MAIN SUBJECT 3

FACTORS AFFECTING THE PERFORMANCE OF PESTICIDES IN PRACTICE

TOPIC 3A

APPLICATION METHODS

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METHODS OF DROPLET PRODUCTION IN RELATION TO PESTICIDE DEPOSITION AND BIOLOGICAL EFFICACY IN CEREALS AND TREE CROPS

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ABSTRACT

Pesticidal sprays are applied to plants to produce a desired biological result. Applications are effective if this result is achieved and economic if yield benefits are greater than input costs. Most conventional spray applications while effective are rarely efficient because much of the pesticide is not deposited on the target. Off target deposition is wasteful and environmentally dangerous and must be minimised. Volumes of spray liquid atomised and the drop spectra and drop momenta produced by different techniques are important factors determining the effectiveness and efficiency of spraying. These subjects are discussed with regard to the theory and practice of spraying cereals and top fruit. Unfortunately some apparently efficient application systems are biologically ineffective. Interpretation of how or why biological results are or are not achieved in practice is severely hampered by a lack of valid basic scientific data. At Long Ashton Research Station we are attempting to measure where and to what extent different types of spray are deposited in cereals and top fruit, and to correlate these measurements with the efficacy of pesticides.

INTRODUCTION

Few who have relevant experience would disagree that spraying under practical conditions is a most inefficient way of applying pesticides (Matthews, 1981a). While most sprays applied to crops by traditional techniques and according to the pesticide manufacturer's recommendations, produce a satisfactory biological result, a large proportion of the pesticide is not deposited on the target of whatever nature and is wasted (Graham Bryce, 1977). Spraying is thus effective but inefficient. The Seventh Report of the U.K. Royal Commission on Environmental Pollution (Anon, 1979), accepted that the continued use of pesticides is essential to maintain food supplies but was concerned about the scale of their use, and called for a reduction of off-target contamination. Increased precision in spraying has long been the goal of both researchers and practical users but it is a sad fact that rarely has the substitution of a novel spraying technique in place of traditional methods produced an improved biological response from a given dose of pesticide. Even more rarely has it been possible to increase the effectiveness of reduced pesticide doses.

The controlled droplet application technique (CDA) is now well established as an efficient system for eliminating very wasteful large spray droplets which contain excessive doses of pesticide, and for reducing the number of small driftable droplets; both of these types of droplets are produced by hydraulic pressure nozzles. The CDA technique is attractive from both theoretical and logistic points of view, since reduced volumes of liquid are efficiently atomised. However, as pointed out at the BCPC Conference on Weeds here last year (Nation, 1982) it is common to see the CDA techniques described as 'commerically acceptable' in effectiveness rather than superior to conventional systems when used to control weeds or diseases. Control of insect pests seems to be the exception (Scopes, 1981) to these comments since CDA techniques have at times improved efficiency. Simple, cheap CDA devices have thus found a ready market for insecticide spraying particularly in developing countries (Matthews, 1981b)

As Fulton (1965) pointed out, spray research is hampered by a lack of fundamental information about where and in what form sprays are deposited and how these factors and others such as the mode of action of pesticides and their interaction with plants and pests, combine to produce a particular degree of biological action. Attempts have been and are continuing to be made to examine factors affecting the efficacy of sprays (Frick, 1970; Hislop & Baines, 1980; Scopes, 1981; Munthali & Scopes, 1982; Merritt, 1982 a,b; Herrington, in press) but translation of these data to practical situations is exceedingly difficult. At Long Ashton Research Station we are attempting to improve the precision of top fruit and cereal spraying by trying to measure how a result is or is not achieved. This work is facilitated by the use of modern laser spray droplet measuring equipment (Malvern 2200) and an image analyser (Optomax) for measurement of the number, size and areas covered by spray droplets on targets. Deposits and residues are measured chemically, and initial deposits on plants are also frequently quantified by fluoresence spectrophotometry (Sharp, 1974) after extraction in a suitable solvent. Our work has been aided by collaboration with the Plant Protection Division of ICI who have made a variety of electrodynamic (Coffee, 1979) spraying devices ('Electrodyn'*) and fungicide formulations specific for the method available to us, and with colleagues of the National Institute of Agricultural Engineering.

MATERIALS METHODS AND RESULTS

Top fruit spraying

Dessert apples are a high value crop afflicted by a wide variety of pest and diseases requiring control by frequent spraying. Traditionally trees were sprayed with large volumes of liquid (c. 2 000 - 3 000 l ha^{-1}) using high pressure sprays atomised through a variety of hydraulic nozzles. Now trees are usually sprayed with smaller volumes of similarly atomised liquid (c. 300 - 1 000 l ha^{-1}) with the droplets carried to the tree in air streams. Morgan (1981) reviewed the need to improve the efficiency of orchard spraying, pointing out that when medium-sized trees (4.5 m high) were sprayed with c. 500 l ha^{-1} (MV), distribution within the tree was uneven and that some leaf surfaces were completely unsprayed (Morgan, 1972). Furthermore, less than one third of the total volume of spray applied was retained in the tree (Herrington et al. 1981), but the pest and disease control was usually very good. Attempts to improve the efficiency of apple tree spraying by substituting the hydraulic nozzles of a commercial mist-blower with proprietary rotary disc atomisers applying as little as 45 l ha^{-1} of spray liquid started in 1974. Results (Cooke et al. 1976, 1977) indicated that orchard pests and often apple scab (*Venturia inaequalis*) were well controlled by the ultra low volume (ULV) sprays and potential savings of insecticides could be considerable. However, control of apple powdery mildew (*Podosphaera leucotricha*) which is a major disease of the commercially important U.K. cultivar Cox's Orange Pippin was either only 'commercially acceptable' or frequently inferior to that achieved by conventional spray volumes (c. 500 l ha^{-1}).

Much effort has been devoted to apple mildew control by the ULV/CDA methods but to date with mixed success. A variety of rotary atomisers capable of producing 60 to 100 µm droplets from c. 50 l ha^{-1} at commercial spraying speeds were examined and some found wanting (Herrington & Western, 1982). Drop spectra were relatively poorly controlled and some units with stacks of discs were mechanically unsatisfactory, particularly for commercial use. Analysis of initial spray deposits on the young leaves of extension shoots which are most susceptible to infection indicated that although mean deposits were often similar to those achieved by medium-volume hydraulic nozzle sprays, variability about the mean was greater.

In 1980 the U.K. Agricultural Development Advisory Service undertook a detailed long term examination of ULV top fruit spraying at Luddington Experimental Horticultural Station, Warwickshire. A Drake & Fletcher 'Commandair' air-blast sprayer adapted to spray conventionally or with rotary stacked disc atomisers was used to apply a full programme of insecticides and fungicides. Machinery performance and pests and diseases were routinely monitored, and fungicide deposits on young flush leaves measured. The full details of this experiment, which is still running, have not been published. Mildew control in 1981 was poor with the ULV treatment. In 1982 low volume Spraying Systems TX3 hydraulic cone nozzles were substituted for the rotary atomisers. These nozzles produce a wide spectrum of spray droplets (Cooke et al. 1982) but were found to be more reliable than the rotary atomisers. Mean deposits recorded on the flush leaves sprayed conventionally were approximately 80% smaller than those applied by the low volume TX3 nozzles. However, the standard dose of fungicide sprayed in 500 l ha^{-1} gave good mildew control (2% infection) while a quarter dose applied similarly permitted c. 10% infection. Standard dose of fungicide applied in 55 l ha^{-1} also permitted c. 10% infection but c. 30% mildew was recorded on trees sprayed by the ULV technique with a quarter dose of fungicide (Morgan et al. in press). The reason why ULV spraying was so ineffective is not known but might be related to the small cover recorded on water-sensitive paper attached to susceptible leaves (0.4% compared to 3% for MV sprays) and the variability of the deposits (SE of mean for ULV ± 10% compared with ± 4% for MV).

A hand-held 'Electrodyn' sprayer was first used at Long Ashton Research Station to apply bupirimate to apple trees in 1980. Four sprays containing 0.25 g bupirimate in either 4 ml of oil or 500 ml of water per tree applied at 14 day intervals resulted in 21.6. and 38.4% (significantly different at 5% level) secondary mildew in August compared with 83% in unsprayed trees. The electrodynamic spray was deposited only on the perimeter of the trees but this encouraging result prompted us to examine a simple hand-held air-assisted system in 1981 (Hislop et al. in press). A single 'Electrodyn' nozzle was compared with an air-shear nozzle each similarly supplied with secondary air using the same oil-based ED formulation of bupirimate. Dose for dose, deposits from the charged spray were at least twice those from the uncharged, and they penetrated right into the tree, but biological efficacy could not be measured because of lack of mildew. In 1982 we fitted four 'Electrodyn' nozzles to one side of a tractor-mounted KEF mist-blower. The other side of the mist-blower was fitted with two air-driven Micronair AU 5000 rotary cage atomisers. The sprayer was used to apply 1.75 l of oil-based bupirimate through the 'Electrodyn' nozzles at either full (175 g ha^{-1} a.i.) or a one-quarter dose. Each 'Electrodyn' nozzle was fed at 0.1 ml sec^{-1} and operated at 22 KV to give droplets of c. 80 µm volume median diameter (VMD). For comparison the rotary cage units were used to apply the same full dose of bupirimate in either 50 or 500 l ha^{-1} of water. Mildew infection was moderate (35% in August) and all ULV treatments (1.75 or 50 l ha^{-1}) except the quarter-dose 'Electrodyn' sprays gave adequate control (c. 10% infection), although again the 500 l ha^{-1} conventional application permitted only 4% infection (Morgan et al. in press). Assessment of spray deposits indicated that the Electrodyn nozzles did not function efficiently in this system because ligament formation at the nozzle tip was disrupted by air shearing. An alternative nozzle was substituted towards the end of the season and droplet production and deposition was much improved, but the biological effect of this has yet to be measured.

The rotary cage atomisers designed for aerial applications (Micronair AU 5000) seem to be a reasonable alternative to previously examined spinning discs and have the advantages of being very well engineered and capable of handling a very wide range of through-puts. Droplet spectra are narrower than with hydraulic nozzles but wider than those produced by spinning disc atomisers functioning optimally. For example with the AU 5000 atomiser at 5 500 rpm we recorded VMDs and NMDs (numerical median diameters) of 76 µm and 14 µm at a flow of 670 ml min^{-1} per head and 103 µm and 21 µm at 4 400 ml min^{-1} (Western - private communication). In 1983 we are again comparing the latest 'Electrodyn' nozzles and Micronair AU 7000 units fitted to a mist-blower and also examining larger hydraulically driven AU 3000 units. The latter have the potential advantage that they can be positioned relative to tree such that convergent and turbulent air movement might be obtained within them.

Cereal spraying

Work on cereal spraying was only started seriously by us in 1980 when we compared deposition of spray from a single hand-held 'Electrodyn' nozzle with that from conventional hydraulic nozzles. Early results (Hislop et al. 1982) indicated that an application volume of 1.5 l ha^{-1} with the 'Electrodyn' and 225 l ha^{-1} with an Oxford Precision sprayer (F110 - 150 nozzles, 225 KPa pressure) resulted in deposition efficiences of 47 and 7% respectively in winter barley crop at GSZ 13-22. However, it was found that most of charged spray deposits were on the vertical leaves which were the nearest earthed target, while the reverse was true for the hydraulic spray. Further the coefficients of variation for the mean deposits were very much smaller for uncharged compared with charged sprays. Experiments in 1981 confirmed the generally poor penetration of charged compared with uncharged sprays and indicated that to some extent this effect could be modified by reducing the charge-to-mass ratio of the spray from approximately 7.0 at flow rates of 0.05 ml sec^{-1} at 25 kV to about 1.0 at 0.3 ml sec^{-1} and 17 kV (Cooke & Hislop, in press). However, these changes increased drop sizes from c. 50 µm VMD to c. 150 µm VMD with a consequent large reduction in drop numbers. Since the 'Electrodyn' is a ULV device it was felt that this could be an unacceptable price to pay for improved penetration. Thus in 1982 we built and examined a tractor-mounted boom fitted with 'Electrodyn' and spinning disc atomisers with added provision for air-assistance. Details of this equipment and results obtained with it have been fully documented (Hislop et al. 1983). Briefly, the penetration of charged 'Electrodyn' sprays and uncharged spinning disc sprays in cereal crops were improved by air assistance and this improvement was correlated with improved control of *Rhynchosporium secalis*. Also included in these trials was an hydaulic electrostatic sprayer designed and built at the National Institute of Agricultural Engineering (Marchant & Green, 1982). This device was used to apply charged and uncharged aqueous sprays at 66 l ha^{-1} through standard 800067 nozzles at 300 KPa pressure. Although we were unable to confirm either physical or biological advantages from charging it was notable that this sprayer and the standard hydraulic sprayer (250 l ha^{-1}

from F110 - 150 nozzles at 250 KPa) produced some of the best biological results. This result, and our failure to experiment successfully with the spinning disc device in small plots prompted us to design a new large-scale experiment on a commercial farm in 1983. Here we are examining deposition, and hopefully biological efficacy, of a 12 m boom fitted with standard hydraulic nozzles (F110 - 200 at 300 KPa or 110015LP at 100 KPa) applying either 175 or 84 l ha^{-1} and with six hydraulically driven rotary cage atomisers (AU 5000) applying 40 or 90 l ha^{-1} (prototype Ransomes 700 sprayer). Also included in the trial is a 12 m boom fitted with Micromax rotary cup atomisers which is being used to apply between 10 and 40 l ha^{-1}. A full programme of herbicides and fungicides is being applied to winter barley and wheat crops and to a spring barley crop. Results so far indicate that the maximum and minimum proportions of the applied spray retained by the winter wheat crops at GS 30 were only 30% (for rotary cage at 40 l/h) and 18% (for the half volume conventional spray) with no clear superiority of one method over another. It is too early to comment on crop penetration by the sprays but it is perhaps pertinent to record that of the total volumes sprayed less than 1% was actually recovered from the weeds present. The advantages or disadvantages of air-assistance provided by fans fitted to the rotary cage units are not yet clear. We detect a conflict, however, between the advantages of a down draft of air which at the present spacing of the units causes striping, and a more horizontal arrangement of the atomisers which gave more even distribution across the swath but also increased drift.

Simultaneously with the above large-scale trials we are also examining the performance of an ICI designed and built tractor-mounted air-assisted 'Electrodyn' sprayer. Preliminary results again show improved penetration of charged air-assisted sprays compared with those not blown into the crop. However, once again total crop capture of charged sprays was at best 38% while the conventional spray system deposited 26 to 30% of that applied at GS 32. Evenness of distribution of the sprays from top to base of the 'Electrodyn' sprayed (1 - 2 l ha^{-1}) cereal plants was inferior to that from standard hydraulic nozzle (11002LP & 8001LP) sprays at either 220 or 110 l ha^{-1}. The biological significance of these observations remains to be measured.

DISCUSSION

This paper records some limited practical experience in spraying top fruit and cereals. The results confirm the inefficiency but effectiveness of traditional spraying systems. More novel spraying systems have occasionally been less wasteful in that a greater proportion of the spray has been deposited on the crops, and they could be more convenient, but in our experience few fungicide or herbicide applications have proved to be more effective in biological terms. Novel spraying systems are exciting from a research point of view, but full assessment of them is time consuming and is hampered by a lack of fundamental information about traditional systems (Hislop, 1983).

To an extent fruit and cereal growers are ahead of research workers in that some have already adopted the practices of controlled drop-reduced volume spraying. Again, however, evaluation of their experience is difficult because of a lack of valid comparative data with alternative systems. Low or ULV spraying of fruit has been claimed to be successful (Gunn, 1980) but the practice is often combined with a rational management approach in which pesticide doses, spray volumes and spray frequency are altered from orchard to orchard and from year to year depending on infection levels. Further, whilst not documented it seems very probable that some growers, in the interest of economy, are accepting less efficient control than was normal when traditional spraying systems were in use. This may be eminently sensible in some situations but it is a fact that in the last two years many growers using ULV spraying have had to revert to higher volumes because of failure to control apple scab disease.

Another complicating factor in assessing the efficacy of ULV spraying is the severity of the pest or disease being tackled. Good management keeps disease levels as low as possible and our own work (Cooke et al. 1982) has shown that the generally less effective ULV spraying systems will cope satisfactorily when the inoculum pressure is slight, but fail when it is more severe. A similar problem arises in the assessment of CDA spraying systems for cereals because they tend to be used for 'insurance' spraying and it is not surprising therefore to hear of claims for efficacy at reduced pesticide doses and spray volumes. The desirability of reducing pesticide doses is obvious, but whether this should be achieved by the practice of routine insurance spraying is highly doubtful. Insurance spraying can involve unnecessary sprays, exacerbate problems of pest and disease resistance to pesticides, and limit the effectiveness of natural control systems.

The theoretical and practical advantages of electrically charging sprays are well documented e.g. Marchant, 1980. Unfortunately, improved drop capture seems hard to separate from reduced penetration (Marchant, 1980; Griffiths et al. 1981; Morton, 1982; Hislop et al. 1983). It is inelegant to have to fit a secondary air supply system to a boom designed for ULV spraying. However, Parham (1982) reported good weed control from electrodynamic sprays not assisted by air currents and Lake et al. 1982 have shown that down draughts produced by an aerofoil on a spray boom could constitute an alternative system to improve penetration if this is proved to be necessary. It is too early to know whether or not it will be necessary to improve penetration of charged sprays in arable crops. However, it is sensible to examine air-assisted electrostatic spraying in fruit crops where mist blowing is an established technique. The 'Electrodyn' might not be the ideal nozzle for this purpose because its throughput is very limited. The rotary cup electrostatic sprayer (Arnold & Pye, 1981) atomises larger spray volumes, while the range of throughput can be varied with an experimental electrostatic rotary cage. Further, the rotary electrostatic sprayers unlike the 'Electrodyn' are not limited to spraying oil-based pesticides.

The logistic advantages of lower volume spraying are clear but enthusiasm for novelty should not mask recognition of the fact that spray volumes can be decreased to advantage with conventional systems; the limit to which this is true needs further study. Low-pressure, low-throughput hydraulic nozzles reduce the percentage of driftable droplets compared with their high pressure cousins (Western, in press). If hydraulic nozzles are selected with care, properly maintained and regulated and fitted to efficient spraying systems - including very much more stable booms (Nation, 1980), then these cheap and reliable atomisers can be used more precisely. Interestingly Allen et al. (1978) demonstrated a small improvement in apple mildew control when they reduced spray drop size from 180 μm to 120 μm (mass median diameters) using hydraulic nozzles. However, the significance of this effect is difficult to interpret because the nozzles produced a very wide range of drop sizes and the spray volumes used were near conventional (270 to 500 $l\ ha^{-1}$).

The last fifty years have seen a dramatic increase in the potency of crop protection chemicals, but our ability to apply them efficiently has altered very little. We must ensure that the evolution of methods for using pesticides keeps pace with improvements in activity (Graham-Bryce, 1981).

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/ **3A—S2**

NEW TECHNIQUES AND EQUIPMENT FOR GROUND APPLICATION OF HERBICIDES IN THE USA

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ABSTRACT

Economic, environmental and energy concerns have caused a renewed interest in developing improved equipment and techniques for applying herbicides. Low volume applications from ground sprayers are now feasible with the introduction of practical controlled droplet atomizers and the development of electrostatic sprayers. Vegetable oil as a carrier in place of water has potential for improving the efficiency of herbicide application. The use of electronic sensors, monitors, and control systems has been readily accepted by growers and custom applicators to assure more precise and less costly herbicide application. The development of effective nonselective herbicides has revived the interest in selective application such as directed nozzles, recirculating sprayers and ropewick applicators. Spraying systems of the future will become more precise, placing more of the chemical on the desired target with less drift.

INTRODUCTION

It is estimated that the cost of weeds to U.S. agriculture is more than $18 billion annually (Sanders 1981). The use of herbicides for crop production has increased 280 percent since 1966 and accounts for nearly 60 percent of all pesticides used on U.S. farms (Eichers 1978). Nearly all the 155 million hectares of major U.S. crops receive at least one herbicide treatment for weed control. The high cost of herbicides along with a growing public concern for pesticide hazards to the environment has resulted in a renewed interest in improving the equipment and techniques for applying herbicides.

Increased energy costs have also had an effect on herbicide application. Because of heightened concerns for energy and soil conservation, growers are attempting to reduce secondary tillage operations while maintaining satisfactory incorporation of soil-applied pre-em herbicides. Energy savings are also a major reason for the high interest in applying herbicides at much lower volumes per hectare and for using fertilizer-herbicide mixes in either liquid or granular form.

A new era of highly selective and efficacious herbicides requires increased precision in placement and in control of off-target deposits. Many of these new expensive formulations are toxic to target weeds at very low rates. The development of application equipment has not kept pace with the development and knowledge of pesticides. Pesticide manufacturers indicate that application precision is the factor limiting the effectiveness of many herbicides. Thus, for economic, environmental, and biological reasons, it is increasingly important to optimize the performance of application equipment and to develop new techniques that allow more precise application.

Several new developments in equipment and techniques can be identified that allow more efficient and precise application of herbicides (Butler and Bode 1980, Bode 1981). Let us review some of the recent developments in more detail.

REDUCED APPLICATION VOLUMES

The application of herbicides using ground sprayers is typically about 200 l/ha, although volumes may range from 75 l/ha for some soil applied herbicides to 450 l/ha for contact herbicides used with no-till farming. A major factor limiting the reduction of spray volumes has been that the nozzles required for low volume applications have very small orifices that are easily clogged. Another reason for maintaining larger application volumes is to produce a spectrum of larger droplets that are more likely to reach the target and less likely to drift out of the field. The development of practical controlled droplet atomizers and electrostatic sprayers has created a renewed interest in reducing the amount of carrier required for applying herbicides.

Controlled droplet atomizers (CDA)

The solution to applying low volumes with ground sprayers has always been known to be a nozzle or spray atomizer that produced uniform drop sizes. The premise for herbicides is that eliminating droplets smaller than 150 µm will reduce off-target drift and eliminating droplets larger than 300 µm will allow good coverage with low application volumes. For example, a spray containing only 200 µm drops applied at 10 l/ha would result in a coverage of 24 drops per cm^2 of soil surface. To obtain equivalent coverage using hydraulic nozzles would require applying many more liters per hectare.

There have been many uniform droplet generators developed and tested (Bouse et al 1974). Those utilizing a controlled frequency pulse either at or above a small hole produce a fairly uniform droplet but do not do so in sufficient numbers and are subject to frequent clogging. Rotary atomizers of the spinning disk or cup type also produce a fairly narrow droplet spectrum if speed and flow rate is controlled properly. The constraint of low flow rates in order to produce uniform drops has been overcome with the use of a large cone shaped cup having deep grooves ending in a needle point (Heijne 1978). Application of herbicides with tractor-mounted units without resorting to complicated multiple disk units is now practical.

Development of the Micromax rotary atomizer for low volume application of pesticides has led to the concept of controlled droplet application (Bals 1975). Since the Micromax was introduced in the U.S. in 1980, many farmers are applying herbicides in spray volumes less than 25 l/ha. The units now available with direct-drive electric or hydraulic motors have eliminated many of the field problems that occurred with the early models. Grower experience and research results on all major crops indicate that when the Micromax is used properly under the right conditions good weed control can be obtained. Spacings of 100 to 120 cm result in much better spray patterns than the wider 200 to 220 cm spacings (Bode and Butler 1983). Cup speeds of 2000 rpm are generally used to apply pre-em herbicides while speeds of 3500 rpm are used to apply post-em herbicides. Displacement of the spray solution out of the swath and lack of droplet penetration into foliar canopies are sometimes reported to limit the effectiveness of weed control from low volume applications with the Micromax. Reports of spray drift generally compare favorably with conventional applications using hydraulic nozzles (Grover et al 1980, Bode and Butler 1983, Erickson and Duke 1981).

Prototype rotary atomizers developed by Spraying Systems Company are presently being evaluated by several researchers in the U.S. The units have a grooved flat disk that is electric motor driven with solid state speed control. Research results are not yet available but preliminary results indicate that the units have characteristics similar to the Micromax.

Electrostatic sprayers

Electrostatic charging of herbicide particles by a high voltage is an effective means of transporting small particles and impacting them on the target (Law 1978). Prototypes of electrostatic sprayers based on Dr. Edward Law's patent have shown excellent insect control when one-half the recommended insecticide rate is applied at low spray volumes (Law 1978, 1979). This design typically uses an air atomizing nozzle where the air blast drives the spray particles through an electrostatic induction charging ring that operates at about 1500 volts D.C. Force of the air drives the charged spray particles down into the plant canopy where the particle movement is controlled by the charge on the particles. Concentrated low volume water based pesticide mixes are typically used with this unit. These nozzles require considerable energy to supply air to each nozzle. We are presently evaluating the efficiency of electrostatic units for obtaining broadcast weed control with foliar herbicides.

An electrostatic nozzle described by Coffee (1979, 1981) uses high voltages of 15-30 kV to atomize liquids having specific conductivity properties. The power requirement for the electrodynamic nozzles is very small and spray volumes of less than 1 l/ha can be applied to field crops. Extensive field tests are presently being conducted in the U.S. on a tractor-mounted electrostatic atomizer unit, the Electrodyn. Published field results of weed control are not readily available but preliminary reports indicate a significant increase in spray deposition on plant leaves. Penetration of the charged drops into a plant canopy may be improved by utilizing an air transport system. The units use only oil-based ready-to-use sprays supplied in sealed containers by the manufacturer.

Vegetable oil carriers

The use of vegetable oils as an additive or complete carrier has gained considerable interest during the past two years. This interest is primarily due to: (1) the cost of vegetable oils becoming competitive with petroleum oils; (2) the high cost in time and money of applying conventional volumes of water; (3) the development of equipment for low volume application such as the rotary nozzles and electrostatic units; and (4) the development of new pesticides such as synthetic pyrethroid insecticides and post-em herbicides.

Available research results indicate that vegetable oil can be substituted for petroleum-based crop oil concentrate additives with equal weed control in most cases. Studies by pesticide manufacturers indicate that weed control increases with the addition of a surfactant to the vegetable oil. Vegetable oils, as additives, are generally considered most important in enhancing weed control with low humidity and high temperature environments. Thus, oil additives generally provide protection against a loss of weed control with a herbicide under adverse environmental conditions.

In addition to using vegetable oils as an additive, vegetable oil alone can be used as the complete carrier. The development of equipment for low volume application has made it feasible to use vegetable oil as carriers at up to 15 liters total volume per hectare. The use of vegetable oil as a carrier in place of water has potential for improving the efficiency of low volume applications because the drops are relatively non-evaporative and should drift less than water and may allow more uniform coverage and canopy penetration. In addition, herbicide-oil mixtures may be less subject to rainwash-off from plant surfaces and an increased spread factor may increase the rate of absorption into the plant.

Most of the research to verify the claimed advantages of vegetable oils has been with aerial application of synthetic pyrethoid insecticides. Work with low volume ground applications of herbicides is in the early stages. Initial studies with pre-em and post-em herbicides indicate that soybean oil carriers can be very effective. Changing physical properties of herbicide-vegetable oil mixtures make it difficult to develop techniques for applying herbicides in vegetable oil carriers. In addition to rotary nozzles, experimental low volume air assist nozzles show promise of maintaining good atomization characteristics over a range of oil properties.

DRIFT CONTROL

Spray drift and target coverage depend largely on the range of droplet sizes produced by the atomizer. Small drops can provide excellent coverage on the intended target but are highly susceptible to drift. Large drops are not as susceptible to drift but may result in inadequate spray coverage unless application volumes are increased to unrealistic levels. All commercially available agricultural spray nozzles produce sprays with a wide range of drop sizes. For each type of application, selecting a nozzle involves a compromise between obtaining adequate coverage and keeping drift potential within acceptable limits.

Spray nozzle manufacturers have been active in designing nozzles that reduce the number of unwanted small drops. Delavan Corporation is marketing two designs of Raindrop® nozzles that rely on a secondary swirl chamber to absorb some of the energy in the liquid after it emits from the primary chamber. The spray leaves the secondary chamber at a low velocity in a hollow-cone pattern made up of much larger drops than those emitted by standard nozzles (Tate 1977). The RA Raindrop nozzle is widely used on tandem disk and field cultivator spray kits to apply preplant incorporated herbicides. Operators of high-capacity flotation sprayers often use Raindrop nozzles when spray drift rather than plant coverage is a primary concern.

Spraying Systems Company has wide-angle full-cone nozzles that can be used with a premetering orifice to decrease nozzle exit pressure and increase spray droplet size. Spraying Systems also has developed the LP (low-pressure) flat-fan nozzle. The nozzle orifice is machined so that an LP tip at 100 kPa produces a flow rate, spray pattern, and fan angle quite similar to those of a regular flat-fan tip at 275 kPa. Consequently, an LP nozzle producing the same output as a regular flat-fan nozzle has a larger orifice, a lower sheet velocity, and a spectrum of considerably larger drops. Measurements have verified that drift is less for the LP and Raindrop nozzles than for conventional nozzles (Bode et al 1976, Bouse et al 1975).

Modification of such spray liquid properties as viscosity is another means of shifting the droplet size spectrum upward. The new polyvinyl thickening products are effective in lesser amounts and easier to use than some of the earlier products. These products, which are seeing limited use, not only increase spray viscosity but also have other viscoelastic properties that reduce the number of fine droplets produced. Tests indicate that Nalco-Trol, for example, is essentially Newtonian under shear, is less salt-sensitive than some of the earlier thickeners, and reduces the evaporation rate of droplets by about 30%. Field research indicates that drift deposits can be reduced by as much as 80% with Nalco-Trol concentrations of less than 0.05% (Bode et al 1976, Yates et al 1976). One must be careful, however, to check the spray patterns and make necessary changes in nozzle height or spacing.

SEPARATE INJECTION OF PESTICIDE AND SELECTIVE PLACEMENT

Work is again being conducted on developing a spraying system that injects undiluted pesticide directly into a conventional sprayer having only carrier solution in its main tank. Pesticides are metered at rates directly proportional to travel speed using adjustable displacement or variable speed metering pumps (Reichard et al 1982). Errors in application can result if the pesticide is injected into the carrier at the pump so there is a time lag in reaching the nozzle and if the pesticide is injected directly into the nozzle where improper mixing can occur. Handling of wettable powders is also a problem. Only one injection unit is commercially available, but several state universities and other commercial firms have systems in development. If the major problems can be overcome, injection sprayers have the potential for eliminating some of the environmental and human hazards of using pesticides. Operators do not have to handle the concentrated pesticides during mixing and loading, there are no surplus mixtures requiring disposal, and the supply tank does not have to be cleaned to prevent contamination.

Efficiency of application can also be improved by spraying only the target pest. Tests have shown that shutting off the spray between each plant reduces the pesticide amount up to 50% with no loss of pest control (Reichard and Ladd 1981). Some intermittent sprayers use mechanical feelers to trigger the spray. Others have photoelectric sensors for activating the system; when the light beam is interrupted by a plant, a solenoid valve opens and pesticide flows to the spray nozzles. Timers allow for various lengths of spray.

Many devices for selective application of pesticides have become available during the past few years, including directed nozzles, shielded nozzles, wax bars, recirculating sprayers, foam-rubber wipers, carpet rollers, and ropewick applicators. Interest in selective application has been revived and expanded by the development of the herbicide, glyphosate. The recirculating sprayer applies the chemical over the top of the crop, and the portion not intercepted by tall weeds is collected and reused. Depending on how many weeds are in the field, herbicide requirements are reduced 80% or more from what would be used for a broadcast application (McWhorter 1970).

Also available are applicators that use a hydraulic-driven, continuously turning roller covered with carpet and saturated with herbicide. An electronic device senses the amount of herbicide on the roller and activates spray nozzles to wet the roller when it becomes too dry.

The newest development for selective application that has gained wide acceptance is the ropewick applicator. The chemical is drawn from the reservoir into the rope by capillary or wick action, then wiped onto the target when the rope is placed in contact with the weeds. Much of the method's popularity lies in the fact the functional models can be easily constructed from inexpensive materials; several companies also manufacture the applicator. Work is continuing on devising new wick materials and configurations to improve contact with weeds (Dale 1980).

Researchers are looking for ways to obtain good coverage with spray mists while minimizing spray drift. Work is being done in North Dakota on an air-blast band sprayer that injects a pesticide mist under a shield over the crop in a stream of air; coverage and placement of the pesticide are good, with a minimum of drift. Canadian researchers are developing an air-cushion spray boom; pesticide is sprayed into an air-supported canvas shield that contains the spray until it deposits on the target surfaces.

ELECTRONIC MONITORS, SENSORS, AND AUTOMATIC CONTROL SYSTEMS

Advances in electronics are having an impact on pesticide application techniques. Agriculture is one of the leaders in adopting electronics and farmers and custom applicators have readily accepted the use of onboard sensors, monitors, and control systems to assure a more precise and less costly application.

Several companies make spray rate monitors. The systems have a meter to sense total flow to the spray boom, a transducer to sense travel speed, a control to dial in the effective width sprayed, and a panel that continuously displays the spray rate during operation. Some units have such additional features as displays of nozzle flow, travel speed, area covered, total volume sprayed, and amount of solution remaining in the tank. Early problems with flow meters have been solved by the manufacturers so most monitors are maintaining good reliability in the field. Spray rate monitors have the potential of eliminating many of the current errors in application accuracy.

Some manufacturers add a control system to their spray rate monitor. A microprocessor-controlled servovalve assembly automatically regulates the flow in proportion to travel speed to maintain a constant spray rate. Several control systems have such features as alarms, manual override and individual boom controls. A factor limiting the operating range of any such control system is the spray nozzle. With the present automatic calibration systems, nozzle pressure must change in proportion to the square of the travel speed. This is more variation than most nozzle types can utilize and still obtain quality atomization. Basic research is under way to develop nozzles that will maintain good atomization characteristics over a wide range of flow rates. Bypass nozzles that return unneeded spray solution to the supply tank are being considered for use with automatic control systems (Ahmad et al 1981).

Studies are also being conducted to develop sensors that continuously monitor soil organic matter content during field application of pesticides (Krishnan et al 1980). In the research studies, reflected light passes through optical interference filters into phototransistors, which transform the reflected light into an electrical signal proportional to soil organic matter content. In a field unit an on-board microprocessor would deliver the properly amplified signal to a stepping motor for automatic control of application rate. The concept needs a great deal more development before becoming commercially available.

Marking swaths is a major problem when applying herbicides, especially with high-speed sprayers that have wide booms. Overlaps and skips could be reduced with accurate swath-marking systems. Current research activities are aimed at utilizing such electronic advances as light sensing and radio-controlled guidance systems.

At least two types of monitors with sensors to indicate clogged or partially clogged nozzles are available. One uses a mechanical system to complete an electrical circuit through the spray sheet. In the other, a sonic sensor molded into the nozzle body activates an alarm buzzer when the nozzle becomes partially plugged. Other electronic innovations include radar speed detectors, automatic self-leveling booms, and electronic sensors for maintaining proper boom heights.

PESTICIDE APPLICATION WITH FERTILIZER

Much of the pre-em herbicide used in the U.S. is applied by custom applicators using flotation equipment. Farmers frequently have the custom applicator apply a liquid fertilizer-herbicide mixture thus saving on application costs. A recent trend is for some fertilizer dealers to impregnate pre-em herbicide onto dry fertilizer during the blending operation and then custom apply the fertilizer-herbicide mixture. There were some problems initially with both liquid and dry fertilizer-pesticide mix applications in that more precision was required than when applying fertilizer alone. Decreasing nozzle spacing to 1.5 m or less and maintaining double coverage or 100 percent overlap with liquid applications and the introduction of pneumatic distribution systems on dry applicators have been the greatest improvements that allow satisfactory applications of fertilizer-herbicide mixtures.

SUMMARY

We look for spraying systems of the future to be more precise, placing more of the material on the target with less drift. Farmers who apply their own sprays will be using less spray volume and some type of controlled drop size applicator. At the same time, more custom applicators will be applying fertilizer-pesticide mixtures in either dry or liquid form. The use of electronic sensors, on-board microprocessors, etc. will continue to increase. These and other developments will help the sprayer operator to improve application efficiency considerably in the next few years.

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RECENT TRENDS IN THE AERIAL APPLICATION OF PESTICIDES

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ABSTRACT

Recent developments have improved the safety, economics and accuracy of depositing material from aircraft by the introduction of new procedures and equipment. A better understanding of the effect of droplet size on biological effectiveness is leading to a reduction in the width of the spray spectra of atomisers and hence lower rates of application. Mathematical models and realistic trials are improving the understanding of spray drift and suggesting means of minimising any adverse effects. There is still a strong need for better aids for aircraft positioning and calibration.

There is a continuous need to improve the safety of the pilot and aircraft and to improve the economics and range of operations of agricultural aircraft whilst reducing the possibility of damaging the environment both within and outside the crop. Although these factors are inter-related it may be clearer if the recent trends are considered separately for each of these aspects.

Safety

Pilot distraction is the biggest problem in flight safety particularly when the aircraft is heavily loaded and has insufficient excess power for manoeuvres. Pilots may fly 5 to 20 sorties per hour at very low levels for up to 10 hours per day on several successive days. They are liable to chronic fatigue and it has been shown that in this state the risk of accidents is high and cannot be improved by a temporary effort, since basic skill impairment has occurred and rest is the only cure. A properly designed organisation to maximise safety is essential and Schmed 1979, has suggested that every organisation, no matter how small, should have a safety officer. He details a procedure which he has found helpful in the widespread operations with which he has been concerned. The objective is to have routine procedures with instructions on action for anticipated problems. Delegation of responsibilities which are not essentially undertaken by the pilot can ease his workload and so reduce fatigue. It has been found that there is a greater chance of pilot error on the first trip of the day or from a new strip and consequently these should not be attempted with a fully loaded aircraft. A lighter load gives a greater safety margin should the surface conditions of the strip or the mental condition of the pilot not be up to standard. An additional safeguard would be to fit the wire cutting device being developed in Australia.

A particular period of risk is when an aircraft is spreading solids. The high application rate required means that the aircraft is almost overloaded at take-off and is normally equipped with a spreader which increases the drag of the aircraft by 30%. Thus the excess thrust available for emergency manoevres is severely reduced relative to normal spray operations. This fact was pointed out by Smith 1969. Trayford & Taylor 1975, designed a spreader using the vortices generated from the edges of a delta wing rather than the conventional venturi plus guide ducts. This device, known as the Tetrahedron spreader, adds little drag to the aircraft but it is limited to about 600 kg/min release rate and gives a much more even distribution when used at lower flow rates.

Cranfield, in conjunction with Bowker Air Services Limited, have tried to reduce the weight and drag of venturi-type spreaders and at the same time improve their width and evenness of distribution. This has been achieved by designing the expansion duct and turning vane assemblies to have approximately the same width as the gate box. The reduction in drag gives a marked improvement in climb performance and hence safety whilst reducing the fuel used by the aircraft during operations by two gallons an hour, a saving of 15%. The guide vane assemblies are easily removable and can be changed to ones giving a different ground distribution pattern if required.

The new Fieldmaster agricultural aircraft incorporates features which aim to improve both the safety and the performance of the aircraft. The full span flaps trim the aircraft to a nose down attitude at spraying speeds, giving the pilot excellent view, and reduce the drag since the spray system is included within its structure. The low drag of the aircraft and the turbo-propeller engine give the aircraft a good power margin at spraying speeds as well as a high ferry speed. The passenger seat behind the pilot is a useful feature although one wonders if there is a weight limit on the occupant to prevent the centre of gravity of the aircraft from moving too far aft. The aircraft incorporates so many new features that a considerable amount of trial and development work must be required to ensure that it does not suffer from unserviceability and spares problems when operating in the remoter parts of the world. It has the biggest payload and almost the highest ferry speed of any aircraft specifically designed for agricultural work so should be efficient when operating in an area where it can be kept busy.

Improved Utilisation and Capacity

One major way of improving the economics of all aircraft operations is to increase the extent to which they are used. The annual utilisation for a translantic airliner is of the order of 3000 hours whilst the average aircraft used in agriculture flies less than 250 hours per year. This low utilisation is due to the seasonal variation of crop protection activities but can be increased by increasing their versatility, flexibility, mobility, and by greater use of forward planning and booking. It is attractive to move the aircraft area of operations to extend the working period. The growth in the use of helicopters reflects to some extent their ability to do other jobs outside the season since their distribution systems are often of the bolt-on type.

Much greater emphasis has been placed in recent years in improving the fraction of the total flying time spent in actually applying chemicals. Many operators now offer a special rate if the farmer provides a suitable operating strip near the area requiring treatment, so reducing the costs associated with ferrying. Extra large main and tail wheel tyres are fitted to allow operations from less even or softer strips. With advanced booking, good communications and efficient organisation the work of an aircraft can be sequenced to minimise the time spent travelling between individual applications. Ferrying time is most important when high application rates are required, usually fertilisers, and in some areas of the world this is so important that it is taken into account in planning the layout of crops. For example, in Brazil some of the mills plant the sugar such that the aircraft applying foliar fertilisers can fly as much as 5 km before turning. Foliar fertilisers are used because the application rates required are lower and the crop response quicker than with granules. Again the layout of the Gezira area in the Sudan makes it easy to make long spray runs between turns.

The economics of scale are such that for the same annual utilisation a big aircraft can be much more efficient than a small one. Thus when a very large local area or a high application rate is required large aircraft are attractive. The high use of fertilisers in the USSR dictates that their fleet has to be of large aircraft such as the AN-2 and the Dromader (M18). However, large aircraft with low utilisation are disastrously expensive.

At the other end of the size range Microlight aircraft have been fitted with spray gear. It is thought that some farmers with moderate to large farms may use these machines for pleasure flying normally but be able to convert them for ultra-low-volume spraying of their own fields. This joint role may make the economics acceptable inspite of the small payload of the aircraft, but poses some severe problems. An open cockpit means the pilot is exposed to the spray which, with small droplets and near still air conditions, could drift into his flight path. Again the low speed of the craft through the air means that its ground speed can be twice the up-wind value when flying down-wind. Obviously spray emmission rates must be geared to ground speed not airspeed.

The advent of the turbo-propeller engine has made a big impact on agricultural aircraft. This type of engine has a bare weight which is less than half that of an equivalent powered piston engine, a fuel consumption which is about 10% less and a much lower noise and vibration level which leads to lower pilot fatigue and structural maintenance. It uses diesel or kerosine instead of high grade petrol and consequently fuel is more readily available and costs less - about half the cost in the United Kingdom! These distinct benefits are offset to some extent by the much greater first cost, shorter periods between major overhauls and the greater susceptibility of the turbine engine to poor maintenance. It must be washed thoroughly after use and must have good, clean filters in the air and fuel systems. Aircraft converted to turbine power have different shapes and weight distributions which in some cases has led to adverse handling and flying qualities. However, their distinct advantages higher speeds and lower operating costs when well utilised and maintained, make them very attractive and in the future more and more of the larger agricultural aircraft, both fixed wing and helicopters, will be powered by turbine engines. Indeed it is becoming increasingly difficult to buy large piston engines.

Droplet Size Control

One of the most important recent trends is that towards lower application rates. An optimum sized droplet is the size shown by trials of the real formulation, delivered in the correct way onto the production crop,which results in the highest biological efficacy. Himel 1969, and others have shown that small droplets are caught much more efficiently by insect pests and it is well known that a good leaf cover is strongly desirable for fungicides and herbicides. Small droplets not only do this but are the only ones which are likely to be caught in the inner and lower parts of crops; large droplets are far more likely to penetrate the crop to reach the ground and are wasted unless absorbed by the root system. It is now realised that the bigger droplets of most sprays are relatively inefficient in achieving most biological objectives. Although a minimum size limit may be fixed by evaporation and drift considerations it is not likely to exceed 300 µm in diameter. Thus insecticide application rates may be one to five l/ha, fungicides five to ten l/ha and even herbicides may be as low as 15 to 20 l/ha in the near future, if not already being used. These values may seem very small but it should be realised that a 50 µm diameter mono-sized spray requires only an eighth of a litre per hectare to give 20 drops per square centimetre average cover: for a 200 µm droplet it requires 8 l/ha. These values have to be multiplied by the leaf area to ground area ratio to obtain this distribution on leaves.

An excellent example of the improvements resulting in this approach is given by Joyce & Beaumont 1978, great exponents of the use of correct droplet sizes. Joyce proposed a spray programme against the larvae of the pine beauty moth in forests in Scotland using only one litre per hectare total spray of a Fenitrothion formulation. In the event permission was given to spray only one fifth of the area in this manner and the rest in a conventional manner at 20 l/ha. The same amount of active ingredient per hectare, 300 g, was used in both sprays. Fortunately the opportunity to monitor and compare the results of the two spray techniques was taken. It showed that with the ultra-low-volume spray the larvae collected three times as much active ingredient, the needles one and a half times and the ground one eighth of that associated with the low-volume spraying. In both cases 97.5% mortality of the target insect was recorded after 36 hours. Clearly half the active ingredient in the one litre per hectare spray would have achieved the same result. The ULV spray rate was over 309 ha/h as against 88 ha/h for the higher application rate inspite of the former having a ferry distance of 100 miles as against 30 miles for the latter treatment. The overall conclusion after monitoring of personnel, birds and fish was that the ULV treatment had no disadvantages and in subsequent years was the only method used.

Whilst this particular example showed excellent results it cannot be used to advocate the same technique for all applications but can be used to advocate the same type of planned trial and monitoring for all other applications. Certainly there have been other trials, particularly in cotton spraying but the knowledge and techniques are not widely known. The Plague Locust Commission of Australia have published a number of reports on their work in spraying locust hoppers and adults. When attacking a swarm they find that a droplet size of about 80 µm is optimum, somewhat bigger than one would expect for a flying insect target, (Spillman, 1976) but this is because a high proportion of the swarm is on the ground at any one time. In both the pine beauty moth and plague locust operations the Micronair AU 3000 atomisers were used to drift spray the concentrated fenitrothion formulations and a minimum windspeed of 3 m/s was specified.

Most of the trials aimed at insect control have used fine sprays of insecticides produced by rotary cage atomisers. These give relatively good control over droplet size when set to produce fine droplets. However, for larger sizes of droplets the range of sizes increases significantly for both rotary and hydraulic devices. As a result trials to determine the optimum sizes for the aerial application of fungicides and herbicides are more difficult to achieve. One would expect in the case of some fungicides that the droplets should be of a size to give them the same airborne characteristics as the fungal spores but this does not allow for the effects of secondary contamination due to splashing.

The report by Hazelrigg 1978, commissioned by the National Aeronautics and Space Administration of the USA, shows that the greatest single improvement in the economics of agricultural aviation would come from a better control of drop size. It argues that not only would this reduce flying costs but the improved biological control would allow a reduction in the costs of both active ingredients and carrier fluids. It estimates that a 20% reduction in application rate would save the USA industry approximately $45 million per annum whilst similar improvements in turn time, payload and ferry time would save about $13 million, $4 million and $1.5 million respectively.

To achieve better droplet size control requires better equipment and a better understanding of the performance of the equipment. One of the outstanding developments in recent years is the introduction of laser type instruments to measure the droplet size spectra of various atomisers. When these are used in conjunction with wind tunnels they give the range of sizes produced by the atomiser when functioning under the same conditions as when airborne. There are various ways in which one can assess the narrowness of the spray spectrum. A common way is to use the ratio of volume median diameter to number median diameter, where a value of unity corresponds to a mono-sized spray. An alternative method more closely associated with the efficiency of application, is to express the fraction of the total volume emitted which is within 25% of the required droplet size. Spillman 1982, showed that for the rotary cage atomisers and hydraulic nozzles he investigated only 45% of the spray emitted was within this range at best and generally the figure was more nearly 20%. Rotary cage atomisers were generally better when droplets below 100 µm diameter were required.

If the droplet size control is to be practiced then spray spectra must be available for all atomiser - formulation combinations to allow the operator to select the most appropriate atomiser. Whilst the International Centre for the Application of Pesticides at Cranfield and others are actively engaged on determining such data there is a vast range of combinations still to be evaluated. To date few atomisers have produced significantly more than 45% of the spray within 25% of any size. Those that have exceeded this value have been of the spinning disc or cup type, suggesting that their method of atomisation is more controlled and gives a greater uniformity of droplet formation. Unfortunately most atomisers of this type do not have a sufficiently high fluid flow rate to make them suitable for aerial operations. An exception is the windmill-disc atomiser recently developed at Cranfield,(Spillman and Sanderson 1982) which uses the airflow past the atomisers not only to drive it but also to improve the maximum flow rate in the ligament mode by almost an order of magnitude allowing up to 80% of the fluid to be atomised into droplets within 25% of the desired size. The ratio of v.m.d. to n.m.d. achieved with the windmill-disc atomiser is 1.6 to 2.5, values measured for rotating cage devices are usually in the range 3 to 5 whilst hydraulic nozzles give values from 5 to 15 or more.

Another method of obtaining a very close control on droplet size is to form them electrostatically. There are no moving parts to such atomisers which seem most attractive for droplets below 100 µm in diameter. Electrostatic systems for aerial spraying have been tried without tremendous success. Part of the problem is that the aircraft can become highly charged but it is likely that this problem is soluble. Presumably droplets generated electrostatically could be discharged subsequently if it was found that there was no particular merit in using charged particles. Unfortunately one has to develop a satisfactory system before field trials can determine the efficacy of aerially sprayed, charged droplets.

Increased Distance Between Aircraft Runs

Another way in which the area sprayed per hour can be increased is to increase the swath width and hence the distance between successive runs. This can be done by either increasing the span of the spray boom or the height of the aircraft or by flying cross-wind and letting the spray be blown downwind, a technique called drift spraying.

Increasing the span of the spray gear beyond 80% of the span or rotor diameter will almost certainly mean that the local airflow about the aircraft will carry some of the spray near the wing or rotor tips upwards giving it an effective height well above that of the spray boom. Such spray is much more susceptible to wind effects and is more likely to be carried outside the desired swath width, possibly to do damage to the surrounding environment. From this point of view the lower and further from the wing tips an atomiser is placed the less the possibility of this happening. Since small droplets are far more responsive to air movements than large droplets one must be very careful to control the size range of the droplets and the positions of the atomisers when biological effectiveness suggests that small droplets should be used. It is essential that such atomisers should generate few droplets below an acceptable lower limit.

Various tip devices have been proposed which are claimed to reduce the amount of spray adversely affected by tip vortex flows. These include the Sportsman tips, the Weatherly vane and various forms of drooped tip. The devices favoured by Cranfield are called wing-tip sails and have been shown to reduce the amount of spray above the aircraft height, one swath width downwind, to about 40% of that which was present when standard wing tips were used (Parkin & Spillman 1980,).

An interesting approach to increasing the swath width without encountering this problem is to use a relatively large span such as those of the Eagle 240 or 300, which are about 30% greater than other aircraft of about the same size. Again by using a biplane layout the perturbations in the airflow about the lower wing are to be kept to a minimum.

Crosswind or drift spraying is used extensively to increase the run separation to between 50 m and 300 m and hence the productivity of aircraft. Outstanding examples are in the control of tsetse flies in the savannah areas of Africa, the control of spruce budworm larvae in Canada, the control of cotton pests in the Sudan Gezira and the control of weeds in Western Australia. In all cases the application rate is very low and the droplet sizes are small. However, drift problems are not serious because of the mono-culture of these large areas or the absence of damage should the insecticide go off-target. However, in a survey of aerial operators of the USA Kaplan, Meeland and Peterson 1977, found that the biggest problem was the control of drift. It is important to distinguish between drift of vapour and of spray droplets: the former can occur even when all the spray droplets fall in the target area and can only be controlled by using a non-volatile spray. Spray droplet damage is a severe problem in high density, multi-crop areas such as California, and even in mono-cultures at various stages of growth, such as in forests.

Damage due to Drift of Droplets

There are two basic ways of avoiding spray droplet damage one can use only big droplets or an adequate buffer zone. A spray spectrum can be chosen in which the droplets are so large that they are not blown sufficiently from a vertical path by the wind to create a hazard. Suppose a 10 metre error zone was permitted and the aircraft sprayed from a height of 2 metres. This means that the terminal velocity of the droplet must be at least 20% of the mean wind speed between 2 metres height and the ground. For a wind of 3 m/s this means a droplet greater than 180 µm and for a gust of 10 m/s droplets greater than 440 µm. To be sure of a sufficiently large fraction of the volume applied to be greater than these sizes the mean droplet size would need to be about three times these values for a typical size spectrum from a hydraulic nozzle. Such sizes are likely to be very inefficient biologically, perhaps even damaging the crop if the formulation is not carefully chosen.

Spraying in still air is fine, provided it really is still for the full time the droplets are airborne. Too often however, the still air condition corresponds to conditions in which a temperature inversion exists between the spray height and the crop. Then small droplets have an extremely slow fall rate since any vertical turbulence in the air is strongly damped. Thus a 50 µm droplet will fall at about 7 cm/s taking up to half a minute to reach the canopy. In this time a short duration breeze of 0.5 m/s could carry the droplets 15 metres, that is beyond the error zone. Since most hydraulic nozzles create a very large quantity of droplets well below 50 µm, often increased in number by evaporation, they can move well beyond the target area before they reach the ground. In hilly country local air currents can be induced above an inversion and these can carry concentrated clouds of small droplets a considerable distance. There is very strong evidence to suggest that many of the reported cases of severe damage to crops outside the spray target area occurred under still air inversion conditions. Because of this many operators are looking for a means of checking that inversion conditions do not exist before commencing spraying. Two suggestions have come from Australia, firstly a smoke generating device using a car exhaust system and secondly a smoke making device in the exhaust of the aircraft. If no such device is available then it may be best to wait until the wind is at least two to three metres per second when inversions are destroyed by wind created, turbulent mixing.

There has been a considerable amount of work recently trying to mathematically model the effects of atmospheric turbulence on the behaviour of droplets. It would seem that one of the better models is that of Bache and Sayer 1975, which shows the importance of the type of crop on the turbulence intensity associated with a given wind condition. The higher the level of turbulence the more rapid the descent to the ground of the majority of the small droplets. Although some will be carried a long way downwind their concentration will be so low that they may not constitute a hazard. In less turbulent conditions at the same wind speed their concentration at a point well downwind of the spray release line will be considerably more. All theories of droplet dispersions are based on probability laws and consequently can only predict the most likely result on any one occassion. The United States Department of Agriculture Forestry Service have been developing models of droplet behaviour above and into the forest canopy. A description of one method is given by Dumbauld, Rafferty and Bjorklund 1977, and one of the recent comparisons of its predictions with practice is described by Rafferty, Dumbauld, Flake, Barry and Wong, 1982. They show that the model estimates were only 65% to 75% of the observed values which suggests that further model refinement is necessary. Perhaps part of the inconsistency in results was due to the use of kromocote cards whose catch efficiencies with difference droplet sizes are very different from those of pine needles.

Whilst mathematical models are not ideal and many more full scale trial comparisons are required, the results to date do point to a number of important conclusions. All results show that the downwind distance of the deposit is directly proportional to the spray release height, that small droplet deposits are similar above wind speeds of about 3 m/s and that conditions over different types of canopy can be very different. Spray deposit patterns made over open land such as a ploughed field or an airfield will not simulate those which will be obtained over a crop. Analysis of where the spray has gone is essential. To do this the results from the samples must be corrected for their limited catch efficiency, which varies with droplet size. Since catch efficiency is difficult to estimate it is desirable to use the actual biological target or other natural surfaces as the samples because their catch efficiency is usually much higher than that of an artifical surface.

The concept of a buffer zone, (Watt 1980,) based on experience and modelling seems an excellent one. A strip at the downwind end of any spray target is left unsprayed or sprayed in a way which will not give a drift problem. This system is suitable for a large spray area where a buffer zones, perhaps 300 m wide, can be used enabling most of the spray area to be treated with a spray whose droplet sizes are those most suitable for the biological objectives. However, in much smaller areas the droplet size must be increased to avoid excessive amounts of spray going beyond the target area. There is a fairly sharply defined minimum size for any given set of conditions and exceeding this size could be wasteful in chemical.

An outstanding need for all aircraft spraying is an improvement in their guidance, including height control. This applies whether it is field or forest spraying. Whilst there are many systems currently used, from flagmen and ground markers to electronic guidance or even guide aircraft systems there is evidence from the biological results that many applications overlap or miss or in a few cases criss-cross! There is a general need for equipment to help position the aircraft accurately and to indicate when to start and stop spraying and, indeed, whether to spray at all! Such instrumentation might be difficult to devise in a low cost form but its contribution to pilot work load, and hence safety, and to the efficient use of chemicals makes it a goal well worth pursuing. Above all the pilot should have means of getting his aircraft properly calibrated so that he knows precisely the size and quantity of the emissions. Equipment for this is available but insufficiently used.

CONCLUSIONS

1) It is essential to plan operations such that the pilot can concentrate on doing a good job. Procedures which anticipate problems should be adopted.

2) The manoeuvrability and fuel consumption of aircraft engaged in spreading fertilisers can be improved by using low drag equipment and designing new aircraft specifically for this purpose.

3) Costs can be reduced by increasing the utilisation of the aircraft. To do this their versatility, flexibility and mobility must be improved. This means better operational planning, better co-operation with the farmers and better equipment such as wide tyres.

4) A more suitable layout of crops, airstrips close to the site of operations and bigger aircraft all help reduce costs.

5) Turbine powered aircraft are lighter, faster and reduce noise levels and fuel costs. However, they have greater engine costs and require good maintenance standards.

6) There is a marked movement towards reducing the application rates of sprays associated with better droplet size control. Drift spraying of insecticides is becoming an accepted practice. It has been estimated that droplet size control could be the most effective single means of reducing costs.

7) New atomisers are being developed which significantly improve the fraction of the total volume emitted which is within 25% of the desired droplet size. These are of the rotating disc or electrostatic types.

8) There is a risk of drift damage when spraying is done in still air conditions. The existence of a temperature inversion should be checked before spraying commences.

9) Spray drift damage can be minimised by using a spray spectrum with few droplets below the critical size. A downwind buffer zone is recommended. Mathematical models of spray movements are being developed and compared with experiments but more comparisons are required to improve these models.

10) There is a need for better equipment to help the pilot judge height, spray position and when to spray. Regular calibration of the aircraft application performance is essential.

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FIELD TESTS OF ROTARY ATOMIZERS AND ELECTROSTATIC SPRAYERS

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Replicated field tests were made in 1981 and 1982 comparing low volume post-directed and overtop application of dinitro herbicide for control of broadleaf weeds in soybeans. Applications were made with standard post-directed off center hydraulic nozzles and a prototype air atomizing electrostatic sprayer based on Dr. Law's patents. Broadleaf weed control achieved with the electrostatic sprayer at half rate was generally as good as full rate. Hydraulic nozzle test results were not as good. Companion test with overtop bentazon herbicide applications compared "Micromax" and "Beecomist" rotary atomizers with the electrostatic and hydraulic nozzles at full and half rates. Results showed that half rates of bentazon gave reasonably good broadleaf control with the spinner atomizers and electrostatic. Control achieved with the half rate bentazon applied overtop with hydraulic nozzles was poor. Weed control with the spinner atomizers was not consistantly better than hydraulic nozzles with full rate bentazon.

Red rice control tests in soybeans (Matthews, 1982) involved four herbicides and herbicide combinations applied at full and half rates with spinner atomizers, hydraulic nozzles, electrostatic and the ICI field type electrodynamic sprayer. Test results showed that sequential overtop applications of full and half rates of fluozifop-butyl and sethoxydim controlled red rice better than the bentazon + melfluidide mix, regardless of application method used. The low volume electrostatic at 28.1 l/ha, rotary atomizer (Micromax) at 21.5 l/ha and the electrodynamic electrostatic at 1.0 and 0.5 l/ha gave good red rice control at both full and half rates of herbicides. Control with the bentazon + mefluidide was not as good as with the two other herbicides. Control with half rates applied by hydraulic nozzles was generally lower than with other machines.

The electrodynamic sprayer was tested in comparison with conventional hydraulic nozzles for control of cotton bollworm and budworm. Permethrin and cypermethrin were used at four concentrations. Conventional spray volume was 28.0 l/ha while the electrodynamic spray was applied at 0.5 l/ha. Efficacy of the electrodynamic spray applications was as good or better than the conventional.

In summary, it may be said that development of better pesticide application equipment has been slow - agonizingly slow. Matthews, (1979) truthfully stated that the basic design of spraying machinery has changed little since the turn of the century. Fortunately we are now in the initial stages of a revolution in pesticide application with ground operated equipment. We now have some of the hardware in commercial form that will accurately control spray droplet size and impact on the biological target. Atomizers that produce droplets with uniform size and electrostatic charging are now in the pre-production prototype and early commercial machine stages. These changes can't come too soon. I, for one, have hauled too much spray water for too long!

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3A—R2

RECENT RESULTS WITH THE VEHICLE MOUNTED 'ELECTRODYN' SPRAYER IN WEST EUROPE

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Background and Objectives

Trials using the first prototypes of the vehicle mounted 'Electrodyn' sprayer started in 1982 in the UK and France. More than 200 trials have now been carried out on cereals and sugar beet in order to bring the system and the formulations of a complete range of chemicals to a development stage.

Materials and Methods

The trials were sprayed with an experimental boom supporting 4 or 5 nozzle generator assemblies. The chemicals were fed to the nozzles through a series of metering and pressurising pumps. Air assistance was included in some of the 1982 and almost all the 1983 trials. For each chemical, the registered rate was applied conventionally and with the 'Electrodyn' sprayer. Standard experimental designs and assessment methods were used in the trials.

Results - Cereals

Isoproturon was tested in 12 trials in the UK and France at the local rates. ED applications gave similar levels of control to the conventional application (97 to 100%). Air assisted results were generally more consistant than non air assisted. Crop damage was always very limited with both techniques.

Mecoprop, ioxynil, and 3,6-dichloropicolinic acid were applied in a formulated mixture. The results were equally good for both methods on a range of broad-leaf weed species. Air assistance improved the activity particularly on dense canopies.

Carbendazim and a mixture of PP450 (flutriafen) plus carbendazim were tested in the UK and France at the local rates on eye spot (Pseudocercosporella herpotrichoides). Results were very similar with both techniques. No phytotoxicity was recorded.

PP450 (flutriafen) was applied for mildew (Erysiphe graminis) and brown rust (Puccinia recondita) control in the UK and France. Results were similar with both techniques when the applications were made in the early stages (GS 32 to 37). Later, air assistance was needed for ED to match conventional applications on all leaves.

Pirimicarb was applied on cereals in France and Spain against ear aphids (Sitobion avenae and Rhopalosiphum padi). Conventional and ED applications gave excellent control of the pest (95 to 100%). Air assistance improved the consistancy of the results.

Sugar beet

Chloridazon was applied as a pre-emergence treatment in the UK and in France. Excellent results have been obtained from ED and conventional applications on Poa annua, and a range of broad-leaf weeds.

Fluazifop butyl was tested in the UK and France in 1982 and 1983. Excellent control was obtained with both application methods on wild oat (Avena fatua), black grass (Alopecurus myosuroides) and volunteer barley.

Pirimicarb was tested in France on Myzus persicae. Both ED and conventional application methods gave good control of the pest.

Conclusion

An almost complete cereal range has been optimised though several additional compounds are still being investigated. On sugar beet, three major chemicals have been optimised and others are currently being evaluated. Significant progress has been made in air assistance technology and boom design. Further field testing is required to fully integrate biological requirements and engineering progress.

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PROGRESS ON DEVELOPING 'ELECTRODYN' SPRAYERS FOR USE IN RICE

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Background and Objectives

Since the invention of the ICI 'Electrodyn' sprayer (Coffee, 1979), emphasis has been given to the production of a hand-held applicator for use in cotton. Prototypes, as well as the commercial sprayer have undergone evaluation in a range of crops, including vegetables and rice (Perrin et al, 1981). Cypermethrin performed well in the early rice trials equalling the high volume control on a range of rice pests. Two possible limitations of the system were highlighted; i) the effective swath, and ii) the penetration of spray droplets into dense rice canopies. The former has ergonomic implications for future machine design and mode of use. The latter indicates potential biological limitations for rice insect pest control with any given chemical.

Field work over the last two years has sought to i) optimise spray characteristics to improve penetration into dense canopies, and ii) evaluate a wider range of chemicals.

Materials and Methods

Two 'Electrodyn' sprayers were field tested, the hand-held applicator (commercialised in cotton), and a prototype air-assisted device. The trials evaluated the effect of varying flow rate, droplet size, charge to mass ratio (q/m) and mode of use. A static mode (sprayer held in a fixed position over the crop, at right angles to the direction of travel) and a 90° swinging mode, were compared with the normal mode of knapsack application. The initial work was limited to fluorescent tracer studies using a 'Uvitex OB' formulation. Crop coverage was assessed after dark with the aid of UV lamps. This work was followed by biological trials evaluating pyrethroid and organophosphate formulations.

Results and Conclusions

With the commercial sprayer the penetration of charged spray droplets improved with an increase in flow rate, ie. a direct function of the increase in droplet size and reduction of q/m. At a fixed volume per hectare there was a reduction in droplet number per cm^2 as the vmd increased. Similarly a decrease in the q/m with a fixed droplet size improved penetration down and into the rice hills, but with loss of the "wrap-around" effect, ie. spray deposit on the underside of leaves and on the "down-wind" side of the hills.

Penetration was increased by low windspeeds ($\leq$ 3 m/sec) and by swinging the nozzle over the crop. This is probably due to a reduction of space charge ie. a thinning of the spray cloud and a decrease in the field intensity between the charged spray droplets and the crop at earth potential. In addition, the turbulance produced by low wind speeds aided penetration. Higher windspeeds decreased the "wrap-around" effect.

Based on tracer studies alone, penetration was optimum in rice hills (0.4 - 1.0m high) when using droplets of between 80-100µm vmd and with a low q/m of $2\text{-}3 \times 10^{-3}$ C kg^{-1}.

The prototype air-assisted sprayer gave excellent penetration at a range of flow rates and air speeds when angled down at the crop. Optimum cover was obtained using small droplets $\leq$ 50µm vmd with an air speed range of 15-25m/s.

Although biological trials have been carried out at widely dispersed sites in both the Philippines and Indonesia, insect numbers have generally been low. Results from applications with 'Electrodyn' sprayers have shown control of whorl maggot (*Hydrellia philippina*), green leaf hopper (*Nephotettix virescens*), stem borer (*Tryporyza sp.*), leaf folder (*Cnaphalocrocis medinalis*), and rice bug (*Letocorisa sp.*), at least equivalent to high volume knapsack applications. Data against the brown plant hopper (*Nilaparvata lugens*) is limited and inconclusive.

Using a 3m swath, the swinging mode has given more uniform pest control across the swath than with the static mode, indicating an effective swath of < 3m for the latter. Variation of droplet size, q/m, and addition of air assistance has, so far, not shown any significant difference in the level of insect control.

Trial work is continuing in the Philippines, Thailand and Indonesia, to produce recommendations for successful pest control with 'Electrodyn' sprayers in rice.

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3A—R4

VEHICLE-MOUNTED 'ELECTRODYN' SPRAYER APPLICATIONS IN COTTON AND SOYBEANS

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Background and Objectives

Vehicle-mounted 'Electrodyn'* sprayers were extensively field tested in the US in 1982 to determine their effectiveness in applying permethrin for Heliothis sp. control in cotton and fluazifop-butyl for annual grass control in cotton and soybeans. The 'Electrodyn' sprayer concept utilises electricity to atomize the pesticide spray into near-equal size droplets and to place a net charge on them. A two-fold increase in target cover with charged droplets has been observed when applications of equal-size charged and uncharged droplets are compared.

Data are presented here from two representative trial locations where the efficacy of permethrin and fluazifop-butyl were assessed when applied either with conventional hydraulic sprayers or with 'Electrodyn' sprayers.

Materials and Methods

Weed and insect control results are drawn from replicated trials, one each in North Carolina and Georgia for permethrin and one each in North Carolina and Arkansas for fluazifop-butyl, comparing applications made with either conventional or 'Electrodyn' sprayers at equal a.i. rates. Permethrin was applied at 0.028 to 0.224 kg a.i./ha. Fluazifop-butyl was applied at rates of 0.14 to 0.56 kg a.i./ha. Three conventional permethrin applications were made at 65 to 94 l/ha and 400 to 414 k Pa with hollow cone nozzles. Three permethrin applications were made with the 'Electrodyn' sprayer at 0.5 l/ha as 50 µm droplets. Conventional fluazifop-butyl applications were made at 187 to 300 l/ha and 138 to 300 k Pa with whirl chamber and flat fan nozzles. Fluazifop-butyl was applied by Electrodyn sprayer at 1.0 l/ha as 70 µm droplets. Insect control was assessed on 50 to 100 cotton squares or bolls per plot. Weed control was assessed visually at 14 and 35 days after treatment. The grass species assessed and their heights at application were: Brachiaria platyphylla (5 and 25cm); Setaria glauca (10 cm); Setaria fabria (38 cm) and Echinochloa crusgalli (51 cm).

Results and Conclusions

Percent damaged square counts indicate that three applications of permethrin at 0.056 kg ai/ha applied with the 'Electrodyn' sprayer reduced square damage due to Heliothis sp. to the 5% damage threshold level, a level which conventional applications of permethrin did not reach at rates up to 0.244 kg ai/ha in these trials. Differences in control between the two application methods at the same rate were probably due to different pesticide placement. The 'Electrodyn' sprayer deposits most of the highly charged pesticide droplets in the upper 1/3 to 1/2 of the cotton plant canopy and on both upper and lower leaf surfaces, the portion of the plant canopy generally infested by Heliothis sp.

Weed control results are presented according to plant height at the time of spraying. On Brachiaria platyphylla and Setaria glauca, applications were made to plants less than 10 cm tall; on Echinochloa crusgalli, Brachiaria platyphylla and Setaria fabria applications were made to plants 25 to 51 cm tall. Applications of fluazifop-butyl with the 'Electrodyn'sprayer and the conventional system gave equivalent control of grasses less than 10 cm tall. For applications made to 25 to 51 cm tall grasses, the 'Electrodyn' sprayer gave inferior weed control when compared to conventional applications at all rates at 35 days after treatment. Poor control of tall grass canopies with the 'Electrodyn' sprayer compared to the conventional high volume sprayer was attributable to the distribution of the highly charged droplets which gave excellent coverage of the upper grass canopy but poor lower grass canopy cover. This resulted in early top kill, poor translocation to the lower grass canopy because of upper canopy tissue death, and allowed regrowth.

Work is currently being conducted in the US to improve grass canopy penetration through manipulation of various spray parameters such as droplet size, droplet charge and spray volume.

* 'Electrodyn' is a registered trade-mark of Imperial Chemical Industries PLC.

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EXPERIENCE WITH A HAND-HELD ULV CHARGED-DROP SPRAYER ON FRUIT

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Introduction

ULV spraying allows fast treatment from lightweight sprayers, both important requirements on fruit farms. Small drops are essential if ULV applications are to be effective, but are prone to evaporate and drift. The ICI Electrodyn system (ED) which produces uniform, oil-based, electrically charged drops, reduces these problems. Hence the ED system was used in field trials to compare the efficiency of ULV and high volume (HV) sprays, against powdery mildews on small non-fruiting apple trees (c. 1.5 m high) and raspberry canes, and against spider mite on strawberry.

Methods and Results

1. The relative depositions from hand-held ED and HV systems were compared on the apple trees. ED sprays of two drop sizes were used (c. 100 and 130 μm vmd): both gave greater amounts of deposit than HV treatment over all important regions of the tree.

2. In 1980 the systems were compared in replicated-plot experiments, using bupirimate for the control of mildews on apple and raspberry and dicofol against red spider mite on strawberry. Each disease/pest treatment employed the same amount of ai, at the recommended rate, but ULV spray volumes were 1/600-1/900 of the HV.

On apple and raspberry leaves (but not strawberry), charged ULV sprays gave the highest deposits, and the smaller drop size was more efficient. However, control was well related to leaf deposits only with apple mildew. This apparent failure of some ULV treatments to achieve the superior control expected from the amounts deposited was deduced to result from inadequate coverage of leaf surface by the pesticide - a consequence of insufficient spray volume, under these conditions. The leaf coverage was quantified: the ratio of the calculated maximum area covered by spray to the actual leaf area was expressed as a "COVER INDEX", calculated from the deposit, spray concentration, drop size and spread factor.

The effects on apple mildew control of various deposits and Cover Indices were investigated during the next two years.

3. In 1981, using binapacryl and the small apple trees, ED formulations of different concentrations were used to give various Cover Indices. ULV and HV treatments employed the same quantity of ai at the recommended rate. Amounts of ULV deposit were, as before, inversely related to drop size but, unexpectedly, were not proportional to duration of spraying. The ULV treatments were again more effective than HV: there was no decrease in apple mildew control even when the Cover Index was reduced to c. 0.2.

4. In 1982, using bupirimate, cover from the ED treatments was further reduced, but the HV remained as in 1980. Four ULV treatments used c. 1/10 or 1/5 of the HV ai, with volumes down to c. 1/10,000 of the HV. These extremely low volumes and fast application speeds still achieved greater deposits than the HV. However, because Cover Indices were so low (down to c. 0.1) there was a decrease in apple mildew control relative to the HV treatment.

Conclusions

ULV charged-drop sprays (applied by the ICI Electrodyn system) gave increased amounts of deposit on all important regions of small apple trees, relative to HV treatment. Deposition of charged sprays was inversely related to drop size.

The control of powdery mildews usually improved as deposits increased. Disease control depended, however, on both amounts of deposit and Cover Index.

A combination of concentrated formulation and fast spraying speed was the most efficient means of depositing charged sprays with the upper limit determined by the need for cover (i.e. spray volume).

Experience on strawberry in 1980 suggested poor interception of charged drops on this ground crop: available methods for the improvement of deposition and Cover Index require investigation.

The high promise shown by this experimental ULV system could be realised for fruit crops when suitable air-assisted machines become available.

3A—R6

NON-TARGET ORGANISM MORTALITY - A COMPARISON OF SPRAYING TECHNIQUES

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Background and Objectives

The mortality of non-target organisms as a result of inefficient pesticide application is an undesirable aspect of chemical control. The environmental damage of such mortality may have long term effects on the pest/crop complex resulting in outbreaks of new pests or inadequate control of the target organism. Such effects are particularly likely if beneficial organisms are killed. Electrostatically charged sprays give the operator some control over the pattern of spray deposition within the target crop. The objective of this research was to determine if the improved accuracy of application achieved by charged droplet spraying significantly reduced invertebrate mortality in a non-target area.

Materials and Methods

A fully replicated field trial was carried out in mature winter wheat to compare the impact on soil macro-fauna of cypermethrin when applied at 250 g a.i./ha through a conventional hydraulic sprayer and an electrostatic spraying system. The Hydraulic system used Teejet 80015LP nozzles at 15 psi giving an application rate of 80 l/ha with a spray vmd of 310µm. An 'Electrodyn' system (Coffee, 1981) was used for the electrostatic application with two drop size ranges - vmd 80 µm and vmd 245 µm giving application rates of 4 l/ha and 8 l/ha respectively. After spraying samples of the head and flag, lower leaves and soil were taken for glc analysis. The macro-fauna were monitored using pitfall traps sampled overnight before spraying and at 1,3,7,14 and 21 days after spraying. For the purposes of the experiment the target area was assumed to be the head and flag leaf of the wheat.

Results and Conclusions

The glc analysis showed major differences in the distribution of cypermethrin achieved by the two spraying systems.

		Cypermethrin Recovery µg/g		
	vmd	Head/Flag	Lower Leaves	Soil
Hydraulic Sprayer	310	12	15	0.16
Electrodyn	80	26	9	0.006
Electrodyn	245	28	13	0.016

The low levels of cypermethrin found in the soil of the 'Electrodyn' plots (1/10th and 1/20th the levels in the Hydraulic plots) were reflected in the recovery of catches in the pitfall traps. After suffering an initial fall on all plots catches recovered faster ($p=0.01$) on the electrodyn plots to levels significantly higher ($p=0.05$) than on the hydraulic plots.

Clearly electrostatic spraying offers potential for the successful avoidance of non-target organisms making it a potentially useful tool for integrated pest management where beneficial organisms must be unaffected by chemical control measures.

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CHARGED ROTARY ATOMISERS FOR CROP PROTECTION SPRAYING

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Introduction

The recent development of equipment to charge sprays electrostatically has made possible efficient application of pesticides to crops in small volumes of carrier without some of the potential hazards of other low volume techniques. Designers, biologists and chemists at Rothamsted have collaborated to evaluate the performance of charged rotary atomisers (Arnold & Pye 1980) on a range of crops and their pests.

Methods

Standard formulations at recommended and lower rates were sprayed in water using a hydraulic sprayer or charged rotary atomiser at respectively 300 - 600 or 4 - 6 l/ha. Measurements were made of chemical deposits and biological effectiveness.

Results

In most tests chemical deposits on plants were greater and soil contamination was smaller with the electrostatic sprayers. However on winter barley, application of a post-emergence herbicide to control *Amsinckia intermedia* gave similar chemical deposits and biological effectiveness with both electrostatic and hydraulic sprayers. In some instances, chemical deposits may not have been placed for maximum biological effectiveness e.g. the control of swede mildew (*Erysiphe cruciferarum* Opiz ex L.Junell): although the electrostatic sprayer gave larger chemical deposits on the upper leaves, the lower leaves were less well treated and disease control was less effective. On spring barley the larger deposits with the electrostatic sprayer gave control of milew (*Erysiphe graminis* F.sp. *hordei*) comparable to that obtained by use of the hydraulic sprayer. In other instances the increased deposits gave improved biological effects; for the control of pea moth (*Laspeyresia nigricana*) half the recommended dose of permethrin applied electrostatically gave better control than a conventional application at the full dose rate.

Quantities of pesticides applied are often in excess of the theoretical amounts required for total control so the greater chemical deposits obtained with electrostatics will not necessarily give improved results; however the greater efficiency of the system in applying chemicals to plants makes possible lower doses without decreased biological effectiveness. Electrostatics can convert the rotary atomiser into a placement sprayer with the advantages of increased rates of spraying and compatability with low ground pressure vehicles making most effective use of good spraying conditions.

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Arnold, A.J., Pye, B.J. (1980) Spray application with charged rotary atomisers. In Spraying Systems for the 1980's. British Crop Protection Monograph No. 24 pp 109 - 117.

3A—R8

APPLICATION TECHNIQUES TO INCREASE CROP PENETRATION OF CHARGED SPRAYS

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Background and objectives

Present electrostatic rotary atomisers give considerably increased deposits on plants, and biological efficacy in most cases is as good and often better than from uncharged systems. The few cases of decreased biological effectiveness can be explained by poor penetration of spray into the crop canopy (Griffiths et al 1981).

This novel method of spraying still leaves many questions to be answered concerning the physical parameters that affect penetration in closed canopies. Charged rotary atomisers produce a broadened drop spectrum. The space charge developed by these drops and the repulsion between them modify velocity, trajectory and subsequent distribution into a crop. The effects on penetration of varying the applied voltage and the angle of spray head were examined with the primary aim of increasing lower leaf deposition.

Materials and Methods

Trials were conducted using the "Jumbo" (Arnold 1982) charged rotary atomiser, developed at Rothamsted, spraying water based formulations into cereals.

The atomiser was fitted with a 180° deflector to capture the highly charged small drops that would otherwise escape when the head was tilted. Wheat grown in trays with 12.5 cm (5 inch) row spacing to simulate field conditions, was sprayed with an ultra violet tracer Uvitex OB and residual deposits were measured by analysing extracts of leaf and stem samples. Four levels of voltage (0Kv, 7.5Kv, 15Kv, 30Kv) were applied to the atomiser at five application angles (0^{o}, 10^{o}, 20^{o}, 30^{o}, 45^{o}).The sprays were applied when the crop was 30 cm high using formulation with a resistivity of 6.0×10^{3} ohms cm^{-1}.

Results and conclusions

Table 1 shows the deposits on upper, middle and lower levels of plant.

Table 1

Mean deposits in ug of Uvitex

Plant segment	Voltage				
	V_{30}	V_{15}	$V_{7.5}$	V_0	S.E.D.
UPPER 10 cm	75.8	49.9	7.1	6.0	6.99
MIDDLE 10 cm	32.1	30.1	20.6	19.2	3.81
LOWER 10 cm	5.8	5.2	9.4	4.2	1.00

Very large total deposits were found at 30Kv, less with all other applications; however 65% of deposition was on upper leaves and 5% on lower leaves and stem.

At 7.5Kv deposits were increased significantly in the lower 10 cm of crop. As voltage was reduced, charge to mass ratio decreases allowing greater access to lower levels. Differences were found when the head was tilted but were not significant in this study.

These results show lower leaf deposition can be significantly increased by low levels of charge. The large upper leaf deposit characteristic of high levels of charge are no longer obtained, but the increased penetration in some situations would be preferable. Further research is necessary to investigate biological effectiveness with pesticides.

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SPRAY DEPOSIT VARIABILITY ON PLANTS AND ARTIFICIAL TARGETS

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The method by which sprays are applied to plants may affect the quantity deposited on their surface. However, attempts to measure statistically significant differences in deposit levels are often masked by large between-plant variations. This work was to identify some causes of this variation by measuring features associated with the plant and the performance of the applicator.

Materials and Methods

Spray applications were made to both plants and paper sheets using 2 Spraying Systems 'Teejet' 8003 nozzles at a spacing of 0.5 m and a distances of 0.5 m above the target surface. Liquid pressure was 210 kPa at the nozzle chamber and speed of travel was 6 km/hr resulting in a mean volume rate of 185 l/ha. The spray solution was water with the addition of a non-ionic surfactant (Agral) at 1 ml/l v/v and a fluorescent dye (Fluorescein LTS) at 0.1 g/l or 5 g/l for the paper and plants respectively.

Barley (growth stage 12) and radish (fully expanded cotyledons) were arranged in 14 rows of 7 plants - the two species alternating both across a 0.5 m swath and down the row. Spray runs were replicated 3 times. Plan areas were calculated from infrared photographs with a telecentric lens.

To measure the variability due to the applicator, sheets of chromatography paper (58 x 68 cm) were placed centrally in the spray swath for three spray runs. After spraying the paper was cut into quarters, a template was placed on each of 4 orientations and a range of geometric shapes (circles, squares, triangles or rectangles), each of 3 areas (1, 4 and 25 cm^2) were marked and cut out. After application the plants and cut shapes of paper were washed in 0.005M sodium hydroxide solution to remove the fluorochrome and fluorescence was measured.

Results and conclusions

Results are expressed as coefficients of variations (cv).

The dry weights of barley plants were more uniform (19% cv) than radish (46% cv). Conversely radish 'plan areas' were more uniform (22% cv) than those of barley (30% cv). The spray deposited per plant varied between species and runs (22 to 34% cv) with a tendency for more uniformity with the radish. Spray deposits per unit plan area gave a cv. of 30% for barley and 22% for radish. In contrast expressing spray deposit values as a function of dry weight increased the variability of the results for radish (81% cv) but not with barley.

Spray deposited on paper gave cvs of 18 or 19% for all 3 runs. Targets of 25 cm^2 were more uniformly sprayed (19% cv) than smaller targets of 4 (23% cv) or 1 cm^2 (26% cv). The effect of varying geometric shape of target on spray deposit variability was confounded by size. Rectangular shapes gave the most deposit variability (26% cv) and triangles the least (17% cv).

The data demonstrate that spray deposit variations originate with the application method and the magnitude of such variations is also dependent on the target size and shape. It seems likely that the distribution of sprays deposited from these typical conventional hydraulic nozzles will give coefficients of variation of deposits on plants in excess of 20%. This poses problems in the design of experiments on spray deposition. We have found that the most effective way to reduce this source of variation is to take all plants for sampling from set areas. In cereals we typically use 4 sample areas each of 1 m^2 in a plot whose overall dimensions are 3 x 20 m.

3A—R10

DEPOSIT AND DISTRIBUTION PATTERN OF SPRAY DROPLETS IN A RICE CANOPY

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Introduction

Most pesticide applied in paddy fields was lost into the water and mud, causing pollution. With the aim of saving costs and eliminating environmental pollution, the fate of spray droplets in a rice canopy was studied in the laboratory and fields. Some research reports have discussed the movement and penetration of droplets, but little have been published on the deposition and distribution pattern (DDP) on rice leaves. It is likely that the DDP on rice leaves is closely related to the effect of pesticides on the control of pests such as the rice leaf roller *Cnaphalocrocis medinalis* Guenée.

Materials and Methods

Leaf samples were collected from Zhejiang, Hubei, Guandong provinces and the Beijing suburb, and leaves were also detached from plants grown in a glasshouse. The DDP were estimated by a spectrophotometric method at 390 nm wavelength on the basis of using $Al(OH)_3$ gel as tracer indicator. The volume of spray deposited on leaves can be calculated from the quantity of Al^{+++} detected since the concentration of Al^{+++} in the spray liquid was known.

Experiments on detached leaves were carried out in a spray tower 29 cm in diameter and 1500 cm in height. A Burkard spray nozzle was utilised at a pressure of 93 kPa. The spray rate was 5 ml/emission, with cresol red as tracer indicator. The detached leaves were placed at the bottom of the tower in different positions: erect, horizontal, 60° declined and in a natural position.

Results and Conclusion

The spray droplets were deposited mainly on the terminal half of rice leaves with a ratio (terminal half/basal half, taking the basal half as 1) of 1.06-6.36, mostly 2/1, when a hand-operated knapsack sprayer was used. A ratio up to 7.06/2.68/1 was obtained with leaf divided into three equal parts (tip, middle, base), if a mist-blower was used. Increasing the spray rate from 750 l/ha to 1125 l/ha changed the deposit ratio (DR) from 1.44 to 1.08 on the upper layer of the canopy and from 2.78 to 2.03 at the lower layer, but run-off was serious at the larger volume rate. When the rate was decreased to 600 l/ha the DR increased to 2.09. The DR of 1.65 without wetting agent improved to 1.92 when wetting agent was added to the 750 l/ha and from 1.89 to 2.09 at 600 l/ha. On horizontal leaves the deposit per unit emission (DUE) on the leaf-tip zone (1/3 of leaf length) was 0.152 ml/10 cm^2 compared with 0.092 ml on the middle leaf zone. On erect leaves deposits were 0.0315 ml at the leaf tip zone, 0.0162 ml at the middle zone and 0.0146 ml at the basal zone. On declined leaves the DUE was 0.117, 0.0714 and 0.0586 ml at the tip, middle and basal zones respectively, whereas on leaves in their natural position the DUE's were 0.0959, 0.0436 and 0.0274 ml respectively.

These data indicate that more spray is deposited at the leaf tip.

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3A—R11

SPRAY DRIFT - MEASUREMENT USING NEUTRON ACTIVATION ANALYSIS

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Background and objectives

There is an increasing emphasis on the development of more efficient methods of pesticide application to reduce chemical costs and minimise environmental pollution (Matthews, 1981). The possible movement of spray downwind from the target crop is causing concern as some pesticides can be toxic to non-target organisms and other sensitive crops (Anon, 1979). There has been comparatively little work done to investigate the extent of pesticide drift under U.K. conditions.

Neutron activation analysis (NAA) as a method for the evaluation of spray drift from a conventional hydraulic sprayer and a spinning-disc drift sprayer (the Ulvamast Mk. 2) is described.

Materials and methods

10% permethrin (75 g a.i./ha) was applied to plots of winter wheat (G.S.87) with a conventional hydraulic sprayer and an Ulvamast Mk. 2 sprayer at rates of 215 l/ha and 2.5 l/ha respectively. Dysprosium (^{164}Dy) was incorporated in both spray tanks at a concentration of 1.3 g dysprosium chloride/l (0.56 g Dy/l). Spray deposits were collected on horizontal filter paper discs at 0, 0.45 and 0.75 m above the ground within and up to 100 m downwind from the treated plots. After spray application the filter papers were removed and irradiated to activate ^{164}Dy to ^{165m}Dy, a short-lived radionuclide with a half-life of 1.26 min. The levels of Dy were determined by direct comparison with Dy standards (Dobson et al. 1983).

Results and Conclusions

The detection limit of the NAA technique, specific to a filter paper matrix, was found to be 1.62×10^{-3} ug Dy. The level of dysprosium deposited at each sampling-station showed a similar trend of increasing concentration with decrease in sample height downwind from both sprayers. Deposits were highest downwind from the plots treated conventionally.

However, calculation of the amount of permethrin from these data indicates that pesticide deposits downwind from the plots treated with the Ulvamast are considerably higher than off-target deposits from conventional hydraulic applications.

These results confirm that NAA has the advantages of sensitivity, safety in the field, speed of analysis and reasonably low cost when compared with other quantitative techniques requiring expensive solvent extraction.

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3A—R12

THE ENCAPSULATED DROP SYSTEM TO ASSESS FORMULATION AND APPLICATION METHODS

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Background and objectives

The search for improving efficiency of pesticide sprays implies optimization of formulation and application techniques, reduction of volume to be sprayed and increased target contact. It is therefore crucial to know the specific drop sizes for each biological target in question. The emerging science of droplet encapsulation provides a system to study the aerial spray distribution and impingement on a conifer tree canopy. Two approaches were used, alterations in formulation properties and the volume of application rate, to characterize in each case, the size spectra and number of droplets impinging on balsam fir needles, and the volume of the spray deposited.

Materials and Methods

Two spray mixtures (B.t.I and B.t.II), containing *Bacillus thuringiensis* insecticide (B.t.) and the third containing sunflower oil (S.F.O.) as a mimic for fenitrothion, (F.M.-III), were formulated in aqueous media with variable types and amounts of polymeric components to give a wide range of viscosity and droplet evaporation values. The two B.t. mixtures were aerially sprayed over conifer forests at the rate of 2 x 4.7 L/ha to give a total of 9.4 L/ha, using a Cessna 188 aircraft fitted with four Micronair AU3000 atomizer units. The fenitrothion mimic, F.M.III, was sprayed at a much lower volume rate at 2 x 1.5 L/ha, to give a total of 3.0 L/ha, using a Cessna 185 aircraft fitted with the same atomizer units. Turbulent weather prevailed when B.t. formulations were sprayed, but with F.M.III, almost still air conditions existed. With all formulations, spray droplets underwent evaporation in flight resulting in encapsulation, and impacted on target matrices as microspheres. Droplets were also collected on Kromekote cards (K-cards) placed at forest floor in clearings made around sample trees. Determination of foliar surface area facilitated comparative evaluation of foliar droplets and deposit concentrations with those on the cards.

Results and conclusions

Data on formulation properties, spray droplet characteristics and deposition pattern are presented.

	B.t.I		B.t.II		F.M.III	
	Foliage	K-card	Foliage	K-card	Foliage	K-card
Drops/cm^2	3.5	27	1.9	21	1.1	3.3
nmd (um)	10	7.4	14	12	30	75
vmd (um)	46	58	40	40	94	144
Deposit* (ml/ha)	76	456	52	360	157	468
% Drop evaporation**	95.7		92.6		70.0	
Viscosity** (cp)	2.04		3.65		41.2	
Windspeed (km/h)	6.5 to 11		12 to 16		0 to 1.5	

*Determined by spectrofluorometry of extracts

**Measured in the laboratory at 20°C and 50% relative humidity

Analysis of variance indicated significant differences in droplets/cm^2 and spray volume deposited per ha between the B.t. formulations and F.M.III. These were attributable to formulation properties. F.M.III had a higher viscosity than the B.t. mixes and therefore provided larger droplet sizes during atomization. These droplets evaporated much less in flight than those of the other two and consequently were bigger during impaction on foliage and on ground cards. This resulted in higher volume of deposits for F.M.-III, in spite of the fewer droplets/cm^2. The two B.t. mixtures on the other hand, because of their high content of water and high evaporation rates, provided extremely small droplets having low impaction capabilities in spite of the favourable weather conditions during spray application. The conclusion of the study is that increased volume rates of application do not necessarily provide high deposits unless formulation properties are so adjusted as to cause optimum spray atomization and desirable droplet spectrum at the biological interface. Thus the influence of formulation properties exert a more pronounced influence than the weather factors and volume rates of application in enhancing spray deposition on the target matrices in a conifer forest ecosystem.

SPRAY NOZZLE AND PRESSURE TESTS FOR CABBAGE CATERPILLAR CONTROL

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Introduction

Insecticide spray recommendations often list a range of pressures and amounts to be applied per hectare for controlling the insects on a particular crop without regard to nozzle arrangement which may vary from sprayer to sprayer. Some grower differences of caterpillar control on cabbage in Florida when similar amounts of insecticides were applied suggested that method of application was responsible rather than the materials used. This paper reports tests of insecticide application for the control of cabbage caterpillars in N.E. Florida, U.S.A.

Materials and Methods

A tractor-drawn sprayer was used to apply dilute sprays of acephate, *Bacillus thuringiensis*, fenvalerate, methamidophos, methomyl, and permethrin to cabbage during 1980 and 1981 using Spraying Systems Co. TeeJet Hollow-cone nozzles in 5 sizes. Spray pressures included 17.6, 12.3, 10.5, and 7.0 kg/cm^2 which furnished spray volumes from 468 to 309 l/ha. The materials were applied 6 times each season to random--replicated one-row plots, 10 m long to control the major pests, cabbage loopers, *Trichoplusia ni*, and diamondback moth larvae, *Plutella xylostella*. Test results were measured by rating 80 plants/treatment at harvest using a system where marketable heads contained less than 5% feeding injury to the 7 loose wrapper leaves nearest the head and no injury to the head.

Results and conclusions

Cabbage marketability ranged from 35-100% and was highest where spray boom designs included nozzles on drop pipes at the sides of the plants near the soil level and decreased with reduction of drop pipe length. Marketability also decreased with reduction of spray pressure and volumes of spray tended to increase marketability but not to the level produced by 17.6 kg/cm^2 and 468 l/ha. Boom designs with 3-4 nozzles/row produced higher marketability than those with 5-6 when the same spray volume was applied indicating that droplet size is a factor. Cabbage marketability produced by fenvalerate and permethrin was the highest and was affected least by differences in spray nozzle number, arrangement, or pressure and volume. None of the plants in the untreated plots were marketable. The tests show that poor results with insecticides for cabbage caterpillar control in Florida may be related to poor application techniques which are not resolved by increasing insecticide dosages.

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3A—R14

SCANNING ELECTRON MICROSCOPY OF SPRAY MICRO-DROPLETS ON LEAF SURFACES

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Background and objectives

The advent of ultra low volume spraying has made it increasingly important to understand the behaviour, form and distribution of micro-droplets on leaf surfaces. The scanning electron microscope (SEM) is the obvious instrument with which to study such micro-droplets at high magnification and resolution. However the established methods of specimen preparation are not entirely suitable for this purpose. The simplest method is direct examination of fresh material, this has the following disadvantages:- (i) the tissue fluid evaporates in the high vacuum of the SEM as do the droplets, this causes the specimen to change in shape and size so that there may be considerable and varying artifacts in the image, (ii) it is difficult for the same reasons to evaporate and keep a conductive film on such a specimen with the result that it is only possible to view the specimen at low accelerating voltages in the SEM due to excessive electron charging at more normal higher voltages. The commonest method of specimen preparation involves chemical fixation in aqueous solution followed by dehydration in organic solvents and drying at the critical point in liquid carbon dioxide. This method is unsuitable because the passage through the various liquids, particularly the organic dehydrating agents removes or disperses the micro-droplets. It has recently become possible to examine biological tissue in the frozen hydrated state in the SEM, and we have developed the method so that the leaf with the micro-droplets upon it may be frozen very rapidly without immersion into the cryogen and examined over a prolonged period in complete stability.

Materials and Methods

Micro-droplets of various oil formulations were sprayed onto the surfaces of plant leaves using a microtip spray nozzle. Discs of the sprayed leaf c. 1 x 1 cm were glued to the specimen stub of the SEM with a small amount of fast drying electroconductive silver paint and inserted into the transfer stage of the sputter-cryo device, based on the design of Robards and supplied by Emscope Laboratories Ltd. The pressure in the transfer stage was reduced to c. 0.2 Torr to remove free water vapour and the specimen rapidly transferred under vacuum to the shielded freezing stage at a temperature of -150°C where it was held for 2 mins to freeze while the pressure was further reduced to 0.05 Torr. The pressure was raised to 0.1 Torr with cooled dry argon, and a coating of gold was sputtered onto the specimen which was then transferred, frozen and under vacuum, to a freezing stage on a Jeol T20 SEM for examination at 18.4 kV accelerating voltage.

Results and conclusions

This method of specimen preparation gave excellent preservation of the leaf cuticle and epidermal cells which remained fully turgid but undamaged as the rapid freezing did not permit the growth of large disruptive ice crystals. The micro-droplets, which were well preserved with clearly defined perimeters, did not appear to evaporate in the high vacuum (10^{-6} Torr) of the SEM due to the low temperature at which the specimen was held. The specimen stability enabled prolonged viewing to be undertaken without damage even at the relative high accelerating voltage. The surface of the specimen was free of frost because the rapid freezing is carried out in a partial vacuum from which the water vapour has been removed and the specimen remains under vacuum from then until examination is complete. The system described using the T20 SEM, which is a relatively low power instrument by modern standards is able to produce pictures between 35X and 10×10^3X magnification at a resolution of c. 15 nm. This magnification range is ideal for the detailed study of micro-droplet distribution and the shape, size and spread of individual droplets. Using this method we hope to determine the characteristics of different pesticide formulations on a range of plant species. We will also study the effect of aging on micro-droplets, and the relationship between droplet proximity and insect mortality with respect to static insects.

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3A—R15

EFFECT OF SPREAD OF PESTICIDES FROM SPRAY DROPLETS

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Background and objectives

Spread of a pesticide from spray droplets is an important factor affecting its biological efficiency. Only a small proportion of target organisms will be hit by ULV spray droplets, thus even under laboratory conditions $<$10% *Tetranychus urticae* eggs were hit by droplets landing on the leaf (Munthali & Scopes, 1982). A bioassay technique to study spread from droplets is outlined.

Materials and Methods

Monosize droplets of oil-based formulations of permethrin containing UV fluorescent tracer were sprayed, using a microtip nozzle (Uk, 1978), on tobacco leaf pieces (4 cm^2) infested with settled first instar whitefly larvae *Trialeurodes vaporariorum*. A single line (12 droplets/2 cm) was sprayed along the middle of each of ten leaf pieces for each treatment. Droplet size was determined using MgO coated slides. The leaf pieces were photographed immediately after spraying in monochrome under UV and subdued white light to show the droplets and larvae. Mortality was recorded four days later. Larvae which failed to moult were considered dead. Death was related to distance from droplets.

Results and conclusions

Mortality occurred within a known area around the droplet, which was influenced by droplet size, formulating liquid and concentration of active ingredient. Decreasing the droplet size from 114 to 59 µm and concentration from 20 to 5% considerably reduced the amount of active ingredient required to achieve 50 and 90% mortality, but more droplets were required (see Table).

TABLE

Effect of droplet size and concentration on toxicity of permethrin

	Effect of droplet size (Formulation JF 8133)		Effect of concentration (Formulation VK1)		
Concentration	10%	10%	5%	10%	20%
Droplet size (µm)	114	59	117	107	113
L Dist.$_{50}$/droplet (mm)	0.415	0.318	0.325	0.385	0.460
L Dist.$_{90}$/droplet (mm)	0.262	0.165	0.186	0.207	0.277
Biocidal area/droplet (mm^2)	0.541	0.318	0.332	0.466	0.665
LN_{50} (droplets cm^{-2})	92	157	151	107	75
LN_{90} (droplets cm^{-2})	232	585	460	371	207
LD_{50} (µg cm^{-2})	7.137	1.688	6.331	6.863	11.333
LD_{90} (µg cm^{-2})	17.997	6.291	19.288	23.797	31.278

LN_{50}, LN_{90}: Droplets number per cm^2 required to achieve 50, 90% mortality respectively

L Dist.$_{50}$, L Dist.$_{90}$: Distance where 50, 90% mortality respectively is reached

Biocidal area: Area where 50% mortality is reached

It is hoped that these studies could improve our understanding of the behaviour of pesticides on the target and indicate which factors modify the biological effect. Such information would help define the specifications for sprayers and formulations that could achieve effective target coverage with minimum wastage of spray material.

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3A—R16

THE TOXICITY OF ULV PERMETHRIN TO GLASSHOUSE WHITEFLY

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The effect of small pesticide droplets using Dicofol against red spider mite has been investigated (Munthali & Scopes, 1982). The glasshouse whitefly, Trialeurodes vaporariorum Westw. which, being static through most of its larval development, also provides an ideal target for the evaluation of spray droplets.

In the study, the effectiveness of oil-based formulations of permethrin combined with a u.v. tracer was evaluated against different larval stages.

Method

Individual leaf discs (1 cm^2) were cut from leaves of Nicotiana tabacum cv. Brazilian Blend, carrying eggs and larvae of uniform development. Numbers of targets were counted before spraying. Using a Microtip nozzle (Uk, 1978) monosized, discrete droplets were placed on the leaf discs. Sizes were determined on MgO slides and numbers of droplets were counted with the aid of a microscope under u.v. light.

After 4 days incubation, dead larvae were counted and % mortality assessed.

The LD_{50} (median lethal dose/cm^2) was estimated by probit analysis.

These tests showed that the dose needed to kill the young crawlers was as low as 0.07 mg/cm^2, but increased 15-fold by the third instar (Table 1). As with red spider mite lower concentrations and smaller droplets were more effective (Table 2) even though more are needed (Table 3). Doubling the droplet diameter increases the amount of chemical per droplet 8-fold. The biocidal area (half the treated area divided by the LN_{50}, represents the area of toxicity affected by the droplet) was also affected by formulation (Table 4).

TABLE 1

Instars	Droplet diam. (µm)	LD_{50} µg/cm^2
Eggs	46	0.0724
1st instar	46	0.2542
2nd instar	45	0.71
3rd instar	48	1.05

TABLE 2

1st Instar	LD_{50} µg/cm^2	
3 concentrations permethrin		
Droplet diam. (µm)	50	100
1%	0.05	0.39
10%	0.37	0.78
50%	5.93	11.88

TABLE 3

1st Instar	50% concentration	
Droplet diam. (µm)	47	100
LN_{50}	175	62
Biocidal area/drop (mm^2)	0.2857	0.8064

TABLE 4

2nd Instar - 10% permethrin formulations				
	JF8130	JF8132	JF8133	10% VK1
Droplet diam. (µm)	69	77	73	77
Ba mm^2	0.195	0.305	0.351	0.508

Conclusions

These data clearly shows the need to study these parameters affecting pesticide activity more closely so that clear guidelines can be given to engineers and biologists for further development of application equipment to improve spray deposition.

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3A—R17

EFFECTS OF SPRAY FACTORS ON THE CONTROL OF MARROW POWDERY MILDEW BY BUPIRIMATE

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Background and objectives

The modern tendency is to spray smaller volumes of liquid atomised into controlled-size droplets. Frick (1970) improved the control of apple powdery mildew (*Podosphaera leucotricha*) by decreasing drop sizes from 400 µm to 175 µm but attempts to use ultra-low volumes atomised into controlled small droplets have often been unsuccessful (Hislop, 1983). Thus an attempt has been made to analyse how spray factors affect control of powdery mildew, using an *Oidium* sp. on marrow as an initial model system.

Materials and Methods

Glasshouse-grown marrow plants (*Cucurbita pepo*) were sprayed with different numbers (1-50 cm^{-2}) of uniform-size droplets (120-300 µm) of water containing 3×10^{-3} g to 3 g/l of bupirimate. Fungicide-treated leaves were inoculated with known numbers of *Oidium* spores and incubated for 10 days. Numbers of colonies developing relative to untreated controls were analysed by weighted multiple regression with logarithmic transformations.

Results and conclusions

Effects of doubling spray parameters (and consequent changes) on infection

Parameters fixed	Parameter doubled	Dose	Vol.	Drop size	Drop No.	Dose/ Drop	Decrease in No. lesions (% + S.E.)
A Drop no. (7.5 cm^{-2}) Conc. (150 mg/l)	Drop size (140-280 µm)	x8	x8	x2	K	K	86(4.7)*
B Drop no. Conc.	Volume (≡ 3.6-7.2 l ha^{-1} leaf surface)	K	x2	x1.25	K	K	48(5.8)*
C Dose cm^{-2} (1.5 ng) Drop no.	Drop size (140-280 µm)	K	x8	x2	K	x0.125	68(12.2)*
D Drop size (210 µm) Conc.	Drop no. (5-10 cm^{-2})	x2	x2	K	x2	K	37(1.7)
E Drop size Drop no.	Concentration (100-200 mg/l)	x2	K	K	K	x2	25(3.9)
F Dose cm^{-2} Drop size	Drop no. (5-10 cm^{-2})	K	x2	K	x2	x0.5	17(4.7)

All effects signif. (P = 0.01) *Effect is reduced as concentration increases; K = constant

Interpretation of these data is complicated because alteration of one parameter whilst keeping others fixed has different effects on spray characteristics. Thus doubling droplet size while keeping drop number and spray concentration constant (A) produces the largest improvement in control because dose and volume on leaves increased 8-fold. Much of this improvement in protection is attributable to the effect of volume since at constant dose and drop no. (C) an 8-fold increase in volume alone gave the second largest decrease in infection. Even a 2-fold increase in spray volume, associated with a 25% increase in drop size (B) or with a 2-fold increase in drop number (F), improved control by 48 and 17% respectively. The small difference in protection shown in (E) and (F) indicated the relatively minor importance of increased dose or drop number. (D) shows a combined effect of dose and volume.

In practice control of apple mildew (for which the above data are a preliminary model) has been attempted by decreasing spray volume and drop size. Thus at constant dose and droplet number, a halving of drop size would decrease the spray volume by 87.5% and our calculations predict that this would produce a significant (5% level) increase in disease (212% ± 119) This might go some way to explain our difficulties in achieving adequate apple mildew control with ULV spraying. Work is in hand to test this hypothesis under controlled conditions and in a practical field situation.

References

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3A—R18

THE EFFECT OF THROUGHPUT ON DROPLET SIZE SPECTRA OF 80° FLAT FAN NOZZLES

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Objectives

Liquid pesticide application is a well established technique for controlling pests. Most users of conventional sprayers understand the principles necessary for changing nozzle spacings on a boom when changing to nozzles having different spray angles, and adjusting application rate by fitting nozzles with different throughputs. However, the effect of throughput on the droplet size spectrum has been largely overlooked. Previous work (Arnold) has shown the effect of changing nozzle angle on the droplet size spectra. This paper shows the effect of nozzle output for three different types of 80° flat fan nozzles.

Materials and method

The droplet size spectra of standard Spraying Systems 80° flat-fan nozzles were measured together with even-spray and low pressure series nozzles of equivalent throughput at 3 Bar and 1 Bar pressure respectively. A Malvern particle size analyser type ST1800 was used to determine the Volume Median Diameters (VMD's) of the three different types. The spray liquid used was water plus 0.1% Agral 90 and each nozzle was positioned 30 cm from the laser beam in a fixed nozzle holder ensuring identical nozzle orientation.

Results and conclusions

Over the range of outputs measured (Table 1) the VMD's of the low pressure nozzles are approximately 125 µm greater than those of the even-spray nozzles, and both increase linearly with increasing output. Even-spray VMD's are slightly but consistently lower than those of standard nozzles. As with the other two nozzle types the VMD's of standard nozzles increase linearly with increasing flow rate from the low output nozzles but more rapidly at higher flow rates.

Table 1: Variation in VMD with output.

Nozzle Type	VMD (µm)		
	Low Pressure	Standard	Even-spray
80005	-	117	-
8001	213	135	126
80015	230	153	137
8002	245	157	146
8003	288	184	169
8004	327	233	200
8005	377	327	225

The range of droplet sizes produced was also found to increase with inreasing output. The effect of output on droplet size should therefore be considered in addition to nozzle angle, spacing and pressure when changing nozzles.

References

Arnold, A.C. (1983) Comparative Droplet Size Spectra for Three Different Angled Flat Fan Nozzles. Crop Protection Vol. 2, No. 2, June 1983.

THE MEASUREMENT OF DROPLET SIZE SPECTRA - A PRACTICAL PROPOSITION

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Laser based instruments allow spray droplets to be measured in flight far more quickly and accurately than the collection techniques in use hitherto, which were time consuming, difficult to assess, and did not even collect smaller droplets.

We can use the computer print-outs actually produced by the Malvern ST2200 particle sizer to measure the relative efficiency of a spray. The table below lists 3 of the 6 lenses which cover the droplet sizes generally desired for agricultural sprays.

B	C	F	VOLUMETRIC VARIATION OVER 1 RANGE	2 RANGES	3 RANGES
188.0-87.2	564.0-261.6	1879.9-872.0	10.0		
87.2-53.5	261.6-160.4	872.0-534.5	4.3		
53.5-37.6	160.4-112.8	534.5-376.0	2.9		
37.6-28.1	112.8- 84.3	376.0-281.0	2.4	5.3	
28.1-21.5	84.3- 64.6	281.0-215.5	2.2	4.8	11.4
21.5-16.7	64.6- 50.2	215.5-167.2	2.1	4.6	10.1
16.7-13.0	50.2- 39.0	167.2-130.0	2.1	4.5	9.7
13.0-10.1	39.0- 30.3	130.0-101.1	2.1	4.5	9.6
10.1- 7.9	30.3- 23.7	101.1- 78.8	2.1	4.4	9.4
7.9- 6.2	23.7- 18.5	78.8- 61.5	2.1	4.3	9.1
6.2- 4.8	18.5- 14.5	61.5- 48.3	2.1	4.2	8.4
4.8- 3.8	14.5- 11.4	48.3- 38.0	2.1	4.1	8.4
3.8- 3.0	11.4- 9.1	38.0- 30.2	2.0	3.9	8.0
3.0- 2.4	9.1- 7.2	30.2- 24.1	2.0	3.8	7.5
2.4- 1.9	7.2- 5.8	24.1- 19.4	1.9		

It can be seen from this that the volumetric (i.e. dosage) variation between the largest and the smallest droplet in the lowest twelve size ranges remains roughly the same at 2-2.5 over one size range, 4-5 over two, and 8-11 over three size ranges. The top three size ranges should be excluded since the progression becomes too steep (i.e. the resolution is no longer constant). Because of this the upper size limit of droplets whose distribution can be accurately measured by the lenses shown in the tables above is as follows: A - 15µm; B - 25µm; C - 75µm; D - 150µm; E - 200µm; F - 250µm, although lenses of different focal lengths could be employed for other droplet sizes.

The relative efficiency of a spray can thus be seen from the proportion of the spray volume contained in the droplet size range required for the particular target. Over three Malvern size ranges the dosage variation is an order of magnitude different, and thus anything outside this can be classified as waste, being almost certain to be inappropriate for the target in both dosage and depositional terms.

I therefore propose, as shown in the table below, that all spray nozzles be characterised by the proportion of the spray produced within one, two, and three droplet size ranges of the droplet size aimed at, excluding, as stated, the top three size ranges for each lens. Ideally, for true CDA, all droplets would be within one size range but in practice a spray can be said to be CDA if over 80% of the volume is contained within the three ranges.

Sprayer type:	Rotary Atomiser
Nozzle:	Micromax
Operating parameters:	6000 RPM, 50 ml/min.
Desired droplet size:	75µm

Droplet size range (µm)	Dosage variation	% volume
64.6- 84.3	2.22	56.4
64.6-112.8	5.32	77.6
50.2-112.8	11.35	95.5
waste		4.5

3A–R20

DROP SIZE SPECTRA FROM FAN, CONE AND JET NOZZLES IN HIGH SPEED AIRSTREAMS

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Background and objectives

The drop size spectra is a major physical parameter that can affect both the efficacy of the pesticide application as well as the potential drift hazards. This research project was designed to evaluate the effects of air velocity, angle of nozzle relative to the airstream, flow rate, fan angle and cone angle on the volume median diameter , $D_{V.5}$, and also to determine the volume of spray that could potentially drift out of the target area. This drop spectra data is useful for operators of agricultural aircraft and ground air carrier sprayers.

Materials and methods

A digital image analyzing system, (Particle Measuring System Model OAP-2D-GA1 probe and PDPS 11C computer system), was used to measure drops that pass through a He-Ne laser beam of the probe. The unit can measure drops from 28 to 2062 µm in diameter and classifies them into 62 size classes. A series of commercial fan, cone and jet nozzles were tested at 276 kPa in a wind tunnel at an air speed of 160 and 240 km/h, and a nozzle angle of 0° and 90°.

Results and conclusions

Table 1 shows a summary of the drop size data. An increase in the flow rate (nozzle size) produced in increase in the $D_{V.5}$. At flow rates of 3.8 l/m or larger the nozzle angle relative to the airstream produced a predominate reduction in the $D_{V.5}$ with a change from 0 to 90°. At 0° nozzle angle and comparable flow rates, all fan nozzles produced a larger $D_{V.5}$ than cone nozzles. At a nozzle angle of 90° to the airstream, the type of nozzle had very little effect on the $D_{V.5}$. Table 1 also shows the percent volume in particles less than 154 µm. This volume represents a potential drift hazard. In general the data shows a sharp increase in potential drift hazards as the $D_{V.5}$ decreases.

TABLE 1

Volume Median Diameter and Percent Volume that may Drift

Nozzle Type*			Flow Rate 1/m	θ km/h	$D_{V.5}$, µm				% V. < 154 µm			
					0°		90°		0°		90°	
					160	240	160	240	160	240	160	240
8001,	80°	Fan	0.38		218	198	182	139	21.2	26.5	33.1	61.7
8044,	80°	Fan	1.51		334	259	242	170	7.7	14.4	18.1	39.4
8010,	80°	Fan	3.79		518	291	260	182	4.2	11.2	14.6	30.7
8020,	80°	Fan	7.57		651	332	295	212	2.9	11.0	11.7	20.9
D2-23,	63°	Cone	0.38		187	172	193	151	31.0	26.4	23.9	52.9
D4-45,	69°	Cone	1.36		255	214	223	171	13.4	17.9	17.0	36.7
D8-45,	90°	Cone	3.18		320	195	261	186	7.8	31.6	13.4	30.5
D8-46,	60°	Cone	6.96		455	271	304	189	3.7	10.1	8.7	30.1
D6,	0°	Jet	4.35		927	---	304	---	1.1	----	10.1	----

θ° = Noz. Angle Relative to Airstream

3A—R21 ✓

SUITABLILITY OF PESTICIDE APPLICATION EQUIPMENT TAKE OVER FOR SMALL SCALE FARMERS IN TROPICAL COUNTRIES

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The knapsack sprayer remains the most widely used equipment for applying pesticides on small farms in tropical agriculture, especially as the majority of pesticidal products are available as wettable powder and emulsifiable concentrate formulations. A farmer would need 2.8 h to walk across a hectare at 1 m/s treating a 1 m swath, but the actual time to treat 1 ha will depend on the availablility of water, size of fields, ferry distance to where the pesticide is mixed and the time needed to prepare the spray. Times calculated from the Baltin (1959) equation (Table 1) show how the total time is affected by volume rate and distance to the water or mixing site. In practice many farmers need 3-4 man-days (8 h/day) to treat one hectare, especially if water is not readily available from a neighbouring stream or bore hole.

Table 1: Calculated time (h) to treat 1 ha with a knapsack sprayer

Volume rate l/ha (loads)		1000 (67)	500 (33)	250 (17)	125 (8)
Distance to Water	100 m	12.2	7.5	5.2	4.1
	1000 m	45.4	24.0	12.2	8.3

Swath 1 m Walking speed 1 m/s: Approximate number of loads for 15 l sprayer.

This long period of manual work in hot climates discourages many farmers from adopting pesticide use, especially when a crop is very susceptible to damage and may require several treatments. In Malawi only about 25% of cotton farmers were prepared to use knapsack sprayers due to difficulty in getting water. Herbicide application is particularly difficult as water supplies are often inadequate at the start of the rains when weed control is vital. Spraying is quicker if the volume of spray is drastically reduced (Table 2), especially if swaths wider than 1 m can be treated. Adoption of ULV techniques depends on farmers being provided with the appropriate formulations in suitable packaging with clear instructions and spare parts to facilitate maintenance.

Table 2: Calculated time (h) to treat 1 ha with ULV/CDA sprayers.

Swath Width (m)		1	2	3
Volume application Rate	1 l/ha	3.05	1.72	1.05
	3 l/ha	3.33	2.00	1.33

Assumes operator walks 100 m to refilling point. Walking speed 1 m/s.

More rapid treatment is not only less arduous to the operator, but allows applications to be timed more accurately in relation to the level of pest infestations, whereas farmers needing 4 man-days to treat their crops have insufficient time to monitor pest levels. Yields of ULV treated crops have generally been comparable with knapsack spraying. Hand-held electrostatic sprayers which require less power (0.1 watt) have now been developed. These can improve deposition and also decrease pesticide contamination at soil level in some crop situations (Endacott, 1982). This reduction in environmental contamination should allow greater survival of non-target species including natural enemies of pests and thus allow greater integration of chemical and biological control.

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3A—R22

REDUCED VOLUME APPLICATION OF GRANULOSIS VIRUS, CPGV, FOR CONTROL OF CODLING MOTH, *CYDIA POMONELLA*

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Background and objectives

In field trials in several countries, Cpgv provided good selective control of codling moth (Payne, 1982) thus allowing biological control of certain secondary pests, including spider mites. Results are reported of field trials comparing the efficacy of Cpgv applied at medium volume (MV) and ultra-low volume (ULV) aimed at potential economy of virus dosage in ULV (Morgan, 1981). Because of the known short persistence of viruses in the field (Richards & Payne, 1982) certain adjuvants (u.v.-protectants) were also tested.

Materials and methods

Replicated trials during 1981-82 were in a mature apple orchard (trees 4-6 m high, 200/ha) with a natural infestation of codling moth supplemented by releases. First sprays in each season were timed for the commencement of egg hatch, estimated from pheromone trap catches and heat sums. Fallen and picked fruit were assessed for codling 'stings' and 'deep entries' on treated and untreated plots. Active virus presence was measured by bioassay of washings from sampled leaves on neonate larvae. In 1981, virus was formulated in water with 1% Acronal and 0.01% Agral 90 and in 1981 with 0.02% Agral 90 and 0.2% skimmed milk and with 10% 7E mineral oil (Philips-Duphar) for ULV only. Droplets from hydraulic nozzles were measured by a Malvern droplet analyser and from the 'Turbair Tot' by magnesium oxide-treated slides placed in trees.

Results and conclusions

TABLE 1

Percentage fruit with codling moth deep entries (% reduction compared to untreated trees, in parentheses)

Cpgv capsules/ tree	Spray volume/ ha	1981 (2 sprays)	1982 (3 sprays)
6×10^{10}	MV, 600 l	1.2 (88)	1.3 (89)
6×10^{10}	ULV, 50 l	3.6 (64)	3.0 (74)
Untreated		10.1	11.6

In 1981, sprays were applied MV (droplet vmd 236 μ) by tractor drawn 'Commandair' mist-blower, and ULV (vmd 103μ) by a hand-held spinning-disk sprayer 'Turbair Tot'. The control from MV was superior, although bioassays revealed similar initial deposits/unit area and virus half-lives from both spray volumes. The poorer control from ULV may have resulted from less complete coverage, fewer droplets per unit area, and an inadequate air-flow to reach the tops of large trees. In 1982, in order to equate the air flow, the same 'Commandair' was used with conventional nozzles for MV (vmd 236μ) and modified with TX-3 cone-jet nozzles (Spraying Systems Ltd) for ULV (vmd 154μ). However, control was again inferior at ULV. Damage was evenly distributed in untreated trees, but with both spray volumes control was poorer in the upper than in the lower halves of tree canopies. Of the u.v.-protectants control at 50 l/ha was not significantly improved by formulation of Cpgv with 0.5% of the polyflavinoid 'Shade' (I.M.C.) or 0.25% of the benzophenone derivative sulisobenzone. The influence of virus concentration, droplet size and distribution on larval mortality appears to be crucial, and studies on this aspect continue.

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3A—R23 ✓

THE POTENTIAL OF REPEATED LOW DOSES OF HERBICIDES

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Background and objectives

The technique of repeated low doses of herbicides has been used with good effect for controlling weeds in sugar beet (May, 1982) and the principle may have some relevance for weed control in cereals (Ayres, 1982). This paper offers further evidence on the use of this technique in controlling annual weeds and discusses its potential in relation to low volume application.

Materials and Methods

Phenmedipham, metamitron or a mixture of ioxynil and linuron were applied as repeated low doses in spray volume rates of 240 and 60 l/ha to annual weeds. Four successive applications of reduced rates of ioxynil, mecoprop and isoproturon were applied either alone or in two way mixtures to dicotyledonous weeds growing in winter cereal. Applications were made at a spray volume rate of 200 l/ha. In all cases the repeat low doses were compared with single doses, the total application of active ingredient being the same. Weeds were assessed by either counts, scores, ground cover or dry weight.

Results and conclusions

In all experiments timing was the most important single factor with treatments that removed weeds at an early growth stage giving the best control. There was no difference between volume rates for phenmedipham or for metamitron applied at the cotyledon stage, but when weeds were between cotyledon and first true leaves there was an advantage in using low volumes for metamitron but not phenmedipham. The mixture of ioxynil and linuron gave better weed control applied in 240 rather than 60 l/ha.

In cereals, the two way mixtures were the most effective treatments particularly those containing ioxynil. Four low doses of the single herbicides were as good as the first full rate applications. Spring assessments suggest that two or three applications would have been sufficient but this was not tested.

Repeated low dose programmes will be most cost effective where herbicides are expensive and the overall rate can be reduced or where savings in labour and machinery can be made. However, the technique may still be feasible for relatively inexpensive herbicides when other applications for the control of pests or diseases are also required and tank mixes are possible. In order to maximise work rates and reduce the risk of soil damage the technique must make use of low spray volumes and low ground pressure vehicles. In sugar beet the technique has taken over from the traditional band spray and tractor hoe on many farms and this has been shown to be cost effective and to have many practical advantages (Breay, 1983). Low ground pressure vehicles would allow more frequent applications at even lower doses and this may improve crop safety. Soil applied herbicides would appear to be well suited to this technique as residual activity can be increased with additional applications and in addition they are effective at spray volumes as low as 60 l/ha (May and Ayres, 1978; Ayres and Cussans, 1980). However not all herbicides maintain biological efficacy at lower volume rates and these compounds may not be suitable candidates. Similarly compounds that require a relatively high threshold dose to be effective or are applied at later crop growth stages may also not be suitable for the repeat low dose approach.

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3A—R24

WEED RESPONSE TO SPRAY AND 'WIPER' APPLICATIONS OF TRANSLOCATED HERBICIDES

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Background and objectives

There are many opportunities for using 'rope-wick' and other 'wiper' or direct contact applicators to control a wide range of weeds in many crop situations. The equipment is relatively simple, easy and cheap to construct, but more difficult to evaluate and describe how to use than conventional spray applicators. The herbicide loadings achieved vary greatly between and within target species (Lutman et al, 1982). More information on the amount of herbicide needed to control individual weeds would enable more soundly based progress.

The objective of the work reported was to determine weed response to two translocated herbicides when applied either as an overall spray or as water or gel-based smears.

Materials and methods

Plants of Rumex obtusifolius (broad-leaved dock) were grown singly in pots and the treatments (3 replicates) were applied when the foliage had a spread of 40 - 50 cm, a mean plan area of 500 cm^2 and shoot dry weight of 6.5 g.

Commercial formulations of dicamba (240 g/l) and glyphosate (359 g/l a.e.) were applied as 500 l/ha sprays with a conventional hydraulic nozzle at rates of 0.3 to 4.2 kg/ha. The amount of herbicide retained per plant was calculated from dye recovered from similar plants sprayed with herbicide plus dye. This enabled the smear rates to be compared with the sprays. The smears were applied to single leaves as 180 g/l solutions in water or 2% calcium alginate (Oswald, 1978) with a Gilson 'Pipetman' micropipette at volumes of 24, 60 or 150 µl, equivalent to sprays of 1.0, 2.5 and 6.2 kg/ha respectively. The liquid was smeared over an area of approximately 9 cm^2 with a glass rod.

Results are presented for root fresh weight 90 days after treatment.

Results and conclusions

The sprays of dicamba and glyphosate reduced root weight more than equivalent rates of the smears. The dicamba spray at 0.7 kg/ha gave a 90% reduction, but 2.5 kg/ha of smear was needed for the same response. With glyphosate 1.7 kg/ha of spray was needed for a 90% reduction and more than 6.2 kg/ha as a smear.

The method of application affected the relative response to the two herbicides. Dicamba produced significantly larger reductions than glyphosate as a spray and significantly smaller reductions as a water-based smear.

There were significant differences between the water and alginate based smears. Alginate significantly reduced root weight with the low (1 kg/ha) rate of glyphosate from 30 to 19% of the untreated. This was the only difference between the glyphosate treatments. Dicamba, in contrast, showed significant differences between rates with the water-based smear, giving a 39% reduction with 1 kg/ha and 96% with 6.2 kg/ha. The effect of adding alginate was rate dependent. At 1 kg/ha the alginate smear was more active than the water-based smear and significantly reduced root weight. But at 2.5 and 6.2 kg/ha the alginate-based smear was less active and the roots were significantly heavier than with the water-based smears.

Three factors relevant to the selection of herbicides for direct contact application to R. obtusifolius emerge: 1) smears are less effective than sprays, 2) the relative activity of different herbicides can vary with the method of application, 3) alginate thickened smears can be either more or less effective than water-based smears, and this can vary with the rate of herbicide.

Future developments in direct contact application could produce more predictable field performance if based on, 1) the loadings achieved with the various applicators at different settings and in different weather conditions, and 2) the dose response of target weeds to the herbicides and formulations available. Consideration should be given to the influence of alginate and other thickeners on the loadings achieved and their influence on rainfastness.

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3A—R25

PP969 : A BROAD SPECTRUM SYSTEMIC FUNGICIDE FOR INJECTION OR SOIL APPLICATION

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Background and objectives

Most systemic fungicides used to control foliage diseases are applied direct to the foliage. Exceptibns are ethirimol and triadimenol, which are applied to cereals as seed treatments. Attempts to make greater use of the systemic properties of chemicals have frequently failed because the fungicides have been insufficiently mobile, especially in perennial crops.

In screening tests, PP969 was found to be much more active against disease when applied to the soil than when applied direct to the foliage. This was more marked than with other triazole fungicides, and indicated that the compound has high mobility in a wide range of plant species. PP969 was therefore used to explore the benefits of novel application methods, particularly in the control of foliage diseases of perennial crops.

Materials and Methods

PP969, (5*RS*, 6*RS*)-6-hydroxy-2,2,7,7-tetramethyl-5-(1,2,4 triazol-1-yl)octan-3-one, was first synthesised at Jealott's Hill by Dr P. A. Worthington. It was tested on coffee, apple and banana either by single application (to the roots or to the stem) or by a regular programme of treatment.

Coffee plants (50-95cm tall) grown in a glasshouse were inoculated repeatedly with rust (*Hemileia vastatrix*) after treatment with PP969. Application was by soil-drench or as a viscous formulation smeared on to the stem surface. Apple trees in a commercial orchard were treated in the spring with PP969. Application was to the soil or by injection into trunk, with or without pressure. Banana plants were treated for control of sigatoka (*Mycosphaerella musicola*) by injection of the soil near the base of the pseudostem using a large syringe or by application of a granular formulation.

Results and conclusions

The coffee plants were protected from rust for long periods by single applications of PP969; 30 weeks by soil-drench with 62mg/plant, and 10 weeks by stem surface application (50-100mg/plant).

On apple trees a soil-drench (10-15g/tree) gave more than 80% control of mildew (*Podosphaera leucotricha*) for 20 weeks and similar control of leaf scab (*Venturia inaequalis*) for 6-8 weeks. Pressure injection into the trunk using as little as 300mg/tree gave similar levels of control but only over 7-8 weeks. On bananas, soil injection at a single point gave better control of sigatoka than standard spray treatments; 250mg per plant injected every 14 days gave disease control superior to chlorothalonil sprays (700mg/plant) on the same schedule. To obtain the same level of disease control using a PP969 spray required about twice the quantity of active ingredient as soil injection. Frequency of application, placement and volume were important. For example, injection of 500mgs PP969 every 28 days was less effective than injection of half the rate every 14 days, although still comparable to the standard chlorothalonil spray. Granules of PP969 were less effective than either injections or sprays.

Control of foliage diseases of perennial crops with PP969 by soil or stem treatment may require fewer applications or less compound than normal foliage sprays and it is therefore attractive. Further work is needed to evolve practical procedures for application of the compound.

3A—R26

APPLICATION OF PESTICIDES TO THE SEEDBED BY THE VERTICAL BAND TECHNIQUE

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The new technique of blowing pesticides into vertical bands in seed-bed soil (Whitehead, Tite & Bromilow, 1981) can be used to control soil-borne pests of both fibrous and tap-rooted crops.

A simplified machine, with distributors mounted behind spring-tine coulters 20 cm apart on the toolbar, was tested against potato cyst-nematodes on potatoes. Granules of aldicarb or oxamyl blown into vertical bands in the top 15 cm of the soil and incorporated laterally by rotary harrowing before planting susceptible potatoes controlled the nematodes just as well as the same amounts of pesticide applied to the soil surface and rotary cultivated-in. As with the earlier machine, this technique is faster and safer than rotary cultivating the pesticide in and does not harm soil structure. For control of pests throughout the top 15 cm of the soil the technique also has the advantage that it does not mix weathered surface soil with the deeper unweathered soil. This is important for crops grown in level seedbeds, especially those sown shallowly.

For early control of pests attacking the tap root systems of shallowly-sown crops, a vertical band distributor can be mounted in front of each seeder unit to apply pesticide in a vertical band in the top 7.5-10 cm of the soil. This ensures that pesticide is available to the young tap and secondary roots, for it does not depend on the leaching of toxicant into the rhizosphere. This technique could improve control of a number of soil pests.

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THE USE AND POTENTIAL OF SEED COATINGS

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Introduction

Seed treatments have been used for many years for the disinfection of fungal and pest infestations on the seed surface or around the growing crop, particularly in the staple grain crops of the world. (Jeffs 1978). Application of these treatments is carried out by seed merchants using a variety of equipment and aiming to stick a known quantity of chemical onto a known weight of seed. The treatments are formulated either as liquids or powders which require a little moisture to help them adhere to the seed and all these formulations contain some wetters and stickers. In short the formulations are very similar to those of products for use as topical sprays. However a different retention capability is required of a product to be stuck onto a seed as opposed to that sprayed onto a field crop. The seed is subjected to abrasive handling both during and after treatment, particularly with the smaller seeds such as carrot. This abrasive action tends to remove the seed treatment which can often be found subsequently as loose powder in the bag or seed drill. Thus the seed may be underdressed or unevenly dressed and often the powder forms into small balls in the drill and may finally block the coulters. Basically the seed treatment is initially required on the seed and then around the germinating seed to be absorbed by the seedling if systemic or protect it from insect and pest attack in its immediate vicinity. The increasing use of systemic materials alone and in mixtures, necessitates even greater precision of application and retention on the seed, since each seed must carry its individual protective requirement. The use of mixtures results in heavy loadings of chemicals which are difficult to achieve with present machinery and difficult to maintain during pre-drilling handling.

Concept of Seed Coatings

Seed coatings provide the solution to many of these problems and have other advantages over topical applications. Initially they were used on small seed such as sugar beet and bulb onion seed to increase the seed size thus allowing for greater precision in drilling and at the same time applying various chemical treatments. However accurate seed treatment is also required in situations where an increase in seed size is a disadvantage. Salad onion and carrot seed for example are drilled at a high seed rate per unit area, (6,000,000 per acre for carrot), and the larger the seed the more difficult it is to achieve such high densities. But they also require insecticidal protection against their respective flies, Delia antiqua and Psila rosae, and ideally a fungicidal treatment. Seed coating is able to solve this problem.

Advantages of Seed Coatings

The newest coatings mimic the discreet shape of the seed and increase seed weight by less than 10%, whilst providing higher loadings of chemical and yet maintaining individual chemical efficiency. The numerous pesticides can be applied to the seed with a greater degree of accuracy, because of the nature of the application method. Now in the development stage is equipment for treating large volumes of larger seed such as peas and beans where it is becoming increasingly necessary to treat with several different compounds. In peas for example the traditional treatment was for the control of the "damping off" diseases. But where seed is infected with Ascochyta spp an additional systemic treatment is required and for early peas the danger of downy mildew infection requires another different systemic fungicide. These 3 treatments cannot be performed satisfactorily with conventional machinery and the final seed loading is too high to be retained on the seed satisfactorily with conventional formulations.

With seed coating there is less danger of abrasion reducing the pesticides loading, since the outer skin of the coating is formed of the sticker and not of the active components. Hence there is also less loose material to block the drill and the seed flows more readily.

All these are advantages to the grower in terms of ease of drilling, better crop establishment and a reduction in the need for topical spray applications, especially those early sprays where traditionally there is difficulty in timing the spray correctly. Seed coatings are environmentally safer since rates of active ingredient applied are reduced compared with topical sprays, and the materials are placed where they are needed and so reduce soil contamination. (Blackett, Toms 1983). They therefore form an essential element in integrated pest management.

3A—R27 contd.

Potential

The above discussion indicates an increased cost/benefit ratio to the grower from seed coatings with a reduction of contamination of the environment. It also reduces the number of operations required by the seed merchant in treating the seed and thus reduces treatment cost.

At present the equipment available is only able to treat small quantities of seed, but increases in machinery capacity should allow for treatment of the large volumes required for the oil seed rape, cereal, and cotton markets. With these crops chemical pest and disease control is moving towards using a combination of systemic and contact materials requiring accurate placement on the seed. Coating would be an ideal method of application, and the resultant seed treatment would be of benefit to the grower and the overall environment.

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STUDY OF APPLICATION METHODS FOR THIOFANOX

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Background and objectives

Thiofanox (3,3 dimethyl -1- (methylthio) 2- butanone 0- (methylamino) carbonyl oxime) is commonly used on potatoes in row treatment at planting time to control aphids and colorado potato beetles. The applied rates vary from 2 to 3 kg of a.i/ha (Hofmaster). Our aim was to determine the minimum effective rate by using a different application method.

Materials and Methods

Field experiments were conducted in 1982 in Rhone-Poulenc Agrochimie stations: Villefranche and Emerainville, France. A band treatment was realized on a width of 25 to 30 cm and the granules were then incorporated on a 15 to 20 cm dephth. Finally, rows were opened and potatoes were planted. Three rates were used : 0,5 ; 1,5 and 3 kg of a.i/ha.

Results

- On aphids, the effectiveness of thiofanox was excellent at 1,5 and 3 kg of a.i/ha till 55 days after treatment ; the population on the plants treated with 0,5 kg of a.i/ha were low. e.g 10 % of the nontreated.
- On potato beetles, total control was obtained till harvest with the two highest rates. The lowest rate of 0,5 kg of a.i/ha gave a good control - 80 to 90 % of mortality - also till harvest time. The selectivity was good.

Discussion and conclusions

These results show clearly that a band treatment with a low rate is sufficient under field conditions to protect the crop. Now then is thiofanox currently applied in seed furrow treatment, for instance on cotton or on sugarbeet at rates from 0,8 to 1,5 kg a.i/ha. Trials are in progress to determine the optimal application method and the minimum rate on a range of crops : rape, sugarbeet, cabbage, bean. Three application methods are compared :

- seed furrow treatment,
- band treatment on a 15-20 cm width,
- broadcast treatment.

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3A—R29

SOIL TREATMENT WITH INSECTICIDES TO CONTROL THE FIG FRUIT FLY

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Background and objectives

Infestation of fig fruits with Silba virescens (Macquar) of 50% and 90% have been reported in Iraq, (Rao, 1922; Anonymous, 1979) where spraying with pirimiphos methyl or dichlorvos three times between the end of March and the middle of June has been recommended for its control (Plant Protection Dept. 1980). Since hibernation and pupation take place in soil under infested trees, experiments were designed to evaluate soil treatment with selected insecticides as a method of controlling this pest.

Materials and methods

Three experiments were conducted, one in the laboratory and two in a fig orchard in which the pest was well established. One field treatment was made in March (prior to adult emergence from hiberating pupae), and the other in June (when the fly population was high). Four insecticide treatments were employed with three replicates of each: diazinon 10% granules or 60% e.c., fenvalerate 20% e.c. and methidathion 40% e.c. In the laboratory and March applications, rates per 2500 m^2 (or 500 g or ml a.i. per downum) were used. The dosages in the field test in June were doubled.

The laboratory test was conducted in one kg. plastic containers, one for each replicate, filled close to the top with soil so that the soil surface area was 104 cm^2. One day after treatment, 20 third instar larvae were placed in each container, the top of which was then closed with cheesecloth fastened with a rubber band to trap emerging adults inside. For both field tests, wooden cages, one for each replicate, were placed on treated soil. Each cage measured 1 x 1 x 0.3 m, covered on top with black cloth and one glass jar screwed on each of opposite sides to a ring lid with screen cone to trap the emerging adults. The March test depended upon the natural emergence of adults from soil hibernating pupae. In the June test, 20, third instar larvae per cage, were placed on the soil surface. In all tests, liquid insecticides were diluted with water and sprayed with a small (1 litre) plastic hand sprayer. The granular form was applied by hand.

Results and conclusions

In the laboratory, diazinon and fenvalerate were very effective in preventing development and emergence of fig fruit fly adults. Mortality rates of 91.9%, 94.7% and 97.4%, were observed for diazinon granular, diazinon liquid and fenvalerate respectively. On the other hand, methidathion was less effective, causing only 42.2% mortality. Similarly in the field, diazinon (granular and liquid) and fenvalerate, prevented 84.8%, 81.8% and 75.7%, respectively, of adult emergence, but methidathion was ineffective.

Soil treatment during a period of high fly populations in early June, showed parallel results to the earlier field test, but since the dosage was double that of the earlier test, mortality was relatively higher. No fly emerged from diazinon treated plots, while 97.6% mortality occured in fenvalerate plots and 92.6% in methidathion plots. Thus methidathion at this dosage is effective.

These results indicate that diazinon 10% granules or 60% e.c. and fenvalerate 20% e.c. are very effective insecticides against the fig fruit fly. This experiment shows that soil treatment could replace foliar sprays, but further tests on the number of insecticide applications, treatment intervals, dsages and volume of water diluent are required

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STUDIES ON CHEMICAL CONTROL OF MUSHROOM CECID FLY* LARVAE

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Several insecticides were tested for the control of cecid fly larvae by either mixing chemicals in compost, casing soil, or spraying on mushroom beds. All treatments, except diflubenzuron, showed a significant reduction in larval densities; treatments of chlorpyrifos, methoprene, malathion, and endosulfan were more superior than the other insecticides. Insecticides mixed in casing soil gave the best control among the three treatment methods. Mushroom yields were not significantly affected by most treatments except when chlorpyrifos was mixed in casing soil. Treatments of diflubenzuron, methoprene, or malathion with casing soil significantly increased the mushroom yield. Residues detected in all treated mushrooms were under acceptable thresholds. Inhibition of mycelial growth following insecticide treatment of casing soil or compost was found to be highest with ethoprop (ED_{50} 10.8 ppm), then in decreasing order chlorpyrifos, endosulfan, pirimiphos ethyl, malathion, methoprene, methomyl and oxamyl (ED_{50} 3240 ppm). No adult cecid flies were captured by the light trap. Cecid fly larvae were found again in the soil under the floor of mushroom houses, and larval densities were higher in the old growing houses than the new ones.

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*Heteropeza pygmaea Winnertz

3A—R31

LABORATORY FOR PEST CONTROL APPLICATION TECHNOLOGY: RESEARCH ON DOSE TARGETING

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Background and Objectives

Pesticides will continue to play a major role in plant protection for the foreseeable future. Current delivery mechanisms are relatively inefficient and need greater accuracy for successful implementation of IPM control strategies and manipulation of pest resistance. A new multidisciplinary research team was formed to increase communications between biologists and engineers and to develop a better understanding of the role of the toxicant and to increase control of its delivery to various targets. Dose targeting can serve to reduce the potential for pest resistance, act as substitute for selective pesticides, and reduce costs of unnecessary environmental and human exposure.

Methodology

The following examples of team research by members of LPCAT (18 faculty in 5 disciplines) illustrate gains made by interfacing activities in pesticide application research.

Results

Air-, and electrically, and photoelectrically operated intermittent sprayers were developed for applying insecticides on plants spaced apart and utilized 40-50% less pesticides than conventional boom sprayers. On cabbage, cauliflower, and pepper, insect control was equal with each delivery system.

A study of 4 high density apple orchard management systems showed close relationships between tree height, leaf density and tree volume and deposits of permethrin. The final delivery rate is dependent upon accuracy of the match between canopy target volume and sprayer capacity. A study of potential sprayer adjustments and actual pesticide use rates at the user level shows great potential for dose/crop volume targeting.

A third example of team research involves a study of the impingement process and the droplet/target surface interface. Effect of surface structure, formulation and drop size greatly affect the impingement process. Coupling high-speed photography and SEM allows a greater understanding of the energetics of the impact process. Electrodyn® -generated permethrin illustrates dramatic avoidance reactions by phytophagous mites. Mortality, dispersal, feeding and fecundity responses of mites were directly correlated to drop density. Hence dose targeting, in the broadest sense, is likely to assume a greater role in the success of these newer, more active pesticides containing more than mortality functions.

The key limiting factors for dose targeting decision rules include availability of expertise to advise on pending problems, adequacy of record keeping systems, adequacy of equipment, availability of time frame or weather windows to adjust to options, and an adequate source of economic information on alternatives. Successful implementation of dose targeting applications should also include: (1) known infestation level relationships, (2) availability of simple sampling protocols, and (3) implies that all other crop production methodology is being accomplished in an acceptable manner (which, however, may not be the case). Hence, multidisciplinary team research on pesticide application techniques is required to solve these complex crop protection problems in the modern agroecosystem.

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A COMPUTER ASSISTED METHOD FOR CHECKING GROUND SPRAYRIG ACCURACY

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Background and Objectives

It has long been known that many farmers do not check the condition of their equipment frequently enough or determine accurately the rate and deposition pattern of their ground spray equipment. Investigations by research and extension personnel in Nebraska several years ago indicated that one in three ground pesticide applicators was making significant errors in application. Calibration mistakes, equipment condition, and configuration were causing a great proportion of these losses. The losses were: 1) crop injury; 2) poor pest control; 3) chemical waste. The Nebraska study showed that one in three applicators was making errors greater than ten percent. The losses due to misapplication were estimated nationally based on the Nebraska results and were found to be approximately one billion dollars.

During 1982, Montana State University developed a computer assisted method for determining ground sprayrig accuracy. It was dubbed Operation SprayCheck and was enthusiastically received and accepted by the ground sprayrig operators in Montana. The Montana Operation SprayCheck demonstrated that ground sprayrig operators were losing in excess of one million dollars in Montana alone due to poorly operating equipment.

Since we believed that significant losses due to mistakes were also occurring in Colorado, and since it was obvious that traditional sprayer calibration efforts had not done an adequate job, our new approach was to bring greater awareness by introducing equipment that would demonstrate the misapplication patterns graphically and emphasize the economics of proper calibration through the use of rapid computer calculations and printouts.

Materials and Methods

The Colorado Operation SprayCheck involves checking a number of factors at five stations through which equipment is rotated to facilitate rapid analysis of each sprayrig. The data is put into a computer and actual output is then printed and electronically compared to what the applicator thinks he is applying.

The first station is set up for the applicator to answer a series of check-list questions to determine the condition and type of equipment being used. The second station is a 200-foot measured distance over which applicators run their rigs at speeds equivalent to those used in field operations. After being timed over the distance, they are directed to each of three remaining stations where data is collected on equipment performance.

At one station, called the pressure check, equipment configuration is documented while pressure is checked at three locations across the boom. The sprayer's pressure gauge is also compared with a standard for accuracy. At the output station, nozzles are checked for individual flow rates across the entire boom. The amounts collected for each nozzle are recorded and later fed into the computer.

The amount of material that is deposited on a spray target cannot be accurately determined by output or flow rate sampling. To be able to examine this important component of application, special pattern analyzing pans are used. These pans split the spray flow into two-inch increments across the pattern. An accurate volume determination can then be assessed to determine if boom height and nozzle spacing are properly alligned. This is the fifth and last station through which the applicators run their rigs.

Results and Conclusions

Once the information is collected from all stations on a sprayer, the applicators proceed to the analysis table where their performance data are fed into a field computer. Along with the collected data, specific information on what the applicator perceives his application rates to be, as well as economic information on the products he applies, are all fed into the computer. The computer then analyzes what the actual sprayer's performance is and compares this with what it should be. Application equipment error is calculated and graphic displays aid in determining problem areas. Changes are then computed for pressure, speed, or nozzles to improve to 100 percent accuracy. As an incentive, the economics of a specific application are calculated for cost of chemicals and dollars wasted from application or equipment error.

Preliminary SprayChecks in Colorado indicate that, on the average, sprayrigs are being operated with thirty percent error in their application. It is the goal of Operation SprayCheck to assist the ground sprayrig operators in correcting their equipment to operate at a level of error of ten percent or less.

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3A—R33

INFLUENCE OF AIRCRAFT WAKE ON THE PENETRATION OF ULV SPRAYS INTO A COTTON CANOPY

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In a dense crop, such as cotton, it is often difficult to achieve spray penetration into the lower half of the cotton canopy. In December 1980 a series of experiments were carried out in the Sudan Gezira to investigate what role aircraft wake might play in improving spray penetration into irrigated cotton.

It was decided, firstly, to establish how differences in aircraft wake affect in-crop turbulence and, secondly, to establish if differences in in-crop turbulence caused by changes in aircraft wake result in measurable changes in spray deposit and penetration.

Measurement of Aircraft Wake

A series of purpose built instruments was developed to measure vertical turbulence. These consisted primarily of sensitive vertical wind vanes linked electronically to tape recorders.

The results from the wake experiments showed:-

1) The high wing monoplaned Pilatus Porter when operated normally produced 1/3rd of the turbulence of the equally heavy low wing monoplaned Thrush aircraft.

2) The Pilatus Porter could produce equivalent turbulence when operated at 80 Kts and 15° flap.

3) Even though distinct differences in turbulence were measured, turbulence levels were low and could be masked by atmospherically induced turbulence at wind speeds above 3-4 m/sec, dependent on crop density.

Spray Deposit Measurements

Two sets of paired experiments were carried out under identical meterological conditions using fluorescent tracer techniques and leaf sampling.

The first set of experiments compared a Pilatus Porter operated under standard conditions to that operated at 80 Kts with 15° of flap. Over 800 samples were taken during the 4 separate paired experiments.

In the second set of experiments a Thrush aircraft was compared with a Pilatus Porter again operated under standard conditions. 500 leaf samples were taken in the 6 paired experiments.

In both sets of experiments no detectable differences were found in both spray deposit or penetration.

General Conclusions

That large changes in aircraft wake provide no detectable improvement in spray penetration in a cotton canopy because of the large attenuation created by the crop canopy.

NEW INSTRUMENTS FOR RAPID SPRAY DEPOSIT ASSESSMENT

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Introduction

The efficiency achieved by most pesticides in the field depends on how well and evenly they are distributed to the biological targets with the least contamination of the non-target surfaces. Spray droplet sizes play a key role in fulfilling this aim. The knowledge of droplet sizes and deposit distribution on various surfaces in the field is fundamental to further refinement of efficiency.

Particle Sizing Instrument for Droplet Size Measurement

Methods of droplet sizing include the slow microscopic technique with eye-piece graticule, the semi-automatic image shearing instrument and the sophisticated computerised image analysers. None of these methods can include on its own, all the features essential to the evaluation of pesticide application, i.e. speed, portability, suitability for measurements on natural surfaces, and low cost. The ICAP Particle Sizing Instrument has been developed to satisfy these requirements. It automatically sizes the droplets by image shearing while the operator counts. By leaving the operator to discriminate the droplets from interfering backgrounds, samples of less than ideal contrast, particularly those on natural surfaces, can be appraised without difficulty. A BCD output is provided for interfacing with micro-computers to ease storage and/or speed up statistical processing of data. At 100X optical magnification, the instrument is pre-calibrated to measure from 10 to 100 µm in steps of 10 µm for the linear arrangement or from 4 to 100 µm following a $\sqrt{2}$ progression. There are thus 10 size classes for the linear or the $\sqrt{2}$ increments which may be chosen by a selector switch. Larger or smaller ranges of particle sizes may be measured at lower or higher optical magnification and each size class corrected by multiplying the original value by (100/new magnification).

Surface Fluorimeter for Spray Deposit Measurement

Detailed distribution of deposits in the sprayed field is another crucial aspect of efficiency assessment. To make the evaluation relevant to the pest to be controlled, large number of biological samples must be analysed within the shortest time possible. There is a need for an instrument which is reliable, simple and able to withstand field use. The ICAP Surface Fluorimeter is a version of such an instrument it operates on 12 V DC car battery and may be used in the vehicle parked in the field. The instrument measures the light emitted from deposits of spray containing fluorescent tracer on leaves or other surfaces from the sprayed area. Reliable minimum detection was in the order of ten 50 µm or five 100 µm droplets per cm^2 of Neon Red or Saturn Yellow fluorescent pigments on field bean or cotton leaves. The instrument readings may be translated into amounts of spray deposited per unit area of the collecting surface by means of a series of calibration curves. The advantage lies in simplicity of operation in the field immediately after spraying. It dispenses with specialised technical skill and ancillary laboratory glasswares and reagents which give rise to difficulties with time, safety and cost.

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3A—R35

THE GIROJET AND VERY LOW VOLUME SPRAYING

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The volume of spray applied per hectare in plant protection is reducing every year. Today the average rate in the U.K. is about 250 l/ha against 350 l/h in France and West Germany. This reduction in volume allows a higher daily work rate, lighter sprayers and lower costs. There is however a limit with conventional spraying of 80 to 100 l/ha below which mechanical problems will occur such as blockage of nozzles, pressure losses, and other factors.

The GIROJET is the only centrifugal flat jet nozzle for very low volume spraying, which produces a vertical jet. The spinning disc is mounted vertically with an effective spraying angle of 140°; while the remaining upper 220° segment of the disc is shrouded. Liquid collected in this stroud is directed to a sump from which it is sucked back into the feed line by a Venturi. The feed tube allows the liquid to flow directly and perpendicularly on to the centre of the disc, which is driven directly by a 12 v electric motor, the speed of which is adjusted by a rheostat according to the required droplet sizes. Any disc speed can be selected from 1000 and 4200 RPM.

The GIROJET is a unique nozzle combining the advantages of a vertical jet with very low volume. As the droplets are vertically spun off at great speed they have the shortest trajectory to reach the target giving greatly improved opportunity for better crop penetration and reduced drift. Uniform and regular ground coverage is obtained by the central feeding of the disc. The maximum spraying capacity is 1 l/min and any standard chemical formulation can be sprayed. The GIROJET is very easy to mount and therefore can be available, for a large number of applications, such as incorporation, band spraying, and broadcast spraying.

After 3 years testing, TECNOMA have marketed since 1982, the GIROJET mounted as standard on a sprayer, the TG 412, featuring a 400 litre capacity mounted tank, a 12 m boom with 8 GIROJETS and AUTOREGULATOR (ground speed related output system).

This sprayer can treat 16 ha at 25 l/ha with one filling. User results have confirmed trials, and shown the success of the GIROJET on the following crops: Pre and post-emergence herbicides on cereals, sugar beet, maize, potatoes and oil seed rape; fungicides on cereals, sugar beet and potatoes; growth regulators on cereals, and insecticides on cereals, sugar beet and oil seed rape

The acceptance of very low volume spraying will bring on the market improved equipment with additional specifications. This new generation of sprayers offers much lighter equipment than commonly used today, but capable of treating the same area quicker.

It is now possible to spray at the right time, irrespective of soil conditions for the best efficiency of the chemicals.

EFFECT OF DROPLET TRAJECTORY ON CEREAL CANOPY DEPOSITS

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Small drops carried by the wind, settling slowly at a shallow angle below the horizontal level, impact more readily onto vertical surfaces of a cereal crop than larger drops. Also in general circumstances, they penetrate to lower levels of the canopy less completely than larger drops. The latter pursue a shorter path than small drops and also their steeper paths are likely to encounter less cereal foliage.

In all, at their respective terminal velocities, larger drops seem more likely to penetrate deeper into a cereal canopy. They may then produce a heavier spray deposit low down on the crop than smaller drops.

In practice since there may be little wind down in the canopy, small drops might also fall at a steep angle. On the other hand, larger drops impelled from nozzles can retain speeds in excess of their terminal velocities and can therefore follow, for several meters, paths inclined at any required angle to the horizontal, independently of the wind speed in the canopy.

To help understand the factors involved and to optimise the selection of drop sizes for use on cereals, for various biological objectives, experiments have been carried out to measure the effects of droplet trajectory alone, whether caused by projection or by settling, at angles to the vertical of 0, 30 and 60 degrees.

Large differences were found in:

a) penetration to the ground below the canopy,
b) chemical distribution on the cereal plants,
c) chemical recovery on the cereal plants.

The results shown below could be valuable for the development of improved boom spraying from the ground, giving the farmer/contractor simple ways of concentrating the chemical being applied onto particular target zones on the crop or the ground beneath. [The canopy was thin by normal standards and in practice, differences would not be so large usually.]

	ANGLE DEGREES		
	0	30	60
	Deposit Density		
30 cm tall canopy			
Top third of plant	55^{a}	$90^{a,b}$	$428^{b,c}$
Bottom third of plant	91^{a}	296^{b}	183^{c}
Ground below	814^{d}	$493^{d,e}$	238^{e}
10 cm tall canopy sprayed along the rows			
Whole plant	123^{g}	274^{g}	507^{f}
Ground below	875^{h}	727^{h}	496^{f}

Statistically significant differences were absent from results marked with the same letter.

3A—R37

CONTROLLED DROPLET APPLICATION OF SELECTED FORMULATIONS TO CEREAL CROPS IN THE UK

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Summary

Following the recent increase in interest in low volume controlled droplet application of pesticides, a series of replicated field trials was laid down in 1983 to evaluate selected formulations of Shell herbicides.

Cyanazine/CMPP, cyanazine/MCPA, CMPP and l-flamprop-isopropyl were evaluated in winter and spring cereals at full and threequarters of the recommended rate of active ingredient. Applications were made, using a Landrover mounted boom fitted with three Micromax rotary atomisers, at 20 and 40 l/ha at nominal drop sizes of 150 and 250 μm. Conventional applications were made with a Landrover mounted boom and nozzle assembly, at 100 and 200 l/ha, depending on the product recommendation.

Winter crops were treated between growth stages 31 and 33 whilst spring crops were sprayed at growth stage 31.

Results in the winter crops showed that due to poor crop penetration CDA gave less consistent and a generally poorer level of broadleaf weed control than conventional application at 200 l/ha. Conventional application at 100 l/ha gave similar results to controlled droplet application. In the thinner, more open spring crops, controlled droplet application gave similar although less consistent results when compared to conventional application at 100 and 200 l/ha.

There was no consistent difference between CDA at 20 and 40 l/ha, nor between 150 and 250 μmicron droplet sizes.

Application at threequarters of the recommended dose rate of product did not give acceptable weedcontrol. Above observations were made from the broadleaf weed trials only as the wild-oat trial results were not to hand at the time of writing.

3A-R38 WEAR-RATE COMPARISONS OF A SELECTION OF HYDRAULIC NOZZLES IN COMMERCIAL USE

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3A-R39 PROBLEMS OF ORGANISING AND CONDUCTING HAND-HELD ULV TRIALS

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