0 |
| 1000 | 3.93 | 20 | 16.0 | 12.0 |
| 1500 | | 20 | | 16.0 |

## 1. Experimental set up with high speed camera

At present experimental and subsequent analytical studies have been carried out by means of high-speed cinematography (Fastax camera), to obtain the drag factor for different drop sizes and to measure the final velocities of drops during the process of spraying with commercially available spray nozzles (Tee-jet 110.02 and 110.04). By syncronizing the camera with a pulsed nozzle it was possible to change the initial velocity of the drops. The additional air was blown into the spray. Since the experiment was carried out in a relatively large enclosed space. possible errors due to wall effects are eliminated. With this set up the paths of the drops from the tip of the nozzle to their impact or sedimentation on natural leaves were filmed at 8000 frames per second, at three different stages. Analysis of the time-motion relationships of fast moving drops of different sizes are more accurately carried out by a slow motion study than with the help of high-speed still photography. Multiflash high-speed photography is applicable only to measure the drop velocity and not the continuous movement of a spectrum of drops.

## 2. Theoretical and experimental analysis of drop dynamics

For a drop moving from a nozzle with a velocity v the resistance is $k\,v^2$. The drag factor k is not the drag alone on spheres according to Stoke's Law at very low Reynold's numbers but includes all other environmental factors resisting the drop during its flight. The equation of motion of the drop with a displacement x at a time t, where x is positive downwards, can be written as

$$- k\dot{x}^2 - m\ddot{x} + mg = 0 \qquad \ldots\ldots \quad (1)$$

where m is the mass of the moving drop. After dividing the equation (1) by factor k,

$$- \dot{x}^2 - \frac{m}{k}\ddot{x} + \frac{mg}{k} = 0 \qquad \ldots\ldots \quad (2)$$

This quadratic differential equation of second order for x(t), after writing $\dot{x} = \dot{v}$, $\ddot{x} = \dot{v} = dv/dt$ and substituting in equation (2) becomes a quadratic equation of the 1st order

$$v^2 + \beta \frac{dv}{dt} + \alpha^2 = 0 \qquad \ldots\ldots \quad (3)$$

where $\beta = m/k$, $\alpha^2 = mg/k$. By separation of the variables and integrating, the velocity of the drop v(t)

$$v(t) = \frac{\frac{v_0}{\alpha} + \tanh \frac{\alpha}{\beta} t}{1 + \frac{v_0}{\alpha} \tanh \frac{\alpha}{\beta} t} \qquad \ldots\ldots \quad (4)$$

and the terminal velocity, where t is equal to infinity,

$$v \ (t \rightarrow \infty) = \alpha = \sqrt{\frac{mg}{k}} \qquad \ldots\ldots \quad (5)$$

By analysing individual pictures of the high speed film the initial velocity $v_0$ of the drop, the final velocity v(t) and the drop diameter, were obtained. These data are substituted in equation (4) to obtain the experimental drag factor k in terms of $\alpha$ and $\beta$ . By substituting the factor k, obtained from the experimental results, the terminal velocities for different drops are evaluated. In Table 3 the highest velocities measured with the high speed camera for different drop sizes are compared with the theoretical results of Zaske (1973). The vertical distance covered by these drops is 500 mm (spray height). It is noticeable that the velocity of the larger drops is more than that of smaller ones. The drops with the highest final velocity are measured, because most probably their initial velocity was 20 m/s.

Since the initial velocity of the spectrum of drops ranges from 0 to 20 m/s (for this particular nozzle at 2.5 bar), the probability of relatively smaller drops, say 200 µm diameter, with an initial velocity of about 0 m/s reaching the target is very low. From similar experimental and analytical investigations of nozzles at various liquid pressures, evaluations of the actual velocities of the drops at different heights were obtained.

## 3. Impaction behaviour of a liquid drop on a natural leaf

Retention and reflection of drops are of importance in connection with the application of different types of plant protection chemicals. The cloud of drops from a commercially available nozzle is composed of a spectrum of drops with different sizes and velocities. As such it is obvious that the impact behaviour of the drops, due to different drop inertia, will depend on the drop size and the impact velocity. Theoretical and subsequent experimental studies with a single drop, Brunskill (1947), Hartley and Brunskill (1958) from a drop generator cannot provide the required information for an efficient application of the spray liquid with different physical characteristics.

To study the process of deposition of a spectrum of drops on a natural waxy surface (cabbage leaf), the impaction and sedimentation of spray liquid drops from a flat jet nozzle was filmed at 8000 frames per second. Two spray liquids with surface tensions of 72.8 dyn/cm (water) and 25.6 dyn/cm (water + synergid) at 20° were used.

Experimental results showed that bouncing of drops occured only for a particular drop size at a certain velocity. At low velocities the smaller as well as the larger drops rolled down the waxy leaf, whereas at higher velocities the bouncing of smaller drops increased. Small water drops (<200 µm) with a velocity of 4.5 m/s were reflected totally while larger drops (>240 µm) with this velocity rolled along the horizontal surface of the waxy leaf. By lowering the surface tension (25.6 dyn/cm) all the drops remained on the surface except for the larger drops (600 µm) with a relatively high impact velocity of 8 m/s. This broke into small drops and got redispersed.

These experimental results showed that the retention and reflection and subsequent penetration of the spray drop could be controlled, to a certain extent, by the combination of a suitable drop spectrum, with a known average drop velocity and the surface tension of the spray liquid. A better penetration could be achieved with drops with a surface tension of 72.8 dyn/cm than with a spray liquid of lower surface tension. Large liquid drops at low velocities are ideal for spreading the fungicide and giving better coverage. For spraying insecticide one could choose spray liquid with a low surface tension and small drops.

## CONCLUSION

The interdepending influence of the relevant spray parameters must be taken into consideration during the selective application of chemicals. At a high sprayer speed of 12 km/h the penetration is very low compared to the deposition on the canopy of the crop. With the help of an aerofoil sprayer boom it was possible to increase the penetration of drops by diverting the air into the crop. Better penetration was obtained by spraying liquid drops into an air stream directed towards the crop. Additional shattering of drops was also obtained. Especially for low-volume application, additional air is inevitable for efficient spraying.

Only with high speed cinematography was it possible to study the drop dynamics, especially the impact of drops on natural leaf surfaces. With multi-flash - double exposure still photography it is not possible to follow a sequence of drop movement. Penetration and deposition takes place by sedimentation and drop inertia. Penetration would become more efficient as drop velocity is increased. This is due to bouncing and redispersion of the drops. The bouncing is directly proportional to the drop impact velocity and inversely proportional to drop size. Table 3 shows that the drop size of the spray (VMD) which penetrates the artificial barley crop decreased due to the additional air flow. This indicates that larger drops are deposited on the upper region of the crop partly due to 1) inertial mechanism 2) smaller drops being carried by additional air currents taking place at low flow rates and 3) the duration of the turbulence in the lower region of the crop stand.

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# REDUCTION OF ACTIVE INGREDIENT DOSAGE BY SELECTING APPROPRIATE DROPLET SIZE FOR THE TARGET

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For many years now I have advocated the principle of C.D.A. spraying or, as it was earlier described, U.L.V. spraying and, even in its early days, concentrate spraying. As long ago as 1969 I stated that the efficiency of a spraying machine is inversely proportional to the range of droplets it emits, whilst the suitability for a specific problem depends on the actual size of the droplets emitted (Bals, 1969). In this same paper I also expressed the hope that one day ultra low volume spraying would be synonymous with ultra low dosage spraying.

Time has rolled rapidly by and we, for our part, have been working hard on improving the efficiency of our rotary atomisers. This has been achieved by long and careful study and investigation into how droplets have been formed. This study has led to numerous designs of atomisers to achieve different parameters of performance according to their intended mode of application. The main types of atomiser are described later in this paper.

However, in 1969 and again in 1975 (Bals, 1975) I suggested a number of areas where a good deal of research was essential, for this is not a one-sided operation. The closer the match between the sprayer and the particular range, or ranges of droplets it can emit, and the chemical product which goes through it, the closer we move towards the desired goal of efficient pesticide application.

Can I remind you of these areas of study which I last stated in 1975:-

1. The definition of the target
2. The behaviour of droplets of different sizes
3. The macro and micro climatic conditions during which the operation takes place and
4. The concentration of chemical needed and the suitability of the formulation to give effective control with a given droplet size

Much more thought needs to be given to the target for the pesticide. In insect control large doses of chemical are often used simply because we are trying to kill full grown larvae after damage has been done. In Pest Management one must consider attacking the stage of the pest which will have the most effect on the subsequent population that does the damage. Thus, in locust control, control of hoppers in the breeding areas was quickly recognised as being more important than trying to control locusts damaging crops. The most efficient spraying has been against swarms of adult locusts which present a clearly defined target.

Unfortunately, the picture is not so clear with most agricultural pests, but there is no doubt that control can be improved by defining the target more precisely (Matthews, 1977) and then choosing the appropriate droplet size and droplet density on that target to achieve control.

Johnstone (1973) pointed out what volume application rate was needed to achieve a different droplet density with various droplet sizes. Furthermore, he pointed out what concentration of spray was needed in relation to various levels of LD50 in ng/insect. Thus, if an efficient pesticide is selected, requiring less than 10 ng/insect, then no more than 10% active ingredient should be in the spray with droplets of 60 µm in order to achieve a kill with the impaction of one droplet on the insect. With droplets smaller than 60 µm it is more than likely that sufficient droplets will impinge on the target to provide satisfactory control.

The point I want to stress is that with C.D.A. we do NOT say 'We need 1 kg/ha, therefore, if we only use 1 l/ha we have to have a formulation containing 100% a.i.' Quite the reverse, it is most essential to establish which droplet size is most efficiently collected on the target, then determine the total spray volume needed for a given droplet density and finally select the concentration appropriate to the pesticide being used. With the wrong approach accidents can happen as witnessed in the U.K. during the aphid infestation of cereal crops in 1976. This, in my opinion, was a classic case of where things can go dramatically wrong without a properly coordinated approach to the subject. While many users safely achieved excellent control, a small minority sought advice from many quarters with the result that they ended up using the wrong chemical at an extremely high concentration under the wrong conditions. Fortunately these incidents, although serious, were not fatal. In one country overseas, more than 100,000 Ulvas have been in constant use for many years using a formulation with 25% active ingredient of an LD50 of 100 mg/kg without any fatal accidents.

C.D.A. opens up immense possibilities of more efficient use of expensive and rare resources. The pests are fighting back and developing resistance to our chemicals so we must use less of them, much more efficiently, to reduce the selection pressure for resistance.

Other papers at this symposium may have considered the movement of different sized droplets and their penetration within crop canopies under various climatic conditions. I just want to reiterate the need for caution in the methods of sampling. We know that the droplets below 100 µm are increasingly difficult to collect on artificial surfaces. The only real way is to examine what is collected on natural surfaces and the biological effects that are obtained. Another important point is that often when examining spray distribution, the results are based purely on a single pass, or multiple passes, along the same line so little, or no, information is obtained of the effect of incremental spraying with the subtle changes in wind strength and direction during the period of spraying, especially as the use of ultra-low-dosage spraying may require a repeated application on the following day under completely different macro and micro climatic conditions.

Obviously the most important factor is choice of formulation. Reduction of the effect of evaporation is of fundamental importance with the smaller droplets, yet use of this phenomena can be made if it allows a larger droplet to fall into a canopy and then, having lost some of its volume, to move within the canopy and be collected on the less exposed plant surfaces. The formulation of the droplet on its arrival at the target must allow rapid uptake through the insect or plant surface to the site of action or, in the case of a residual pesticide, a surface deposit is more important. Clearly there is much to be learnt in relation to C.D.A. in this respect.

## EQUIPMENT

We now have a series of spinning disc nozzles to cope with a range of droplet sizes and volumes.

| UNIT | DISC DIAMETER | VOLTAGE | DROPLET SIZES | RECOMMENDED VOLUME L/HA/SURFACE | ACHIEVING AN APPROX. DROPLET DENSITY PER $CM^2$ PER HA/SURFACE |
|---|---|---|---|---|---|
| MINI ULVA | 55 mm. | 15 | 30 - 40 µm | 0.100 | 50 |
| MINI ULVA | 55 mm. | 12 | 40 - 50 µm | 0.250 | 50 |
| MINI ULVA | 55 mm. | 9 | 60 - 70 µm | 0.800 | 50 |
| ULVA | 85 mm. | 12 | 70 - 90 µm | 1.25 | 50 |
| HERBI | 80 mm. | 12 | 220 - 260 µm | 10 | 10 |

These range from the MINI ULVA which can be operated at speeds up to 18,000 r.p.m. to produce droplets of 25 - 30 µm to the Herbi which produces 250 µm droplets. From Johnstone & Johnstone (1976)[5] there is an optimum flow rate with ligament formation when the ratio of v.m.d./n.m.d. is minimal. Thus, with HLP.16 oil:-

| r.p.m. | ml./min. | v.m.d. | n.m.d. | **ratio** v.m.d./n.m.d. |
|---|---|---|---|---|
| 15000 | 8.5 | 41 µm | 32 µm | 1.3 |
| 12000 | 26 | 52 µm | 39 µm | 1.3 |
| 9000 | 26 | 71 µm | 50 µm | 1.4 |

We have confirmed this factor with high speed photography.

From the table mentioned in Johnstone's paper, it is very interesting to note that the MINI ULVA atomiser is already overfed at 9,000 r.p.m. at 30 ml./min. as, from the figures shown in this paper, and our own observations on high speed photography, the ligament atomisation ceases and sheet formation takes place. The minimum speed for the MINI ULVA is approximately 10,000 r.p.m. with a feed of approximately 30 ml. with a v.m.d. of 65 and a n.m.d. of 50. Thus, with the 55 mm. disc it is absolutely essential to avoid overfeeding so the maximum flow rate is in the range of 8 - 30 ml./min. depending on rotational speed. If less viscous liquids are applied, the restrictor must be changed to adjust the flow rate accordingly.

Although originally designed to produce aerosol droplets, another advantage of the MINI ULVA is the reduced power required so that, as an alternative to the ULVA for droplets of 70 µm battery life should be increased approximately four times.

|  | v | r.p.m. | milliamps |
|---|---|---|---|
| ULVA | 12 | 8000 | 500 |
| MINI ULVA | 9 | 10000 | 125 |

The challenge of the MINI ULVA is that instead of thinking only of weekly sprays set on a calendar schedule, there is now the scope for rapid treatment when a pest is present. Large areas can be treated in minutes so, if necessary, sprays could be applied each day over a wide area to prevent an immigrant insect population getting established. At present, on a crop like cotton, farmers in some parts of the world put heavy doses on every week throughout the season endeavouring to protect their crops instead of checking the invasion of the pest. However, success with pest management will require a regional approval to the problem as is needed with locust and tsetse control.

The MINI ULVA can also be mounted in front of a fan for spraying up into bush and tree crops such as coffee. A small version is planned for glasshouse crops and other versions are in development.

## THE ULVA

This has continued to pioneer the way for C.D.A. in the tropics and will continue to be useful in the 70 - 90 µm size range. Nearly half a million are now in use throughout the world in many countries. We could, in the light of our current knowledge, make considerable improvements in this sprayer. However, as it now has a widely understood mode of use, we have decided to continue its production in its current form and incorporate the later innovations in the new MINI ULVA. This unit will be available in the second half of this year. The present MINI ULVA was only a research model to prove this new approach to spraying.

## THE HERBI

This was designed to provide drift-free droplets of 250 µm over a 1.2m. swath. It has been successfully used on a wide range of tropical crops including maize and perhaps most important of all, it has been used to prepare the land for crops. In the NO-TILL approach advocated by Ray Wijewardene and colleagues at the I.I.T.A., a fresh approach to farming systems is needed in the humid tropics to reduce soil erosion and build up the soil structure. Farmers in the tropics adopted a shifting cultivation, moving on when they had drained the fertility of the soil and could no longer cope with the weeds (Wijewardene, 1978)

Mechanisation with the plough, as in Western Europe and America, has aggravated the problems in areas of intense rainfall. Hitherto, herbicides could not be used as farmers were unable to get sufficient water for knapsack sprayers (Matthews, 1976)

With a sprayer such as the HERBI, proper use of herbicides can be made to prepare land leaving a protective mulch over the surface. The farmer can then 'jab plant' seeds through the mulch and obtain excellent yields. Reluctance to use herbicides in the tropics stems from a fear of moving people to the towns and cities. If the drudgery of hand hoeing is removed, and better yields obtained, there would be better use of resources and more food available to help keep, and support, people in the villages.

## TRACTOR SPRAYING

### THE BATTLESHIP

So far, all our development has been aimed on helping the poorer nations but, at long last, the farmers in the U.K. are realising the benefits of C.D.A. in reducing the expenditure on pesticides and allowing them to treat the fields quicker and more timely. The problem has been to design a spinning cup to cope with both a range of droplet sizes and much higher throughput of spray liquid to accommodate faster travel over the ground. A new 12cm. diameter grooved toothed cup has been under development. The performance of it requires further study, but initial studies indicate that it eliminates the problem of stacking discs as used at the W.R.O. (Taylor, Merrett and Drinkwater, 1976). The aim is to provide a nozzle which can be fitted easily to existing booms, with a little modification, although ultimately there will be a need to design a self-propelled light weight sprayer.

### AERIAL ATOMISER

This unit, based on the MINI ULVA disc, I described in my recent paper (Bals, 1977) This incorporates a stack of 15 discs rotating around a stationary shaft and fed from this shaft. It was designed for situations where a large cloud of droplets are required, e.g. helicopter spraying, tsetse control, urban fly control, etc. The atomiser is externally driven and can be used with electric or hydraulic motors or by a windmill in the case of fixed wing aircraft. By changing the pulley size on the driving unit, droplets in any range from 25-30 μm to 60-70 μm can be produced. Care must, however, be taken to use the right feed rate for each rotational speed. Thus, with 25-30 μm droplets approximately 150 ml./min. and with 60-70 μm droplets approximately 800 ml./min. it should be borne in mind that with these quoted feed rates and droplet sizes, twice as many droplets are available for deposition with the smaller feed.

### CONCLUSION

This is a brief outline of our range of atomisers and sprayers. They all have one thing in common, a very narrow droplet spectrum of the appropriate dimensions to get desired results on specific targets. Without an extremely narrow droplet spectrum it is impossible to achieve efficient pest control, be it on weeds, fungi or insects with the low dosage which now an increasing number of progressive farmers are using. Excellent results have been achieved, in many different crop situations, with between 5 and 25% of the recommended dosage rate of active ingredient diluted with the appropriate amount of carrier liquid for the specific droplet size. All the recommended dosage rates, at present on the product labels, give the dose necessary to achieve control with irregular droplet sizes. These dosage rates are understandable if a spray pattern is used which, to be conservative, can have a spectrum ranging from 50 μm at one end of the scale to 500 μm at the other, i.e. a dosage variation of 1:1000. If a droplet of 50 μm contains enough chemical to kill an insect, the 500 μm droplet is wasting 999 units of chemical thus leaving residue and environmental contamination.

We, for our part, have moved a long way forward from the original concept of the spray nozzle. Surely the time has now come for formulation and dosage rates of chemical to be adjusted to these current techniques?

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# DEVELOPMENT OF THE MICRODROP CDA SPRAYER

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Summary A description is given of the development of the Microdrop applicator for applying 20 l/ha with 250-300 µm drops and the potential use for such a machine in U.K. agriculture is discussed.

## INTRODUCTION

Since the early 1970's the performance of spinning discs has been studied in workshop and laboratory, in particular with the Herbi disc to determine optimum flow rates and distribution patterns. The first practical field equipment was built in the winter of 1974.

## HISTORY OF DEVELOPMENT

For 1975 testing a spray rig of spinning disc units was built and mounted on a 'boom' attached to the rear of a Land Rover. Each unit consisted of two, 8 cm diam discs mounted on a common vertical spindle, the whole being partially enclosed in a cylindrical sheet metal casing designed to control the distribution of emitted spray (Farmery et al 1976). With the spindle rotating at 1800 rev/min (driven by individual electric motors) chemical was fed at 80 mls/min on to the upper disc, non-emitted spray being deflected by the casing on to the lower disc, each unit giving a 1.25 m diameter ring pattern of drops within the range 200-250 um. Ten such units were mounted on the Land Rover so that their spray patterns doubly overlapped giving a total spray swath of approximately 5 m. For practical considerations it was decided to evaluate a volume rate of 15 l/ha achieved by a forward speed of 4 km/h. This machine was tested locally and was made available for trials by a number of agrochemical companies throughout the U.K.

For the 1976 season the disc units were modified to include a second masked disc making a total of three discs. Flow rate was increased to 160 mls/min, 80 mls/min being fed separately to the two upper discs. Non-emitted spray from these discs was transferred to the lower disc a similar masking principle being adapted as in 1975. Individual electric motors were again used to drive the discs at 1800 r.p.m. Drop size range remained unchanged. The increased flow rate enabled 20 l/ha to be achieved at a tractor speed of 8 km/h. Again this machine was made available for widespread testing by agrochemical companies.

By 1977 season a tractor mounted machine - the prototype Microdrop Sprayer was built. This machine fitted with hydraulically operated booms that covered a spray swath of 10 m was a much more practical proposition than the earlier Land Rover mounted models. The individual battery operated electric motors were replaced by more reliable belt drive from the tractor hydraulic system. The discs were modified and the split feed of the 1976 model was replaced by single feed to the upper disc only. Holes punctured in this disc allowed chemical to be equally distributed between the two upper discs. The role of the bottom disc remained unchanged and the customary masking system for the two upper discs was retained. Flow rate was increased to 170 mls/min, disc rotation speed remained at 1800 r.p.m; drop size was found to be within the range 250-300 µm.

The three-section boom carried four units on the central section and six on each of the wing sections. The units were arranged to give double overlap of pattern and a spray swath of 10 m. Chemical was fed from the 225 litre tank via four hydraulic pumps, one per boom section, the fourth for recirculation. Each boom section was provided with a transparent flow meter used to calibrate flow rate to 170 mls/min using measuring cylinder and stopwatch. The feed onto each unit was then checked against this reading and finally the total output for each boom section was checked to ensure that it was either four or six times that of a single unit. This procedure is necessary only at the initial setting up of the machine.

Rotary speed of the discs was first set by the tractor tachometer and then checked by strobe light. Forward speed was calibrated over a given distance. A volume rate of 20 l/ha was predominantly evaluated. This was achieved at a forward speed of 8 km/h. On smaller scale 40 l/ha was achieved by halving forward speed.

The design for the 1978 production model involves a three point linkage tractor mounted assembly with hydraulically operated boom and height control. Hydraulic boom movements and output of chemical are all controlled from an electrically operated console fitted in the tractor cab. The tank is of 500 l capacity which at 20 l/ha enables 25 ha to be treated for each fitting. The sixteen disc units are fed in three sections using individual pumps. All surplus is returned to supplement the separate agitation pump. The motive power for the discs is provided by a hydraulic motor with fully compensated control to maintain uniform speed. Final drive is by flexible cables and chemical resistant belts and pulleys. Disc units are arranged to give double overlap as in 1977 (the pattern from each unit overlap 50% of that from neighbouring units) thus eliminating pattern joining problems. Each unit containing three discs (six may be fitted if higher volume rate than 20 l/ha prove to be necessary) incorporate a mask to rectify pattern discrepancies as in earlier models. Flow is regulated by specially designed flow controllers and indicated by flow meters. A flow rate of 170 mls/min, disc rotation speed of 1800 r.p.m. lead to a drop size range of 250-300 µm. A volume of 20 l/ha is achieved at a forward speed of 8 km/h (5 m.p.h.).

A limited number of these machines will be commercially available in 1978.

## RESULTS

A wide range of herbicidal products has been evaluated since 1975 throughout the various stages of development of the Microdrop Sprayer (Taylor 1975, Farmery et al 1976, Lush and Palmer 1976, Cook 1976, 1977, McLeod 1976, 1977, Joyce 1976, 1977, Mayes and Blanchard 1978). Herbicides achieving an acceptable standard of weed control were standard production material formulated as water soluble salts, emulsifiable concentrates, flowables and in a number of cases, dispersible powders. Substituted phenoxy aliphatic acid herbicides predominated but also tested were, for example, products containing 3,6-dichloropicolinic acid, 3,6-dichloro-2-methoxy benzoic acid, difenzoquat, 3, amino-1,2,4-triazole and glyphosate. Work conducted on fungicides by independent collaborators has been encouraging with translocated materials.

A number of applications has been made by agrochemical companies for the commercial clearance under the Pesticides Safety Precautions Scheme of many of the above herbicides for 1978 to be applied at 20 l/ha with a drop range of 250-300 um. As more products are evaluated and found to give biologically acceptable results, the number of applications for PSPS clearance and approval under the Agricultural Chemicals Approval Scheme is expected to increase.

## DISCUSSION

The availability to British agriculture of the means of applying herbicides with a drop size range of 250-300 µm means the virtual elimination of drift with all the problems that this brings to the farmer. It will lead to a dramatic increase in the number of days suitable for spraying. It will also remove the problems associated with adjacent sugar beet fields and cottage gardens. Another valuable feature of the Microdrop Sprayer is the fact that the volume of spray applied is reduced to 1/10 of that used in conventional hydraulic pressure spraying.

Several workers have pointed out, the most recent being at this Symposium (Gunn 1978), that CDA is not restricted to any specific drop size range and therefore a CDA machine is not automatically one that is designed to avoid spray drift. We are also reminded (Gunn 1978) that CDA is not exclusively associated with volumes of application of 20 l/ha and lower. It may therefore be wise always to qualify the abbreviation CDA that has been used perhaps too specifically in recent years and to refer to the Microdrop Sprayer as a CDA type machine capable of applying volumes as low as 20 l/ha at a drop size range of 250-300 µm thus virtually eliminating drift and inhalation risk.

Looking into the future one can anticipate the development of self-propelled Microdrop Sprayers involving closed system transfer equipment. Possibly the introduction of a pulse free solvent proof, simple, trouble free calibration system should come first. Certainly the ability to vary drop size and volume of application will be required as the range of chemicals used is extended.

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