The addition of oils to pesticide formulations in spraying

by

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Abstract

Most pesticide sprays diluted in water are applied with nozzles which produce a wide spectrum of droplet sizes. Evaporation of the diluent water during transfer from the nozzle to the target occurs especially under certain climatic conditions, when prevailing temperature is high and humidity is low. The effect of adding oil to water based spray formulations was investigated both under a series of temperature and relative humidity conditions in the laboratory and in the field under natural conditions to determine to what extent evaporation would be minimised.

When sprays with a narrow droplet spectrum were produced with a spinning disc nozzle the addition of oil increased viscosity and reduced flow rate through a single orifice so that at a given disc speed smaller droplets were produced, but larger droplets were produced if the flow was constant irrespective of viscosity.

Droplets of water significantly decreased in size while falling 200 cm from the nozzle even in conditions of low temperature and high relative humidity, (18^{o}C, 69%). The addition of oil did not totally prevent evaporation but the change in size of droplets was less especially if the proportion of oil was at least 10 - 15%.

In the field more droplets of sprays with oil were collected on artificial targets and leaves within 0.25 - 16 m of the spray nozzle than when water sprays were applied.

Droplets emitted from an Exhaust Nozzle Sprayer were detected much further downwind owing to the higher level to which droplets were projected upwards above the tip of the exhaust nozzle

and to the wide droplet spectrum produced.

Laboratory evaluation of two new organophosphorus insecticides namely, propetamphos and etrimfos, 2% w/v of each, indicated LD50s of 6.4 and 15.8 and 59.6 and 60.9 µg/g of body weight respectively to adult and 5th-instar locusts (*Schistocerca gregaria* F.) for a 12 hour post-application period.

On the basis of spray deposit assessment downwind of a spray formulation applied with a multiple-disc sprayer, control of locusts (*S. gregaria* F.) would be achieved with 64 m swath or more depending on prevailing wind conditions.

Similarly with greater control of droplet size, a higher yield of wheat was obtained following the control of cereal mildew (*Erysiphe graminis* DC) with CDA (controlled droplet application) sprays with 50% of the recommended dosage of triadimefon fungicide and greater control of the spray formulation than with conventional sprays (200 l/ha) although seed treatment was the most effective means of controlling the disease.

The results confirmed that the addition of oil stabilized droplet size and together with the use of a spinning disc nozzle to give greater control of the production of droplets should contribute to greater efficiency of sprays and allow the use of lower dosages of active ingredient.

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List of abbreviations

a.i.	= active ingredient
ALRC	= Anti - Locust Research Centre
Appx.	= Appendix
CDA	= Controlled droplet application
C^o	= Centigrade (of Celsius's thermometer)
cm^2	= square centimetre and CM^2 is also used in the text
cm^3	= cubic centimetre
CON	= control i.e. untreated
COPR	= Centre for Overseas Pest Research
deodorized	= The term is synonymous with deodourized in text
DS	= dressed seeds i.e. seeds are treated prior to sowing.
Fig.	= Figure
g	= gramme, the term is synonymous with gram in text
g/cm^3	= grammes per cubic centimetre
g/m^2	= grammes per square metre
ha	= hectare
HV	= high volume
ICCC	= Imperial College Computer Centre
in^2	= square inch
kg	= kilogramme, the term is synonymous with kgs in text
km^2	= square kilometre
l	= litre
lb	= pound
l/ha	= litre per hectare
m	= metre and M is also used in text
M%	= mean percentage mildew infection
ml/ha	= millilitres per hectare
ml/m	= millilitres per minute

List of abbreviations

mN/m	= milli newtons per metre
m/s	= metres per second
NMD	= Number median diameter
ODA	= Overseas Development Administration
Para.	= Paragraph
oz	= ounce
rad/s	= radians per second
rev/min	= revolutions per minute (synonymous with rpm, or r.p.m. in text)
RH	= relative humidity
S. Dev.	= Standard deviation: the term is synonymous with SD in text
Stacked - disc	= The term is synonymous with multiple - disc in text
SSS	= Sunoco sun - spray
ULCC	= University of London Computer Centre
VMD	= Volume median diameter
w.a.	= wetting agent (teepol was used as wetting agent)
w/v	= weight per volume
X	= mean
ε	= summation sign
μm	= micrometre

1. INTRODUCTION

1.1 Problems

Application of synthetic insecticides has increased enormously since the development of DDT in the 1940's and despite the appearance of undesirable side effects, the use of insecticides remains a key tool in integrated pest control. Similarly with increased labour costs, more and more herbicides are used to reduce competition with weeds and although selection of crop varieties with disease resistance is of paramount importance, the use of fungicides is also increasing. This world wide trend in the greater use of pesticides is due to the need for rapid short term action and is essential in man's continued struggle to reduce crop losses and the spread of diseases. With increases in cost of pesticides, their use should be minimized as far as possible and fully integrated with other methods of control.

Ware (1975) reported that 75% of all pesticides were applied as sprays either as particulate or globular suspensions (i.e. wettable or flowable or emulsifiable concentrates) in water. Many users prefer the emulsifiable concentrates as they are easier to measure and mix in contrast to wettable powders. These sprays are applied through a variety of spray nozzles which are generally classified according to the energy used to form the droplets e.g. hydraulic, gaseous, centrifugal. kinetic and thermal energy (Matthews, 1973a). The most commonly used nozzle is the hydraulic nozzle. Irrespective of the spray pattern achieved, the spray is produced from the irregular break up of thin sheet of liquid which emerges from an orifice in the nozzle tip. Fraser (1957, 1958) described three distinct modes of disintegration, but whichever mode occurs, droplets in any spray will vary considerably in size. For example with a fan nozzle (8002) at a pressure of 2 bar, 0.25% of the volume of spray formulation (water + 0.1% Agral) was of droplets less than 16 μm and the same sample had 9% of the volume over 440 μm droplets (Arnold, 1979). This wide range of droplet sizes, results in poor efficiency as the smallest droplets with a low terminal velocity are liable to drift and the largest droplets falling rapidly may bounce off foliage (Lake, et al., 1978) or coalesce and cause 'run off'. Thus the extremes of the spray distribution contribute to the exo-and-endo drift as defined by Himel (1974). Failure of droplets to reach their targets within a spray area or drift to areas beyond the operational boundary is responsible for the contamination of the environment.

Most sprays are diluted in water so evaporation of the diluent results in a decrease in droplet size between the nozzle and target. The effect of evaporation is enhanced in the case of the emulsifiable concentrate formulations as the solvent, such as xylene is also volatile so the smaller droplets decrease in size and may become 'dust' particles. Formulations based on water evaporate much quicker under hot, dry climatic conditions frequently found in Savanah and desert areas of the tropics. Water based droplets would shrink in size in seconds (Bals, 1970a). Indeed the life time of a 100 μm droplet of water at 30^{o}C, 50% RH is only 14 seconds (Amsden, 1962). The effect of evaporation is thus a major factor in reducing droplet sizes so that they contribute to 'drift' (Maybank et al., 1974).

The initial impetus to develop a spray technique using minimal volumes of less volatile liquid was in a desert area where water was not readily available. Lorry loads of treated bait had been used against desert locust hoppers (Schistocerca gregaria F.*)

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* Schistocerca gregaria (Forskäl)

and red locust, (*Nomadacris septemfasciata* Serville) (Gunn *et al.*, 1948a, 1948b and 1952), but a more rapid spray technique was required. In the 1950's the Exhaust Nozzle Sprayer (ENS) (Sayer and Rainey, 1958; Sayer, 1959; Sayer and Joyce, 1966) was developed to fit a Land-Rover or similar truck to apply an oil-based spray with 70-90 µm droplets of dieldrin at ultra-low-volume using a system of 'vegetation baiting' [(1)] (Courshee, 1950, 1952, 1955 and 1959). Swaths of vegetation were treated at 264 ml/ha (8 ml/m along the line of travel) in a cross wind of 3 - 5 m/s (8 mph). On one occasion a band about 300 m long of 2nd- and 3rd-instar hoppers, which crossed the treated area six days later was almost completely killed (Sayer and Rainey, 1958).

Further development of ultra-low-volume spraying on agricultural crops was delayed because of the phytotoxicity of the oils on crop foliage (Shaw and Timmons, 1949; Havis *et al.*, 1950; Baker, 1970 and Martin, 1973) and lack of equipment suitable for applying such low volumes. The next upsurge of interest in ultra-low-volume was when technical malathion was promoted for agricultural and public health pest control. ULV spraying attracted world wide attention after the publication by Skoog *et al.*, (1965) of the experience of grasshoppers control in East Africa. Its systems of evolution and meteorological data was later analysed Skoog *et al.*, (1976). Technical malathion is a liquid containing 95% a.i. and of low volatility. Ultra-low-volume applications were principally applied by aircraft, for example a population of *Aedes aegypti* L., the mosquito vector of dengue haemorhagic fever in South East Asia

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(1) 'Vegetation baiting' is a term coined to draw attention to the elimination of bran which represented 98% by weight of the bulk which had to be transported to the field in control operations (Joyce, 1974).

was effectively reduced for 10 days post-treatment by two sprays at 430 ml/ha over a total of 18 km^2 in Thailand (Pant, 1974).

A study of the effect of ULV aerial application of malathion on epidemic malaria was encouraging (Lee, 1974 and Taylor, 1975).

ULV aerial spraying has also been developed for tsetse control. Hadaway and Barlow (1965) showed that 20 - 40 μm droplets were effectively collected by tsetse flies on cylindrical targets, representing branches placed in a wind tunnel. Recent work has shown that with the newer pyrethroids, control efficiency could be increased (Bullivant, et al., 1971; Elliot, 1977 and Elliot et al., 1973a, 1973b and 1978; Ruscoe, 1977; Breese, 1977; Breese and Searle, 1977; Lhostle and Pieallu, 1977 and Plapp and Vinson, 1977). A number of ULV trials in tsetse control have given satisfactory control (Irving et al., 1969a, 1969b and Tarimo, 1970 and 1974). Owing to the need to employ small droplets, with a ULV technique, it has been possible to disperse droplets with aerial spray methods within a swath width of 2 miles in order to control different types of pests such as house flies (Lofgren 1970 and Lofgren et al., 1970 and 1972), midges (Glyptotendipes paripes) (Patterson et al., 1966), horn flies (Haematobia irritans) and face flies (Musca autumnalis) (Kantack et al., 1966).

On agricultural crops the range of insecticides available as ULV formulations and equipment suitable for ground application remained limited. Hand-carried battery driven spinning discs were developed in the late 1960's and have subsequently been used to apply insecticides on cotton (Matthews, 1973b; Matthews and Mowlam, 1974; Beeden, 1974), fungicides on tomatoes (Johnstone and Huntington, 1977) and groundnuts (Mercer, 1976). Modified knapsack mistblowers have also been used for ULV application (Clayphon, 1974). Joyce

(1974 and 1975) suggested that the future potential of ULV application lies in such techniques which include drift, incremental and air-to-air spraying to meet specific biological targets defined by their geometry and extent in space and time.

Increased awareness of greater control of droplet size has developed to ensure efficient application of minimal volumes. This led to greater emphasis on controlled droplet application (Matthews, 1977a). Controlled droplet application refers to selection of the appropriate droplet size for a given target and also hitting the target with sufficient droplets to transfer the correct droplet to the pest. Thus CDA is ULV when applying the minimum volume to achieve economic control. Production of droplets within a narrow spectrum of sizes is achieved principally with centrifugal energy nozzles such as the Micronair [(1)] equipment used on aircraft and small electrically driven spinning discs (Bals, 1970b, 1973 and 1975b). The latter have been improved by adding teeth known as zero issuing points and grooves. As droplet size is inversely related to the peripheral speed of the rotating surface, droplet size can be selected. Himel (1969a) suggested that when the optimum droplet size is used, less pesticide is needed and environmental contamination is reduced. The optimum droplet size collected on insects and foliage is, however, usually less than 100 μm so greater attention is needed to formulation to reduce the effect of evaporation of solvents and carrier liquids.

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(1) Obtainable from Micronair (Aerial) Ltd., Bembridge Fort, Sandown, Isle of Wight, PO 36 8QS, England.

1.2 Aims

This study investigates the effect of the addition of oils to sprays on:

a) the formation of spray droplets,

b) evaporation and hence the size of droplets between the nozzle and target,

c) downwind movement of droplets and

d) deposition of droplets on leaves,

to determine whether the addition of an oil had a significant effect on the droplet spectrum achieved and increased deposition on target surfaces.

The method of drift spraying being conducive to vegetation baiting (on grasses), the results of these studies in particular, were considered in relation to the control of locusts (*Schistocerca gregaria* F.) by assessment of mortality of both adult and 5th-instar hoppers treated in the laboratory with dosages comparable to those which would be deposited on foliage when certain insecticides were applied.

The method of vegetation baiting by downwind drift of droplets was extended to the control of powdery mildew (*Erisiphe graminis* DC) on wheat. A narrow swath was adopted to allow overlap to achieve a better distribution of fungicide. CDA sprays were compared under field and laboratory conditions with conventional or high volume application when using the fungicide triadimefon (para. 3.4).

2. MATERIALS AND METHODS

2.1 Methods of droplet production

Production of droplets can be achieved with a number of different nozzles, but centrifugal energy nozzles are the most suitable for achieving a relatively narrow spectrum of droplet sizes (Walton and Prewett, 1949; Hinze and Milborn, 1950; Dombrowski and Lloyd, 1974 and Frost, 1978).

Walton and Prewett (1949) showed that:

$$\delta = k\frac{3.8}{\omega} \times \sqrt{\frac{\gamma}{D\rho}} \quad \text{--------------------(1)}$$

where

δ = droplet diameter (µm)

ω = angular velocity of disc (rad/s)

γ = surface tension of liquid sprayed (mN/m)

D = disc diameter (mm)

ρ = liquid density (g/cm^3) and

k = constant

The constant (k) has varied - 4.5 (May, 1949), 3.76 (Walton and Prewett, 1949) 3.8 (Yeo, 1961) and 3.68 (Fraser, 1956).

2.1.1. Droplet formation from centrifugal energy nozzles.

Droplets are formed from these nozzles in three ways:

a) direct droplet formation: fairly uniform droplets are thrown directly from the edge of the disc for direct droplet formation provided flow rates remain minimal.

b) ligament formation: liquid forms threads on the ligaments which become unstable and disintegrate into droplets a short distance from the disc.

c) sheet formation: a film of liquid on the surface of the disc extends beyond the periphery and breaks up in an irregular fashion producing uneven droplets (Hinze and Milborn, 1950).

2.1.2 Types of centrifugal energy nozzles used

Three types of plastic, toothed and grooved spinning discs were used:

a) Micron-Herbi: An 8 cm diametre with flat centre and 1.2 mm wide flange around the edge angled at 60^{o} on the inside of which were 360 grooves, one groove to each of the peripheral teeth. The disc was designed for a hand carried herbicide applicator, the Micron 'Herbi' (1) (Bals, 1975a). The DC motor supplied with disc has a governor to control speed at 2000 rev/min. In an experimental hut (2.4 x 2.4 x 3.7 m) the spray head of the disc was used with an AC power source via a power pack. Droplets were sampled at 30 and 200 cm distance below a suspended 'Herbi' nozzle operated under temperature conditions of 18 and 42^{o}C.

b) Micron Mini-Ulva: A cup-shaped plastic rotor of 5.5 cm maximum diameter and 2 cm deep with the sides tapering to 3.0 cm diameter base. Johnstone and Johnstone (1976 studied a prototype of this disc with 360 teeth known as the Mini-Ulva (2) with reference to its power requirement and droplet size characteristics. His study indicated that with the 5.5 cm disc, VMD/NMD ratios of 1:1.3 were possible when spraying an oil (HLP 40) at 8.5 ml/min at 15,000 rev/min., producing 41 µm VMD droplets or with 26 ml/min at 12,000 rev/min. 52 µm VMD droplets were obtained.

The 5.5 cm disc with electric motor was mounted for droplet studies in the laboratory as shown in Fig. 1.

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(1) and (2) Trade names of Micron Sprayers Ltd., Three Mills, Bromyard, Herefordshire, England.

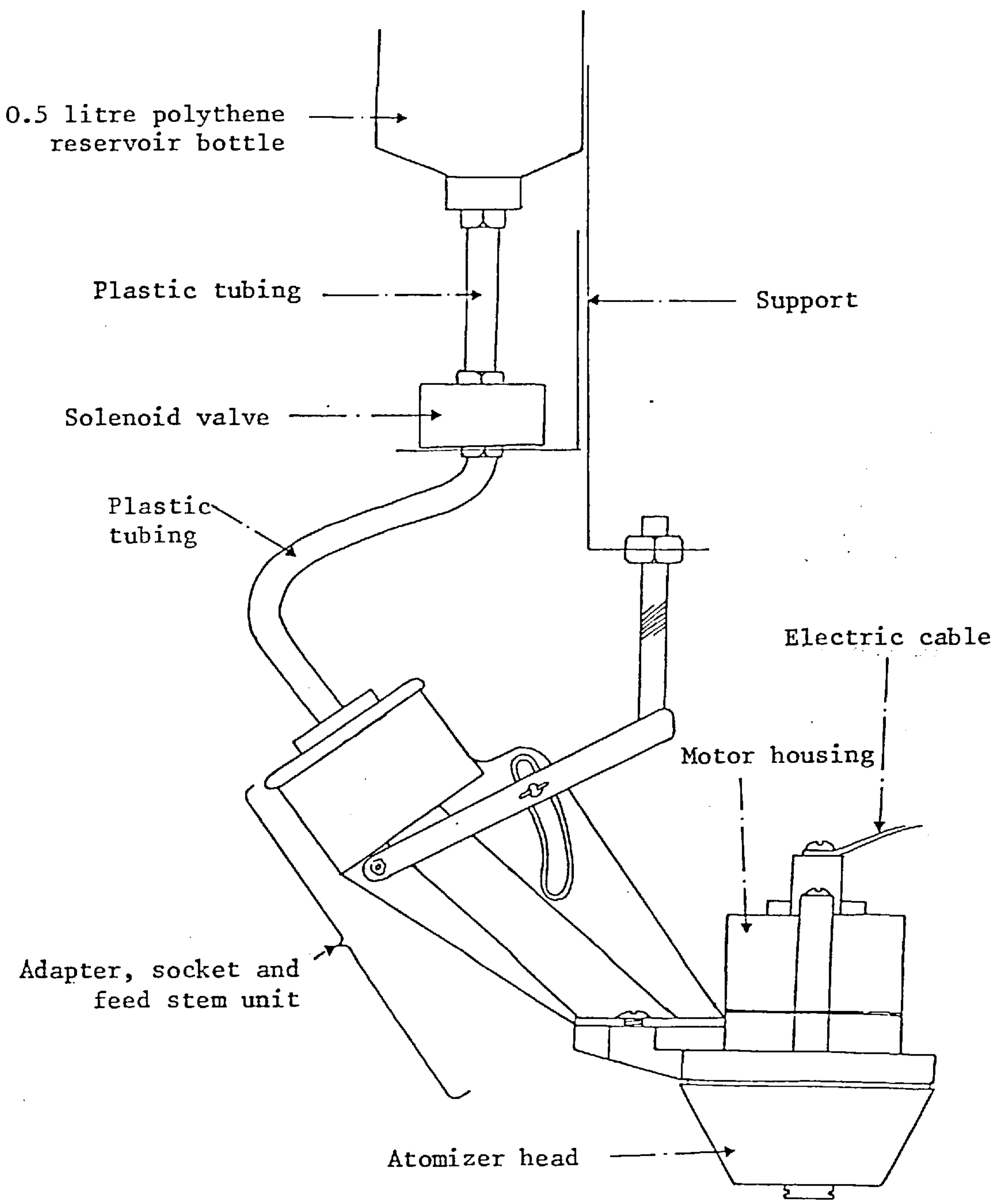


Fig. 1 The spinning atomizer as suspended in a laboratory hut.

c) Multiple-discs: A series of plastic discs (as b) above) up to 15 in total were arranged to rotate on a stationary shaft (Bals, 1977). This multiple-disc nozzle was used both in the laboratory and in field studies (Fig. 2) of the downwind movement of droplets.

The spinning discs described above produce droplets without any directional control of their movement towards a target. Dispersal is dependent on gravity and natural air movement.

In the field trials a DC power source 10 - 12 HP.2 batteries was used to power the 5.5 cm disc. Similarly a 12-volt DC battery on the Land-Rover was used to power the multiple-disc unit.

The power requirement in relation to the speed of the multiple-disc unit was examined with or without liquid flow. Rotational speed of the unit in this study became unstable when 12 volts was exceeded, the irregularity of speed becoming more pronounced when the flow of liquid was 150 ml/min i.e. 10 ml/disc (Fig. 3 and Appendix I. Table 1).

2.1.3 Exhaust Nozzle Sprayer (ENS)

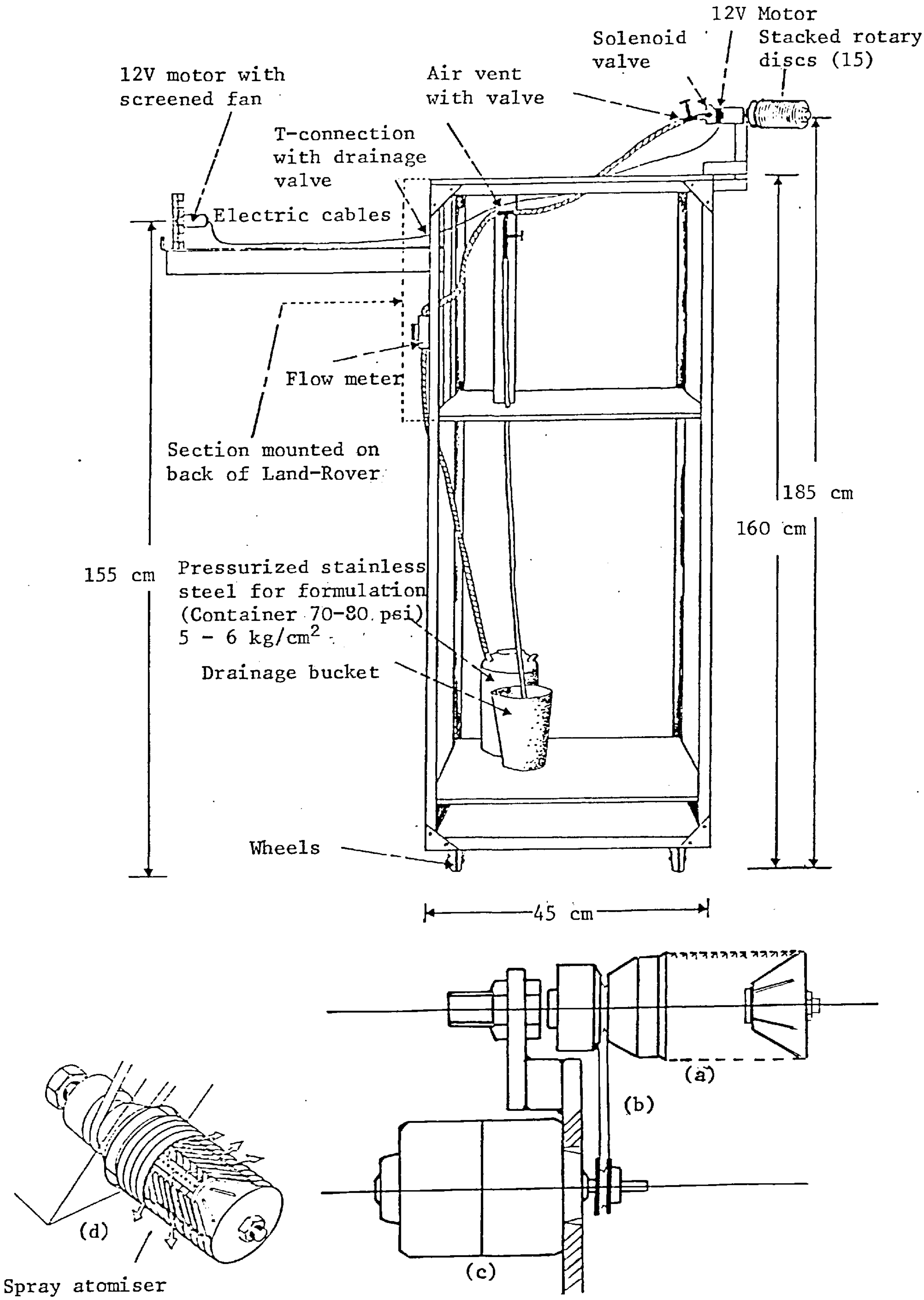
The Exhaust Nozzle Sprayer had been the earliest used for ULV application so its performance was compared with the multiple-disc (spinning disc) nozzle (Plate 1). An MK II Exhaust Nozzle Sprayer (Watts et al., 1976) was attached to a long-wheel Land-Rover Station Wagon with a 4-cylinder 2286 cc petrol engine (Plate 2).

2.1.3.1. Operational temperature of the Exhaust Nozzle Sprayer

To assess whether the heat from the exhaust gases would affect the temperature of the spray liquid the operation temperature of an Exhaust Nozzle Sprayer was measured with a digital thermometer [(1)].

(1) Supplied by Comark Electronics Ltd., Thermometer Type 3001, $-50 + 800^{\circ}C$, uses T1/T2, NiCr/NiAl Thermocouples.

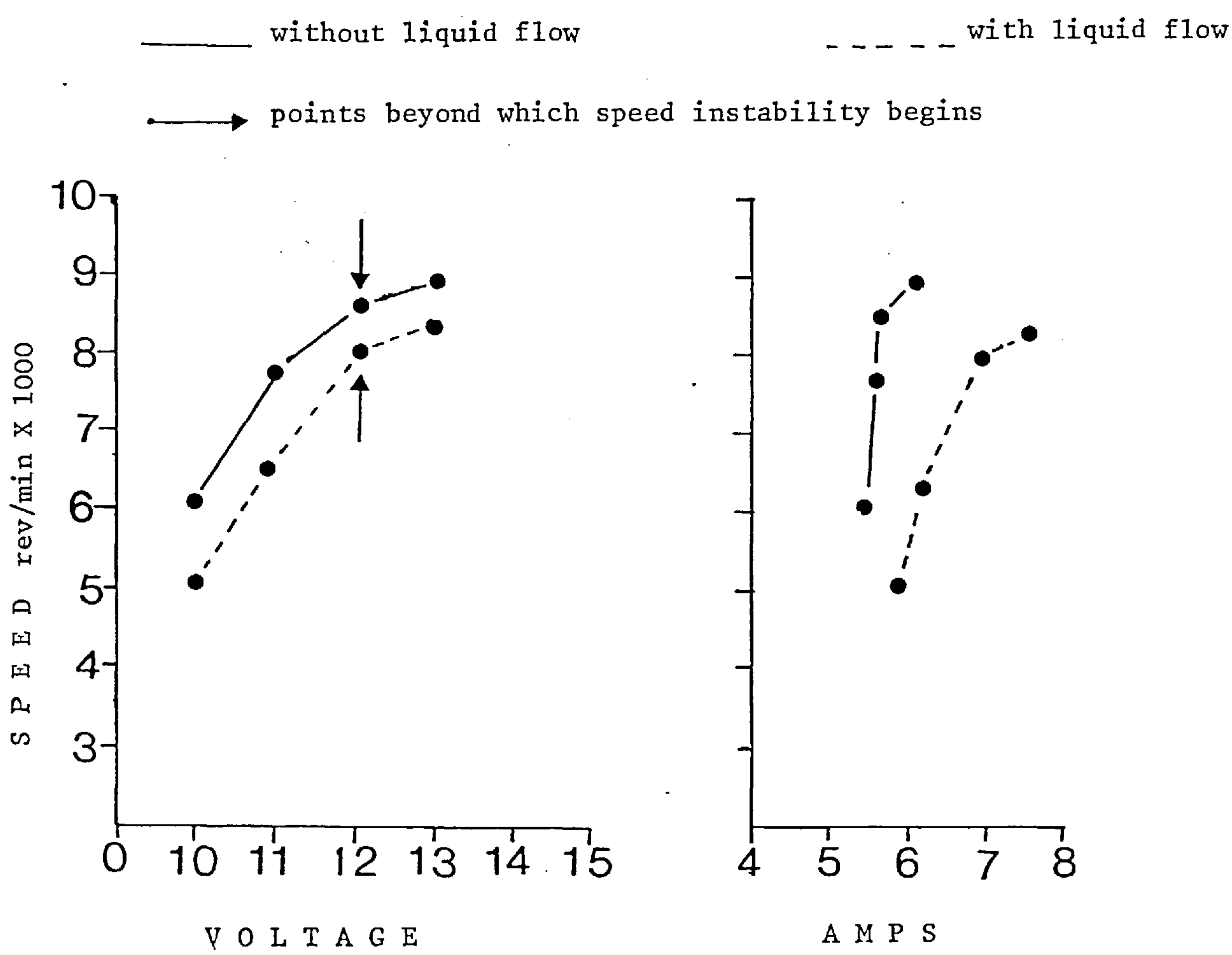
Fig. 2 Multiple - disc spinning discs as used in the laboratory and field studies of the deposition of spray droplets.



a) Position of multiple - discs, b) drive - belt, c) motor and d) an array of multiple - discs showing points of droplet release.

(psi = pounds per square inch)

Fig. 3 Rotational speed of multiple-disc in relation to voltage.



The probe was inserted directly into the nozzle and restrictor to a depth of 8 cm.

The initial temperature readings were taken after running (idling with medium acceleration) the engine for 10 minutes and then continued at intervals of 10 minutes (in both nozzle and nozzle restrictor, Fig. 4 for up to 40 minutes without introducing any liquids. At the 50th minute spray was introduced and thereafter readings continued to be taken after every 10 minutes up to 80 minutes. The procedure was repeated over a period of four days (only one complete set of readings was taken each day) and the mean results obtained over the period was plotted (Fig. 4).

The temperature of the spray nozzle rose within 10 minutes of the engine being started from a mean of 54 to 77°C at which it remained fairly constant until spray was introduced. The introduction of deodourized kerosene as a spray liquid reduced the temperature of the nozzle initially to a mean of 35°C then the temperature increased slightly to 38°C. An increase in the tank pressure from 0.1 to 0.2 bar, resulted in the temperature being reduced to a mean of 24 and 23°C at the 70 and 70th minute respectively (Fig. 4).

The temperature of the restricting nozzle rose after the initial idling period of 10 minutes from a mean of 44 to 67°C. However, with the introduction of the spray through the nozzle the temperature of the restrictor nozzle was reduced from 67 to 53°C but rose to 60°C at a tank pressure of 0.1 bar; with increase of the tank pressure to 0.2 bar first, the temperature fell to 57°C and then rose to 75°C where it remained during a 50 to 80 minute testing period.

The surface temperature of the flexible tube through which the exhaust gas was taken from the vehicle to the spray tank was

Fig. 4 Operational temperature of Exhaust Nozzle Sprayer

A = without spray

<u>Tank pressure 0.1 bar</u>

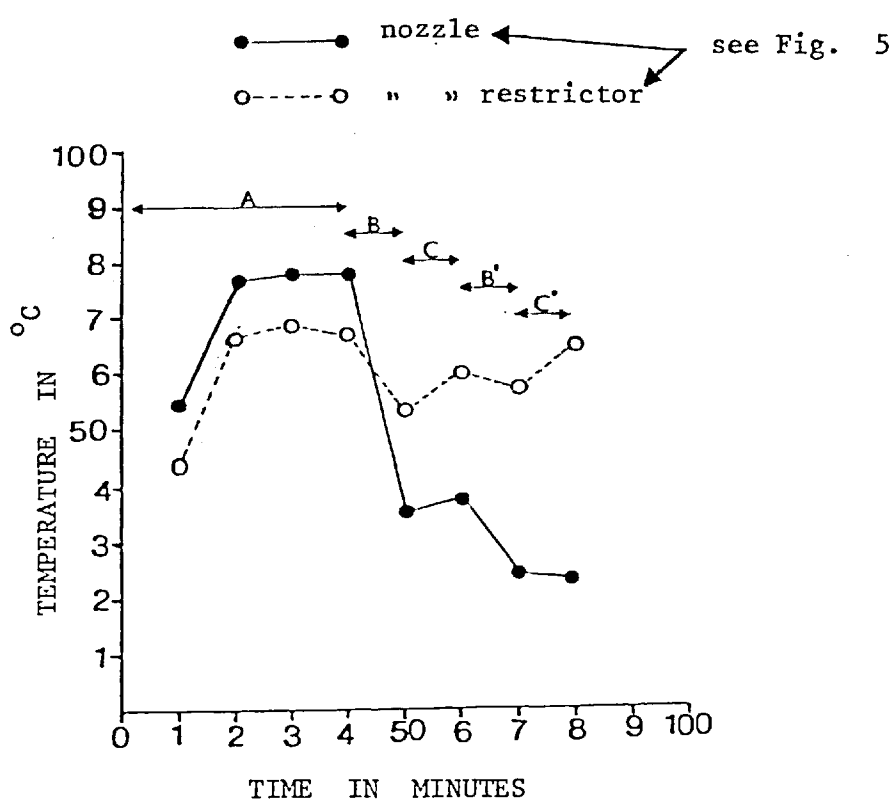
B = with deodourized kerosene sprayed

C = with water + 20% Ulvapron sprayed

<u>Tank pressure 0.2 bar</u>

B' = with deodourized kerosene sprayed

C' = with water + 20% Ulvapron sprayed



109 ± 3.5°C, when measured at intervals of 10 cm along the tube.

The operational temperature of the nozzle and restrictor was not investigated when the vehicle was used for longer operating hours in the field. Higher temperature would be expected when there are higher ambient temperatures in the tropics.

Various (air shear) nozzles (2.5, 4.0 and 5.5 mm diameter) and restriction orifices (4.5, 12.5 and 16 mm in diameter) can be used with an MK II Exhaust Nozzle Sprayer system depending on spray requirements and types of vehicle available. For the present spray tests i.e. both under field and laboratory conditions, the 2.5 mm liquid delivery nozzle was used in combination with a 4.5 mm air shear nozzle.

The basic construction of the Exhaust Nozzle Sprayer and flow directions of the exhaust gas and insecticide formulations are shown in Figs. 5 and 6.

2.2 The formulation of sprays

2.2.1 Spray liquids

Various proportions of special oils formulated with an emulsifier were mixed with water. The oils used were Ulvapron oil (1) and sun oils 7E and 11N (2). Different concentrations of Ulvapron (15, 20 and 40%) were especially micronized with water in addition to mixtures not requiring micronisation. For the characteristics of different oils, see Para. 2.2.2.

The oil formulations were compared with water plus wetting

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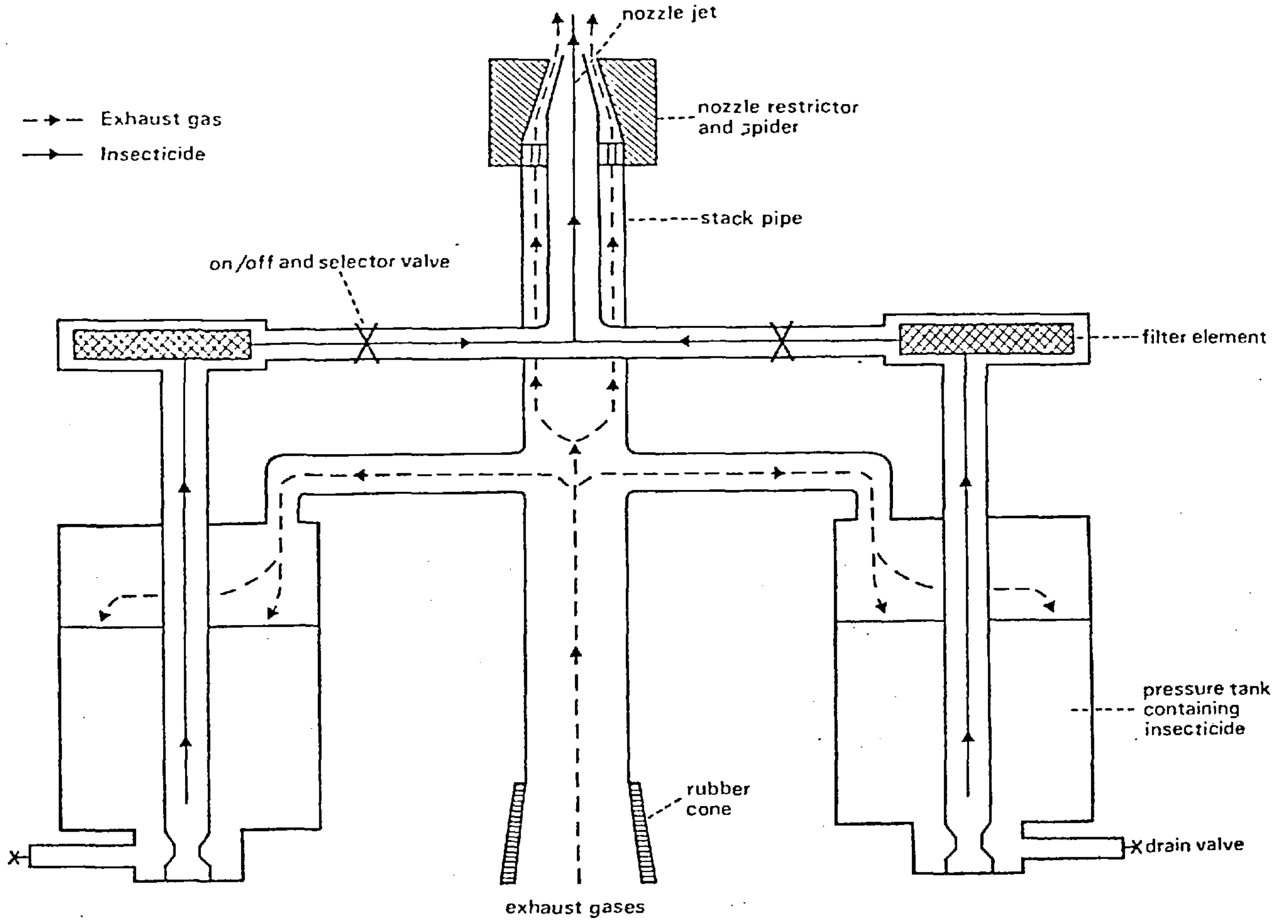
(1) Supplied by the British Petroleum Co. Ltd., B.P. research centre. Sunbury on Thames, Middlesex.

(2) Obtainable from Sunoco, Blending plant, Manhatton Wharf, Silvertown, London E16.



Mk II exhaust nozzle sprayer flow diagram.

(Adapted from Watts et al., 1976)

Fig. 5 The (MK II)[1] Exhaust Nozzle Sprayer showing direction of exhaust gases and insecticide solution.

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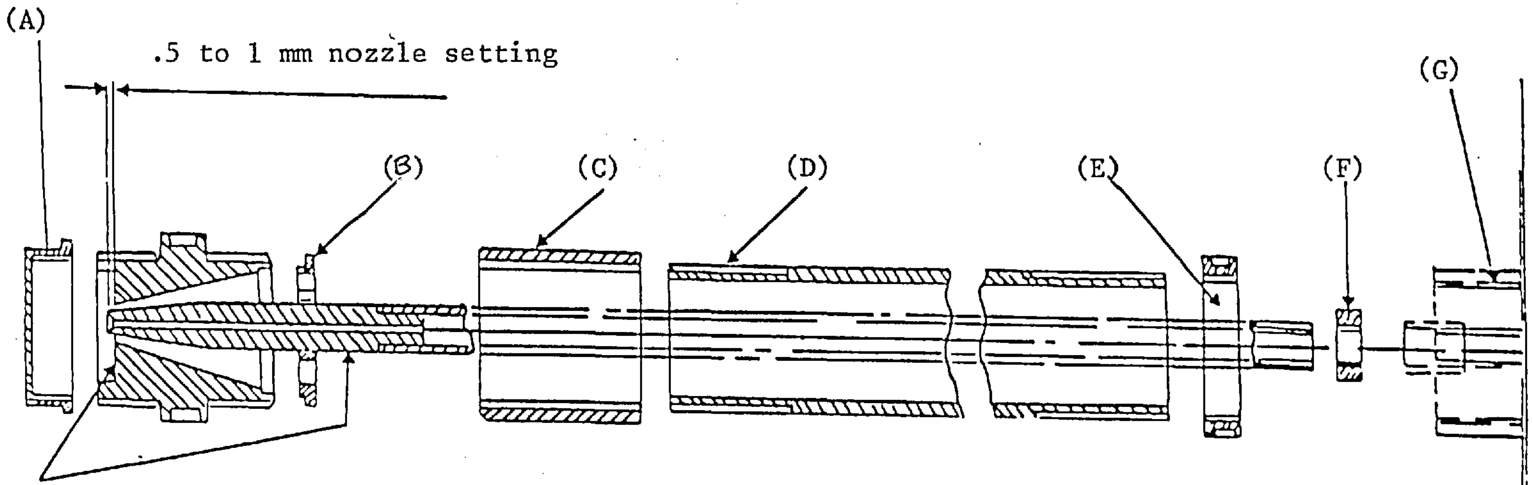
(1) Supplied by : Evers and Walls Ltd., Lambourn Woodlands, Nr. Newbury, Berks RG 7 RX.

Fig. 6 Basic units of MK II Exhaust Nozzle system.
(Ref.Fig. 5 footnote)



(A) 1½" B.S.P. blanking cap
(B) Spider for nozzle restrictors
(C) Full 1½" B.S.P. socket
(D) 1½" B.S.P. stack pipe X 715 long
(E) 1½" B.S.P. locking ring
(F) 1/4" B.S.P. back unit
(G) Chain-dot line exhaust chamber
(H) Annular rings to be assembled according to selected sizes: (i.e. 12, 14 and 16 mm diameter restrictor).

Note: MK II Exhaust Nozzle has modifications for use with vehicles of different engine capacities (2 - 3.5 litres).

Plate 1 Multiple - disc (15 discs) sprayer fixed to a Land - Rover

Plate 2 Exhaust Nozzle Sprayer

Plates 1 and 2 show spray arrangements for field spray operation and droplet drift studies (Nozzle heights = 2.50 cm) agent under a range of temperatures both under laboratory and field conditions. Details of the organophosphorous insecticides used on both adult and 5th-instar hoppers of desert locust (Schistocerca gregaria F.) are described in Para. 2.6.

2.2.2 Determination of viscosity

Viscosity of a spray liquid affects not only the flow rates in relation to temperature i.e. some liquids are less viscous at higher temperature, but also directly the break up of liquid into droplets. The more viscous a formulation the more energy is required to produce a given droplet spectrum and the higher the viscosity the greater will be its variation with changes in temperature. Prior knowledge of viscosity characteristics of any spray formulations would be useful in the study of spray characteristics and droplet formation (Oliver *et al.*, 1959). The relationship between viscosity and temperature with most materials is exponential in nature. An extremely small temperature change can cause an extremely large change in viscosity.

As a preliminary background in relation to the droplet studies, the viscosity of different fluids was determined in order to have a wider basis for comparisons. Although there are a number of methods for determining viscosity, a Cone and Plate measuring system Type KP [(1)] was used. This system has the following advantages:

a) requires a small quantity of the sample to be tested,

b) is easy to clean and operate with a constant shear rate over its entire radius,

c) does not need correction for the influence of the flow properties of a sample under test and

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(1) Contraves Industrial Products Ltd., Times House, Station Approach, Ruislip. Middlesex, HA4 BLH, UK. Bulletin T 160e-716. The readings were made at Tate and Lyle, Group R & D, POB. 68, Reading, England.

d) is rapid

Among the different fluids in the study, water plus 5% wetting agent and water plus 20% Ulvapron (Nos. 1 and 2 in Fig. 7) were determined by a U-shaped Technico Viscometer [(1)] having a constant (k) of 0.00046. Among the oils tested, Shellsol-AB showed a constant rate of viscosity under a temperature condition of 20 to 60°C but the viscosity of Ulvapron decreased from 63.2 at 20°C to 16.9 centipoise at 60°C. Water plus 20% Ulvapron decreased in viscosity from 1.0 at 10°C to 0.8 centipoise at 20°C and remained constant for subsequent increase in temperature. For details of the results of viscosities see Fig. 7 and Appendix I Table 7A and 7B.

2.2.3 Examination of spray droplets

Magnesium oxide coated slides were used in the study of droplet size. The addition of a dye such as waxoline and lissamine red for oil or water sprays respectively gave a slightly clearer image of droplets when viewed directly under a microscope with a Fleming particle analyser (Plate 3.) so the dye was used to facilitate the intensive use of MgO coated slides. Nevertheless, droplets of most of the spray formulations could be viewed without difficulty, even without dyes.

2.2.4 Examination of spray deposits on leaves

The use of fluorescent materials as a spray tracer was reported in 1955 and later by others (Sharp, 1955, Staniland, 1959, 1960, 1969; Yates and Akesson 1963 and Stafford, 1969).

Patterson (1963) suggested that the quantity of tracers

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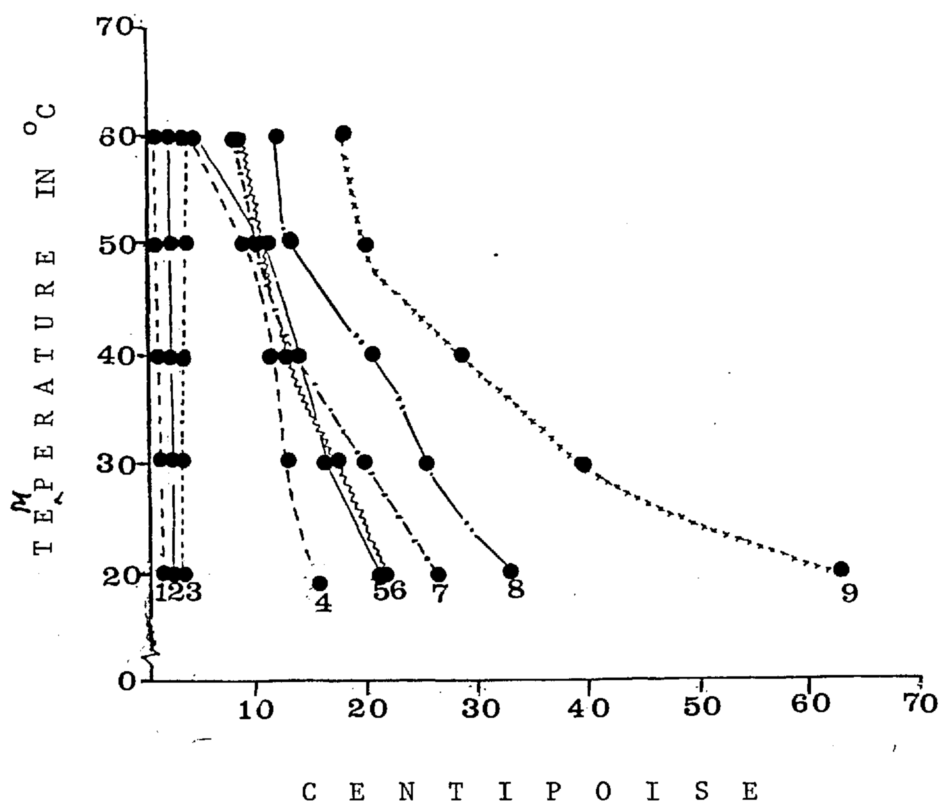
(1) Gallenkamp & Co Ltd., POB 290, Technico House, Christopher Street London ECep 2ER (obtained through COPR).

Fig. 7 Viscosities of different fluids in relation to temperature.



Numbers in graph refer to:

1. water plus 20% Ulvapron oil
2. tap water
3. Shellsol-AB
4. HLP 10 oil
5. Sunoco sun-spray 7E
6. HLP 40 oil
7. Risella oil
8. Sunoco sun-spray 11N
9. Ulvapron oil.

e.g. Saturn yellow [1], (both micronised and non-micronised grades) for spray assessment be limited to 0.1 and 0.6% for the lower and upper limits respectively. But this quantity which had been used with high volume sprays was found so minimal that it was impossible to trace any spray droplet deposits in the field when minimal volumes were applied. Therefore, the upper limit chosen for tracing sprays in the field was 10% Saturn yellow which was homogenized with Ulvapron oil using a simple 240V electric mixer before use with any water based oil formulations. However, for water plus 5% wetting agent, 4% Fire orange [2] was satisfactory for tracing and comparing droplets on both MgO coated slides and on leaves.

In the field study of droplets, assessment of spray deposition on leaves was conducted using the standard method by Patterson (1963) and Pereira (1967). The scheme of assessment was to assign an arbitrary scale according to droplet distribution viewed under an ultra-violet lamp as follows:

8 = even heavy cover

7 = uneven heavy cover

6 = even medium cover

5 = uneven medium cover

4 = even light cover

3 = uneven light cover

2 = trace cover

1 = uneven trace cover (added to the standard under our field condition).

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(1) and (2) Supplied by Swada (London) Ltd., 1 Sugar House Lane, Stratford, London E15 2QN, England.

The UV-lamps used to view deposits were:-
ultra-violet ray lamp, particle 100W, black light [1] and mineral light-band ultra-violet lamp, MSL-4B[2].

2.3 Droplet sizing

Droplet sizing can be performed by a number of techniques and descriptions of some of the earlier methods were given (Giesseke et al., 1965) but three methods described below were used in these studies of droplets to measure the volume (VMD) median diameter and number mean diameter (NMD). The ratio of these two parameters was used as a measure of variation in droplet size (Matthews 1975).

2.3.1 Matrix

This is a method for determining droplet sizes of fine and coarse water sprays. Droplets are collected in a matrix which consisted of two parts of light mineral oil to one part of petroleum jelly (WHO, 1971). The matrix was melted and poured into a small plastic dish (4.8 cm diameter and 0.6 cm deep) to a depth of 2 to 3 mm. As soon as the mixture had set at room temperature, water based spray droplets were collected on the matrix under laboratory conditions at different distances from a spray nozzle (Micron-Herbi). The surface of the matrix was then immediately covered with a thin layer of light mineral oil (risella oil) sufficient to enclose the droplets so as to prevent evaporation of the collected droplets. Once droplets were completely enclosed within the matrix, they resumed their original spherical shape and no spread factor was necessary in the computation of droplet size.

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(1) Supplied by Magnaflux Ltd.,South Dorcan Industrial Estate, Swindon, Wiltshire, England.

(2) Supplied by ultra-violet Products Inc., San Gabriel, Calf.,U.S.A.

2.3.2 Magnesium oxide (MgO) method

Magnesium oxide coated slides made by burning a 10 cm length of magnesium ribbon (May, 1950) about 10 to 15 cm below microscope slides (2.5 x 7.6 cm) were satisfactory for collecting droplets both under laboratory and field conditions (WHO, 1971). A single slide or a series of slides were placed across a long narrow slit to deposit MgO in the centre of (2.5 x 2.5 cm) each slide giving a 6.25 cm^2 droplet collecting area.

The quality of MgO coated slides was examined by retaining slides in a box for 10 minutes and up to 330 days prior to spraying to determine the period over which prepared slides could be kept before use. Water plus 5% wetting agent, water plus 20% ulvapron oil were sprayed separately on slides of different age categories by laying them (three slides of each group in line or 33 slides) on a horizontal surface. A 5.5 cm nozzle using a restrictor No. 4 was held 30 cm above the slides while moving at 1 m/s under a constant temperature of 25°C, 65% RH.

As the MgO deposit aged, the number of droplets sampled and the apparent size decreased (Fig. 8) due to the hardening of the surface. Droplet sizes for water plus 20% Ulvapron oil changed significantly after 330 days (Appendix I, Table 2A - C 3, 4 and Figs. 1 and 2) so slides were prepared within 2 - 5 hours of use in the following droplet size assessments.

Spray droplets collected in the matrix and on MgO coated slides were counted and categorized according to size using a Fleming particle size micrometer analyser Type 526 (1) (Barnett and Timbrell, 1962; and Matthews, 1975). The fleming vibrator

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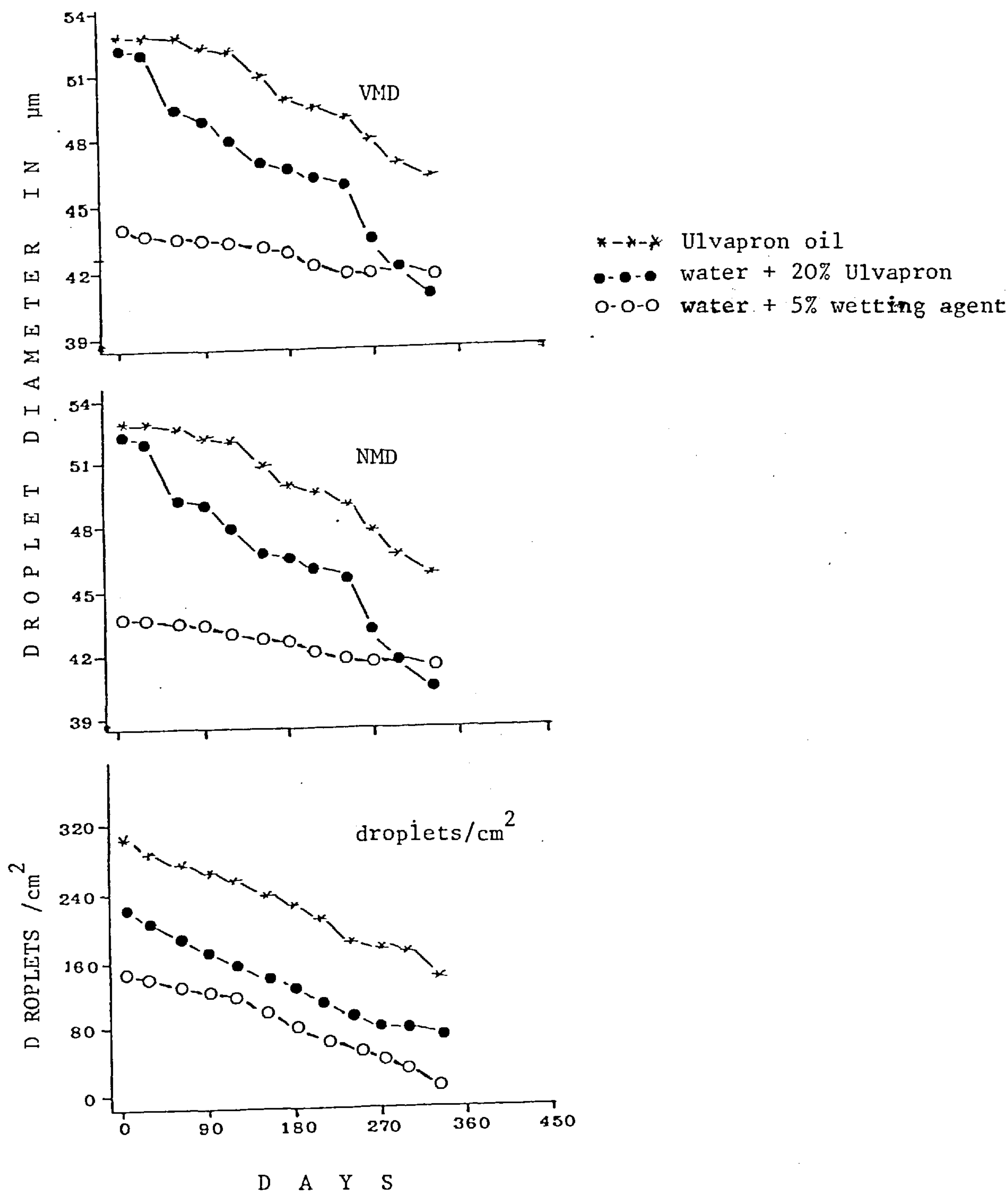
(1) Obtainable from Fleming Instruments Ltd., Caxton Way, Stevenage, Hertfordshire, England.

Fig. 8 Changes of VMD, NMD and droplets/cm^2 of water plus 5% wetting agent, water plus 20% Ulvapron oil sprayed on MgO coated slides kept from 10 minutes up to 330 days.



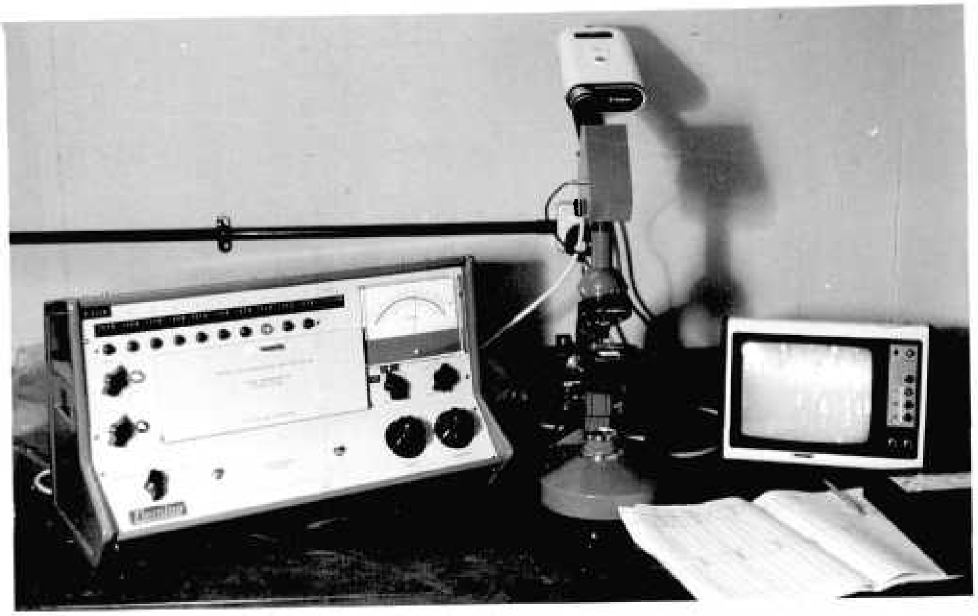


Plate 3 A Fleming particle size micrometer Type 526 attached to a National microscope attachment No. WV-9005, TV camera model WV-401 and video monitor model 411 N/B.

and microscope attachment unit No. WV. 9005, TV Camera model WV-401 and video monitor model WV-411N/B (National Panasonic was fitted with closed video system (Plate 3). The system is operated by using a vibrating unit fitted between the eye-piece and the draw tube of microscope and the image of droplets.

An example of the computation of data for a sample of droplets collected on MgO coated slides and sized by a Fleming particle analyzer is shown in Appendix I Table 5 Fig. 3.

2.3.3 Laser method

Some droplets were measured in flight using a laser system, namely with a Malvern particle and droplet size distribution analyzer Type ST 1800 (1). The system is based on the Fraunhofer diffraction of a parallel beam of mono-chromatic light by moving or stationary droplets or particles. A Fourier transform lens provides a stationary light pattern in relation to the size of the droplet. A multi-element photo-electric detector located at the focal plane of the lens produces an electrical analogy of the energy distribution of the diffracted light (Fig. 9). Using a computer, this measured energy distribution is compared with a calculated energy distribution based on a Rosin-Rammler (1933) model (Furmidge, 1954) continuously modifying the mean diameter and exponent parameters used for the model until a best fit is obtained.

Percentage weight fraction and normalized percentage, number density for the range of particle sizes are calculated from the best fit and the results printed.

An example of a laser computed distribution is shown in Appendix I Table 6.

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(1) Malvern Instruments Ltd., Spring Lane, Malvern, Worcs, UR14 1AL, UK.

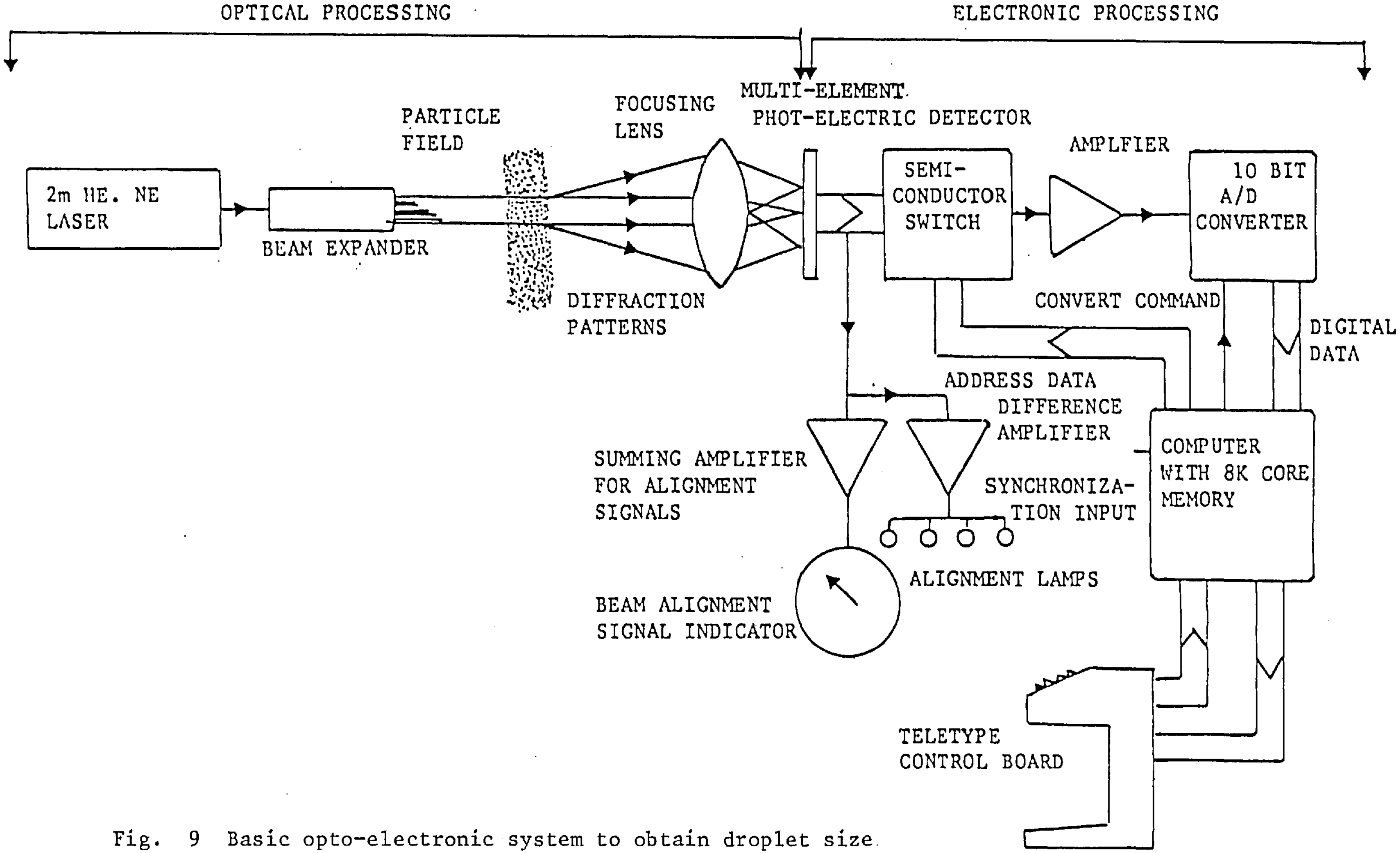

Fig. 9 Basic opto-electronic system to obtain droplet size and distribution.

(After malvern instruments Ltd.)

2.4 Sampling of droplets in the laboratory at different distances from a nozzle.

2.4.1 Droplet collection on surfaces

Droplets were collected in a room (2.4 x 2.4 x 3.7 m) in which the temperature could be controlled. No control of humidity was possible.

a) Initially droplets were collected at 30 and 200 cm below a nozzle (Para. 2.1.2a) as shown in the plan drawing with a matrix (Appendix I and Figs. 4 and 5). An equal number of 13 collecting surfaces were arranged each in 2 concentric circles having an area of 3, 848 and 13, 685 cm^2 for the 30 and 200 cm levels below the nozzle respectively. Droplets were collected separately under both low (18°C) and high (42°C) temperature conditions.

b) Spray droplets were collected on MgO coated slides at three (10, 30 and 200 cm) levels below the 5.5 cm nozzle (Para. 2.1.2b). The 13 slides at each level were arranged in a row (lengthwise) on an aluminium angle section (2.5 x 200 cm). The aluminium beams were suspended horizontally in a criss-cross pattern one on top of the other to provide a clear passage for the freely falling droplets once emitted from the nozzle (Appendix I and Figs. 6 and 7). The maximum spray droplet extension to the centre of these lines each having a total circular area of 0.04, 0.4 and 1.4 m^2 respectively at distances of 10, 30 and 200 cm below the nozzle. Droplets of the same origin from the nozzle were collected (under a range of temperature conditions) at all three levels.

2.4.2 Droplet sampling using a spray tower

Droplets of various spray formulations were directly assessed by a Malvern particle and droplet analyser described in Para. 2.3.3. It was not practical to raise or lower the level of the Malvern laser beam to suitable heights so a spray tower was designed to allow a sample of droplets to be emitted at different distances above the laser beam (Fig. 10 and Plate 4).

The spray tower 10 cm in diameter and 350 cm long had narrow openings or windows at heights of 10, 30, 100 and 200 cm from the level of the laser beam. A 5.5 cm spray nozzle fitted with a solenoid valve and manually operated flow control valve system was moved up and down the tower by a hand operated pulley. The nozzle was positioned at any required level by aligning the spinning disc at the appropriate spray window in the tower. Accurate height and distance of the droplet trajectory from the laser beam was maintained by moving and adjusting the whole spray tower on its 4-wheels and rails relative to the laser beam. A two way power switch system controlled the solenoid valve and operation of the nozzle. The formulations were fed from a 0.5 litre plastic container at the top of the spray tower via flexible tubing connected to the nozzle.

Unfortunately studies of droplet size using the laser system could be carried out only at one temperature of only 19^{o}C, 59% RH.

2.4.3 Sampling of droplets under field conditions

Three methods of sampling droplets were examined in the field, namely, slides (in different positions), Cascade impactors (May, 1945) and Rotorods [(1)] (Matthews, 1975). In each case droplets were collected on surfaces coated with MgO.

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(1) Obtainable from Metronics Associates Inc., Palo Alto, CA, USA.

Fig. 10 Details of a spray tower (A) with top section (B) and its spray shuttle (C).

(C) Spray shuttle with its accessories, (B) Top end of spray bottle, (A) Spray tower

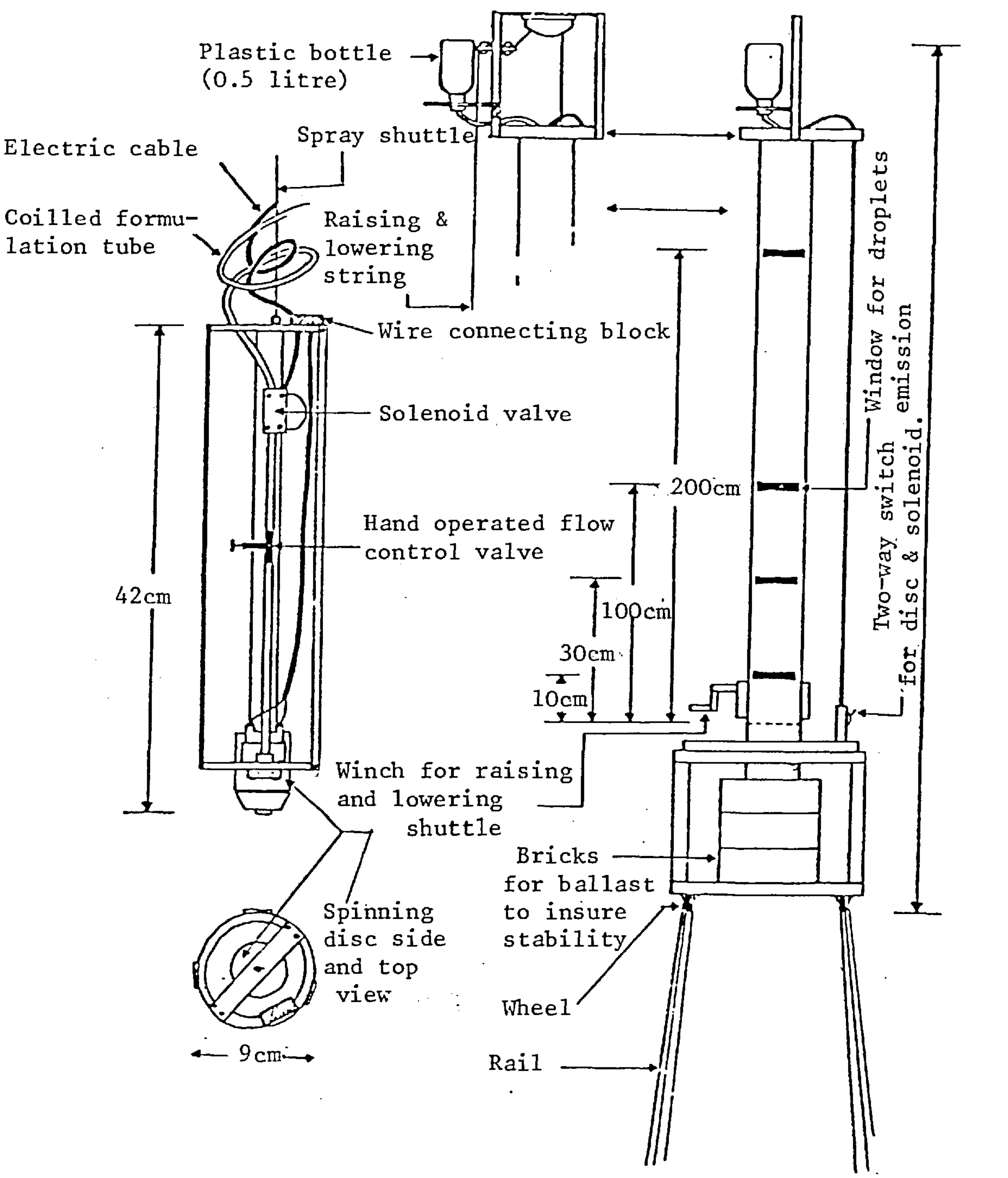

Plate 4 A spray tower with its complete gear:

- an erect spray pipe with its spray shuttle hanging on its coiled pipe and pulley system on the outside for display,
- laser generating unit with its optical lens system on balanced stand on the foreground,
- a mini-computer left bottom with a teleprinter on top.

a) Two MgO coated slides were arranged vertically in parallel to a rotating frame fixed to the shaft of a 3 - 12 vol- DC powered motor, Type 6V/1000 (1) with a 6-ratio gear box (i.e. with speed ratios of 3:1, 6:1, 12:1 16:1, 32:1 and 60:1). The slides were rotated in clockwise direction at a speed with a ratio of 3:1 (motor to slide speed) using a 6-volt compact lantern battery Type PJ996 power supply (Thornhill, 1979a).

b) Cascade Impactor (2) : A portable vacuum (suction) pump operated from a field electric generator (capacity 20 W/50) was used to draw air through the sampler at a rate of 18.5 l/min.

c) Rotorod: U-shaped rods with collection surfaces of 1.59 mm in diameter coated with MgO were rotated at a speed of 2400 rev/min with a DC power supply from a 12V battery.

The droplet samplers discussed in a, b, and c above were set at distances of 2 and 16 m from a spray path. Slides were also fixed vertically and horizontally close to the above samplers. Water plus 5% wetting agent and water plus 20% Ulvapron were separately sprayed from a 5.5 cm nozzle using a No. 4 restrictor. For each spray an equal amount (50 ml) was sprayed with the spray nozzle 40 cm above the ground and moved at a walking speed of one m/s.
The mean temperature during the spray operation was 20 $\pm 2^{\circ}$C with a relative humidity of 72 $\pm$ 6% and an average (cross) wind of 2 - 3 m/s and 2.5 - 3.5 m/s for water and the emulsion (water plus 20% Ulvapron) respectively. The experiment was repeated twice a day (morning and afternoon) over a period of 3 days.

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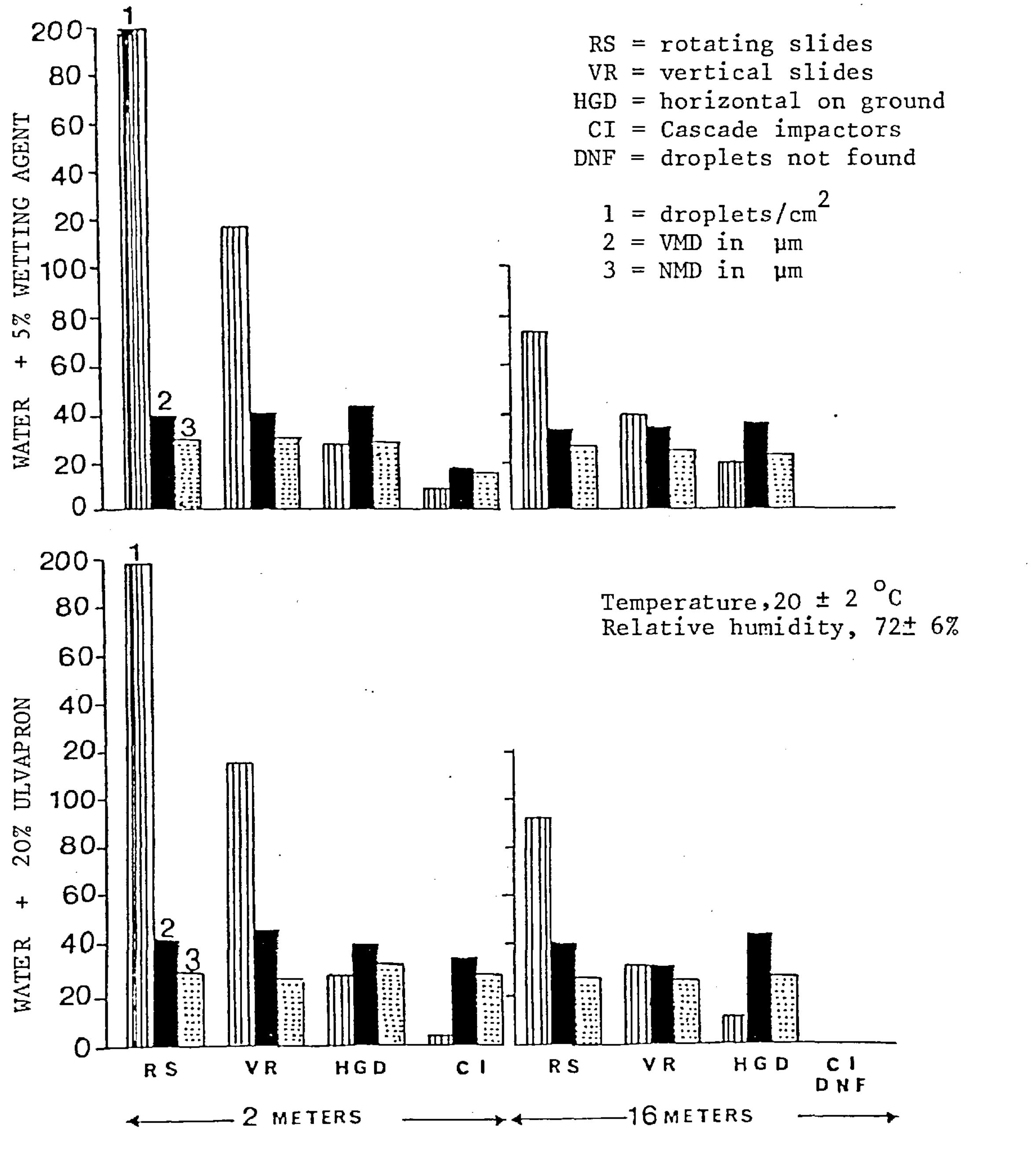
(1) Obtained from Meccano Ltd. Binns, Rd. Liverpool, L13 1DA, UK.

(2) Obtained from Cf Cassella and Co Ltd., Regent House, Britania Walk N1 7ND (Instruction Leaflet No. 3018/TE).

Fig. 11 Relative droplet collection efficiency of slides and Cascade impactors coated with MgO. (Sprayer = 5.5 cm spinning disc, Speed = 10,000 rev/min.



The higher number of droplets collected per unit area and the VMD and NMD index of the two spray formulations indicate that of the three droplet collecting surfaces namely, rotating slides, Cascade impactors and Rotorods, MgO coated slides were significantly more efficient under field conditions (Fig. 11 and details in Appendix I Table 8).

In all the samples more droplets were collected on rotating slides than on either vertical or horizontal slides and the least were collected by the Cascade impactors which collected only a few droplets at a distance of 2 m from the spray path. No droplets could be seen on the Rotorod sampler so this method was not used in subsequent experiments.

2.4.4 Downwind movement of spray droplets

Johnstone et al (1977) pointed out that deposition of droplets (60 - 150 μm in diameter) is influenced considerably by the micro-meteorological conditions prevailing at the time of spraying. Variable factors such as wind direction and speed, air turbulance (frictional and thermal) and air temperature play an important role on the down-wind movement (drift) of droplets. The water content of many of the smaller droplets may evaporate before they settle. In case of water-based sprays, relative humidity has a major role on droplet sizes (Johnstone et al., 1974). Akesson and Yates(1964)and Yates et al., (1967) have shown that downwind drift of a spray depends not only on the way a spray is applied but also on volatility and proportions of solvents and other formulating agents.

Droplets were sampled at different distances downwind when spraying water with wetting agent or with different proportions of Ulvapron oil. Sprays were applied with a) a single 5.5 cm disc,

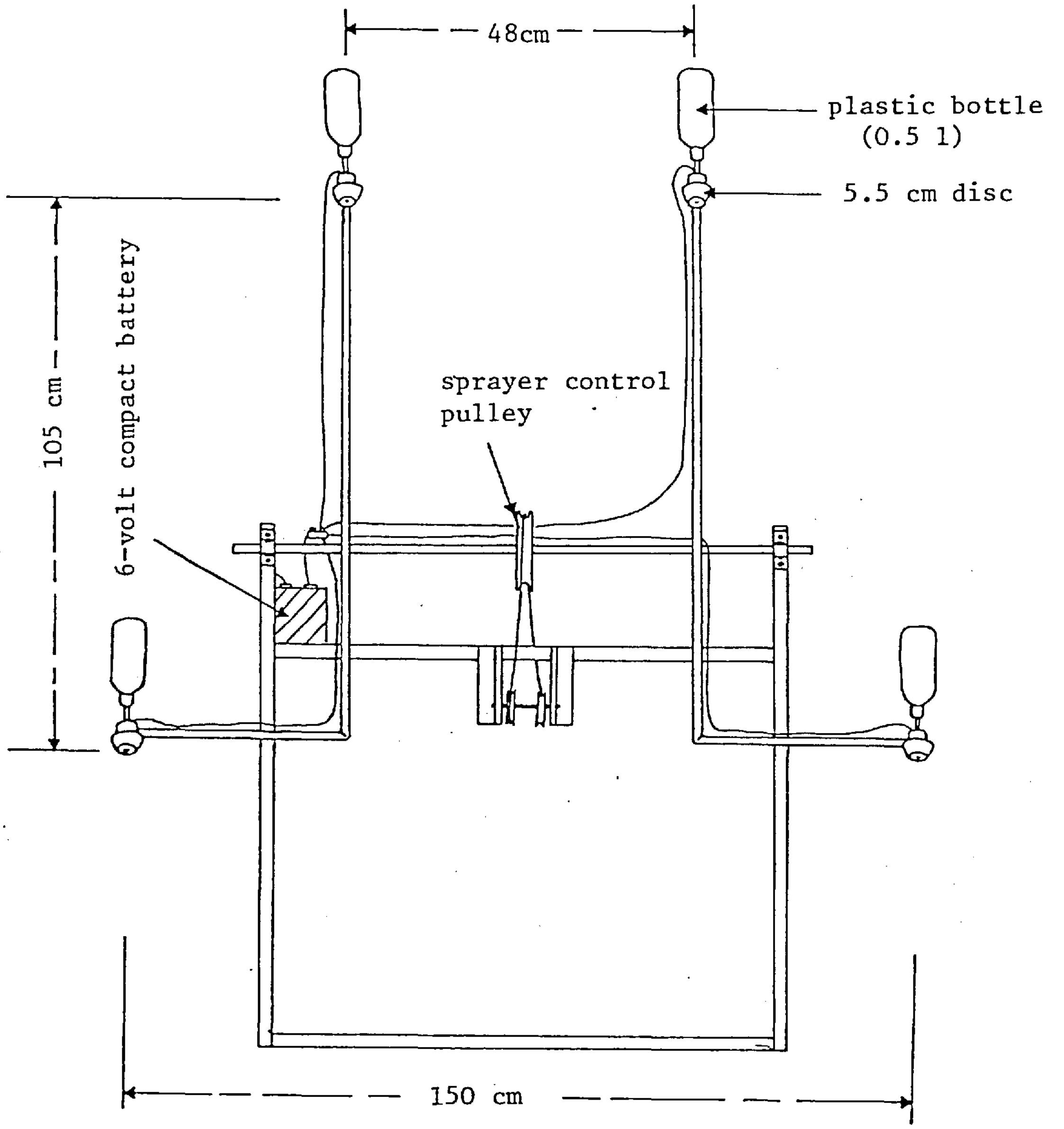
b) an array of 4 single discs and c) a multiple-disc (15 discs) nozzle. Deodourized kerosene and water plus 20% Ulvapron formulations were sprayed also with d) an Exhaust Nozzle Sprayer. Both the multiple-disc unit and the Exhaust Nozzle Sprayer were mounted at same height (250 cm) above the ground i.e. slightly higher than the roof of the Station Wagon Land-Rover (Plates 1 and 2) to allow adequate air movement to carry droplets away from the nozzle.

The 5.5 cm hand held spray was maintained at about 90 cm above the ground level when spraying. On the 4-disc sprayer the discs were arranged in parallel with 48 cm between the top discs and 150 cm between the bottom two discs; a gap of 105 cm separated the lower and the upper discs which were maintained at spray heights of 145 cm for the lower two and 250 cm (off the ground) for the upper two discs (Fig. 12) (Thornhill, 1979b).

Magnesium oxide coated slides were mounted vertically at heights of 35, 70 and 150 cm on stakes. Five stakes one meter apart were placed at the same distance downwind in a row, and 10 rows were spread out in geometric progression at distances of 0.25, 0.50, 1, 2, 4, 8, 16, 32, 64 and 128 meters downwind from the spray path. A total of 15 slides per row or 150 slides per spray were examined repeating each set of spray test five times.

When the Exhaust Nozzle Sprayer was used with a mean wind speed of 2 - 5 m/s in the open, droplets could not be sampled within 6 m downwind of the spray path, so the sampling distances were positioned an extra 6 m downwind i.e. sampling distances of 6.25, 6.50, 7, 8, 10, 14, 22, 38, 70 and 134 m from the spray path were used. Under sheltered (still condition) a total of six magnesium

Fig. 12 Arrangement of 5.5 cm four-disc sprayer showing the relative position of discs.



oxide coated slides, three on vertical position on stakes and three on horizontal positions on ground were placed for each consecutive distance which was spaced out a meter apart downwind up to a maximum of 25 m.

Also with the Exhaust Nozzle Sprayer, upward movement of the spray above the nozzle was determined both under open and sheltered conditions. Droplets were sampled 1 m below the nozzle on MgO coated slides with faces up and with a series each a meter apart were clipped face down on a rope 11 m long hoisted up a spray tower.

The Station Wagon Land-Rover either carrying the multiple-disc spray unit or the Exhaust Nozzle Sprayer or a trailer carrying a 4-disc spray frame were all driven at a speed of 1 m/s while spraying.

2.5 Spray study on locusts (*Schistocerca gregaria* F.)

2.5.1 Background

The desert locust being one of the oldest and most damaging insects (Exodus 10 : 15), requires unabated vigilance (Collins, 1978) and effective chemical weapons. A number of insecticides can be used effectively for the control of locusts (MacCuaig, 1958, 1968) and although intensive use of insecticides such as DDT, γ-BHC, dieldrin, diazinon, dichlorvos and malathion have hitherto been effective (Bennett & Symmons, 1972), the possible build up of resistance both within the insect and the environment heralds the need for continued search into alternative chemicals and spray methods.

The pattern of agriculture in most 'locust belt' areas of the world is changing fast from simple low input to a complex high input commercial type farming, thus exposing agriculture to an even riskier and challenging condition where it remains quite vulnerable to the attack of locusts. An outbreak of locust swarms can be devastating as entire crops can be wiped out overnight.

There is a need to reduce the quantities of persistent toxic chemicals applied to the environment as well as maintain control with ultra low volume rates of application. Locusts being mobile, pick-up of sprays is likely to be important with small droplets and to have greater effect when locust populations are aggregated. (MacCuaig and Yates, 1972). Since the study of the effect of adding oil into water based formulations involved spray nozzles that are appropriate for the formation of small spray droplets, the study of pick-up was investigated together with the use of insecticides on locusts reared under laboratory conditions i.e. mobile and semi-mobile adult and hoppers.

2.5.2 Rearing of locusts

The method of rearing of locusts in the laboratory was that described by Jones (1966). All locusts were supplied by the Centre for Overseas Pest Research (COPR) at 2nd- to 3rd- and 4th-instar stages. After arrival they were allowed to develop either to 5th-instar or adult stages by keeping them in rectangular metal cages (38.5 x 38.5 x 56 cm) which contained small doors at the top for daily feeding and cleaning. The metal tins were bolted to an aluminium framework and the front side was covered with a transparent glass panel. A 20W electric bulb was incorporated inside each cage to provide sufficient light and to supplement heating. A 16-gauge perforated zinc (apertures 2mm in diameter) provided a false floor which was inserted about 10 cm above the main floor to allow faeces to fall through. Each cage would accomodate up to 200 locusts during the early stages of development.

Most of these experimental studies were limited to 5th-instar hoppers or adults (15 days old after the last moulting), which were transferred to smaller cages in groups of 10. The smaller cages were either square shaped (15 x 15 x 15 cm) or a perspex cylinder about 35 cm high and 16 cm in diameter. All cages big or small with the locusts in them were kept in other larger cages varying in sizes (from 1.5 x 1.5 x 0.7 to 1.5 x 1.5 x 1.5 m) made from handy-angle fittings and covered with black polythene sheets. A mean temperature of 28°C and a relative humidity of 40% was maintained by electric fan heaters which were controlled by thermostats set up in each cage. Twelve hours of artificial light using fluorescent tubes was alternated with 12 hours of darkness by means of a master automatic electric switch system.

A daily supply of fresh grass and formulated dry wheat bran (middlings) were provided to the locust (about 10 times their body weight) during each 24 hours period and cages cleaned. The purpose of providing such a large quantity of food daily was to insure that no cannibalism occurred at any time between any of the locusts.

2.6 Bioassay technique on Adult and 5th-instar hoppers (*Schistocerca gregaria* F.)

Several fixed dosages of insecticides were applied to groups of randomly selected individuals and the responses to the various dosages was assessed by recording the time taken by each individual to die (Woods, 1972). Quantal measurement was possible by taking the numbers dead in each group and the numbers alive only when the experiment reached a steady state i.e. when the poison was having no further effect but before natural mortality became significant. The data for the assay was provided by the records of death or survival (Finney, 1977).

Two new organophosphorous insecticides both as technical and emulsifiable concentrate formulations a) propetamphos [(1)] b) etrimfos [(2)]

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(1) Ref. No. SAN 52 139 I and (2) Ref. No. SAN 197 I : both supplied by SANDOZ Ltd., Agrochemical Research Department, CH-4002 Basle/Switzerland.

c) fenitrothion [3] were selected for the bioassay. The two new organophosphorous insecticides were assessed as possible replacements for fenitrothion which has been used instead of the chlorinated hydrocarbons.

The level of effectiveness of each insecticide was determined by screening tests. A convenient scale of doses for such tests was established starting at a higher dose level and then decreasing by a factor of approximately 3 (e.g. 100, 33, 10, 3.3 and 1 µg/g of body weight) until a dose was reached which killed no insects. Since the screening tests of each of the above three insecticides indicated varied levels of effectiveness both for 5th-instar and adult locusts, different levels of doses were set as a basis for determination of LD50 and LD99.

The doses required for each application of insecticidal solution in volume (µl) which yields a given dose in µg/g (i.e. relative to weight of locusts) was applied with a micro-capillary applicator (Fig. 13) (MacCuaig and Watts, 1967).

The capillary was filled to the required scale mark by applying cotton wool saturated with the insecticide solution to its tip. The solution was then applied by squeezing the bulb with the fore finger covering the perforated hole in it to force air through the capillary therby expelling the insecticide to the desired target area or zone. The scale of the capillary conveniently covers the range 0 - 0.6 µl divided into units of 0.1 µl with further subdivisions of 0.02 µl. Any dosage required above 0.1 µl level was repeated and the total amount needed for each insect was thus completed by instalments.

The method of application of the required doses and keeping of records of the relevent information was similar to that followed

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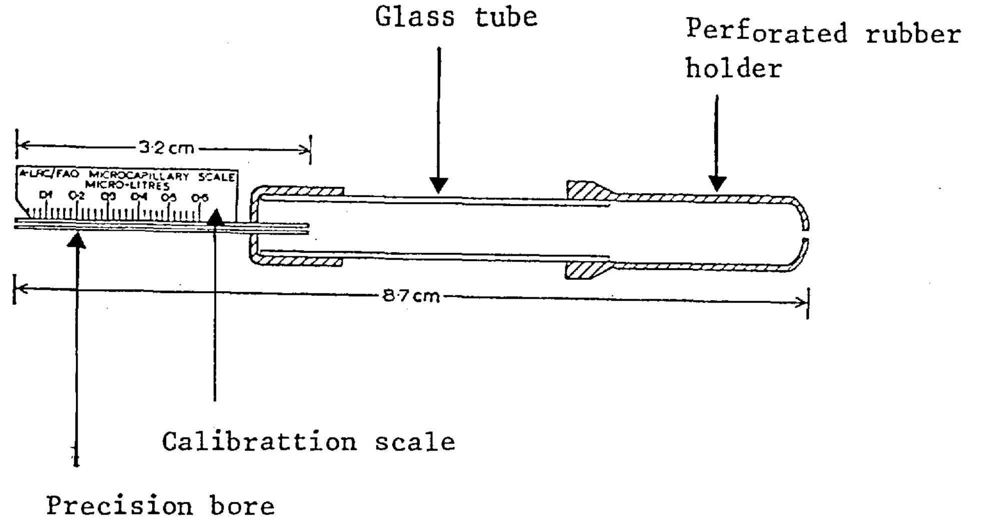
(3) Supplied by CIBA-GEIGY, Agrochemicals, Whittlesford, Cambridge, CB2, 4QT, U.K.

Fig. 13 Sectional diagram of the micro-capillary applicator and holder.



(After MacCuaig et al., 1967)

by McCuaig (1967). Proper randomisation was followed before application of the insecticide.

Active ingredient in micrograms, contained in 0.1 µl of solution is numerically equal to the percentage of active ingredient (weight/volume) in the solutions (McCuaig, 1967). This means that if a 20% solution is to be applied, 0.1 µl will contain 20 µg of active ingredient, so that if the dose is 50 µg/g, 0.25 µl of solution will be needed for each gram of the insect's body weight.

After every experimental insect was weighed and the appropriate dose calculated with respect to its weight, the quantity required was applied by the micro-applicator to the intersegmental region between the first and the second abdominal sternites. After dosing, the insects were kept in appropriate cages according to dose groups. With stomach toxicity tests for 5th-instar hoppers, calculated amounts of insecticides were applied in the centre of a single blade of grass leaf and provided to each hopper which was kept hungry for 12 hours prior to the test. The contaminated blade of grass was provided from a hanging position down through the air inlet of perspex bottles shown in Plate 5. Time was taken until the whole blade particularly the contaminated portion was eaten by each experimental hopper before being transferred to its respective group cage for mortality observation.

As the insecticides for the bioassay were colourless, a small quantity (0.01%) of waxoline red dye was used in each of the insecticide solutions to facilitate dosing with the micro-applicator.

All observed final data for each insecticide and dose groups were analysed on a computer with the aid of a single and parallel probit analysis programme (S103) from the permanent file of the ICCC/ULCC computing facilities (Appendix IV, Table 26 (A) and (B).

Plate 5 Method of feeding a single dosed grass blade to each 5th-instar hopper.

2.7 Spray deposits on locusts

Spray deposits on both male and female locusts (15 days after fledging) were measured in the laboratory while in flight and in a stationary (suspended) position. A total of 12 i.e. three locusts of each sex were put on each of two stands, one of which was rotated (Plate 6). This stand was fitted with a 6V-motor (Para.2.4.3a) and bearings to enable it to rotate effortlessly. Each revolving stand had six (slightly rigid) arms extending from the centre with an equal length (of about) 37 cm in diameter. A device was incorporated to provide a hook on which locusts were suspended by their pronotum all facing in a clockwise direction. About 15 cm back from the tip of each extended-wire-arm, a hub was provided to hold a MgO coated slide in vertical positions, when the stands rotated each of the locusts suspended at the tip of each arm rotated through a circle of 232.5 cm circumference.

A series of dilutions (10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6}) w/v of waxoline red dye in Shellsol-AB oil were prepared prior to spectrophotometry of the spray deposit. The absorbancy of each dilution was read by an automatic scanning spectrophotometer Type-UNICAM, model MSP800 at the ICI Laboratory, Jeallot's Hill (Fig. 14) and a calibration curve plotted (Fig. 15).

Different quantities 0.24, 0.29, 0.34, 0.58, 0.66, 0.80 and 1.1 ml/m^2 obtained through a series of calculations (Appendix IV Table 27) from the field spray deposits collected on MgO coated slides downwind (Para. 3.3.3) of 1% waxoline red dye in Shellsol-AB was sprayed in the laboratory both on a rotating (flying) and suspended (stationary) locusts. The two stands were set one after the other on a conveyor belt which carried the locusts through a transparent polythene

Plate 6 A stand on which locusts and glass slides were rotated in a cloud of spray droplets.

Fig. 14 Absorbtion spectra with points of wavelength, percentage concentrations of waxoline red dye and absorbance as determined by auto-photo-electro scanning.

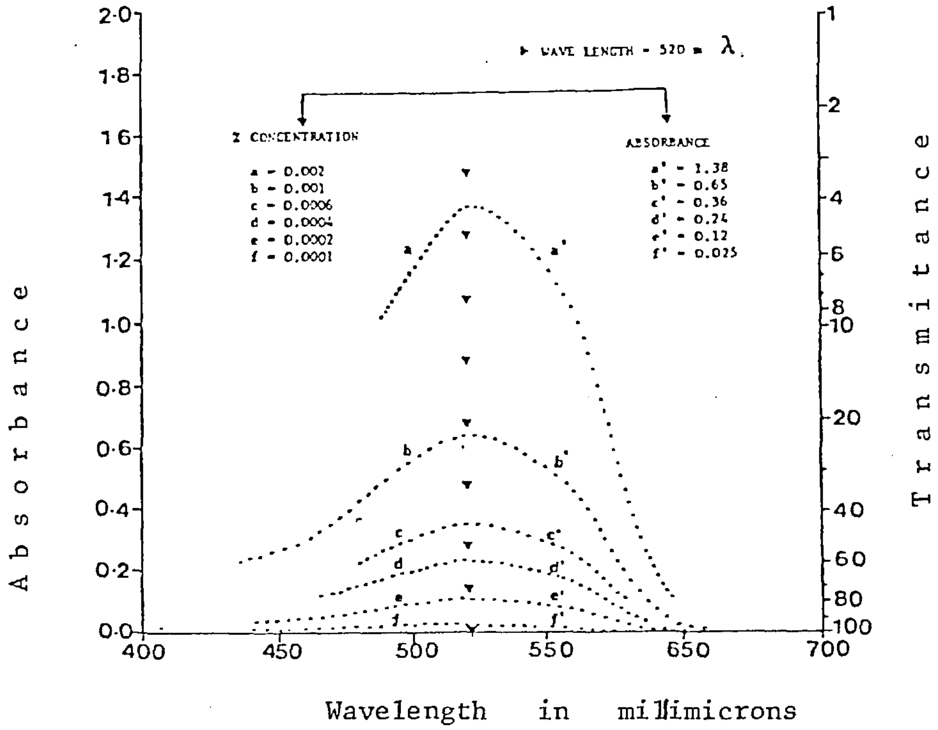
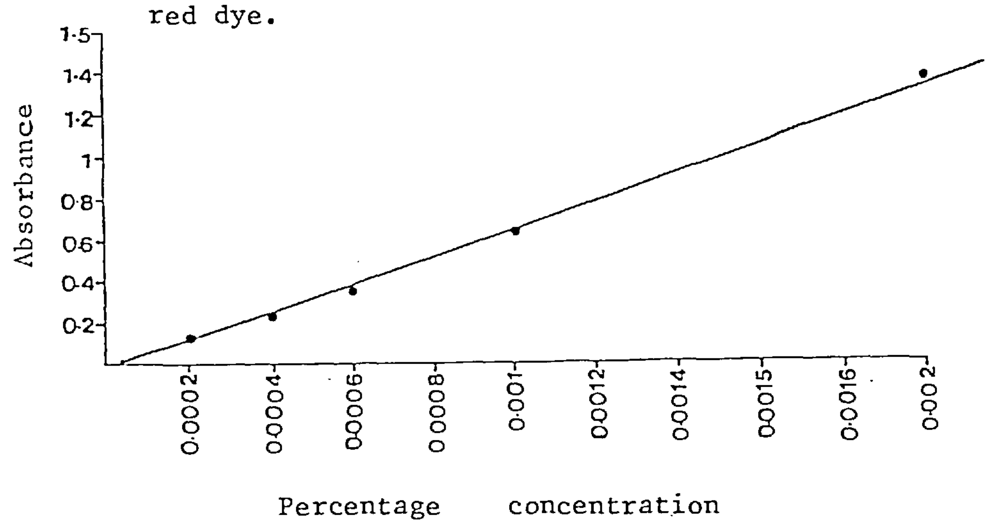


Fig. 15 Calibration curve of a series of dilutions of waxoline red dye.



(Spectrophotometer used = at ICI Jeallot's Hill) covered passage and 30 cm below a suspended 5.5 cm spinning cup. A sage pump, model 341 [(1)], controlled and delivered the required amount of spray solution per unit area applied for every batch or group of test locusts. Spray droplets varied in size between 68 - 70 μm and 60 - 66 μm VMD and NMD respectively.

As soon as the stands of rotating and suspended locusts reached the other end of the covered passage on the conveyor belt, each locust was bathed in 25 ml of acetone in individually prepared test tubes marked with the weight of each respective locuts. Also 25 ml of acetone was used to wash a standard (or reference) locust during each set of transmittance and absorbance measurements.

The measurements of absorbance and percent concentration of solutions are shown in Appendix IV Table 29A - E.

2.8 Field trials in the control of powdery mildew

2.8.1 Importance

Powdery mildew of cereals is known to affect over 100 species of grains and cereals and is wide spread in temperate zones. In parts of the Southern United States crop losses in barley were estimated to have reached 10 - 14% over the five year period beginning in 1937 (Roberts and Boothroyd, 1972). Lodging is not uncommon in diseased plants and in severe conditions flower heads blast. Mildew inhibits photosynthesis and stimulates respiration i.e. diminishes net assimilation rate (Rea and Cott, 1973).

Mildew attacks cereal plants at all stages of their development from emergence to ripening of the ear. Affected glumes and ears become discoloured and grains usually shrivel. In variety trials in England between 1959 - 62 there was a mean loss of grain

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(1) Sage Pump Insturments, Division of Oregon Research Incorporated Cambridge, Mass, 02139, U.S.A.

in winter wheat of about 2.5% with losses rising to 7.5% at a mean mildew infection of 16%. Also trials on barley over four years covered the range of severity of natural mildew attack from slight to 25%.

The number of mildew races was on the increase from year to year. By 1966, 38 races were identified on wheat in north-east Europe and 32 races in barley in North America (Moseman, 1966). Grain yield of barley was reduced by 22% (Last, 1955 and 1962) and between 1957 and 1960 mildew field trials sustained a loss of 125 kg/ha (Large and Doling, 1963). On commercial crops of spring barley and winter wheat in England and Wales, it was observed that mildew was the major disease of barley in five years (1967 - 1973) out of six (King, 1973). The estimated value of losses in those six years amounted to an average of £23.3 million per year.

In England and Wales disease surveys between 1970 - 1975 (King, 1977) showed that high levels of disease occurred on winter wheat incurring an estimated loss in yield of about 10%. The loss in spring barley in 1976 and 1977 was estimated to be worth £35 and £25 million respectively, whereas in winter wheat during those two years it was £7 and £5.5 million. Despite increasing losses in yield and revenue amounting to 19% in spring wheat and 10 - 15% in winter wheat, the control of powdery mildew has gained little in importance (Kradel, 1967).

Heavy losses of cereals may occur in some seasons due to mildew infection either alone or in combination with other foliar diseases so a continued search for efficient and positive methods of control is justified. While a variety of fungicides (e.g. over 45 different fungicides listed in the 1979 Approved Products alone) for plant disease control may be available, the delivery of each one of them to targets of infection requires precise control of timing and correct dosage. Traditionally fungicides have been applied by high, or to a lesser extent, low volume, spraying. Recently, however, some farmers have used controlled droplet application to increase the speed of application and reduce wastage of chemical.

The need for greater conservation of pesticides in general and the consequent saving in cost and reduction in hazard, requires a change from high volume spraying. A national control campaign of coffee leaf disease eradication in some parts of Ethiopia had to be abandoned owing to large volume of spray requirement (200 - 2000 l/ha) and the problems of haulage over a rugged and difficult terrain. Consequently, the loss in crops and cash was economically significant. This incident emphasizes the need to look into convenient methods of applying fungicides to a wide range of crops. This study concerns the use of fungicide sprays on mildewed wheat plants under both field and laboratory conditions.

2.8.2 Experimental programme

Mildew control was studied by comparing controlled droplet application (CDA) and high volume sprays (HV) of fungicides with the effect of treated prior to sowing (DS) against mildew on pot planted greenhouse grown plants. Concurrently, CDA application of fungicide was applied to field plots.

2.8.3 Materials and procedures

A winter wheat cultivar Maris Kinsman, a high yielder in general use with a short and very stiff straw (NIAB [1] 1978) and low vernalization requirement was used. Assessment of mildew was restricted both for greenhouse and field planted wheat to the upper

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(1) NIAB : National Institute of Agricultural Botany, (Cambridge) 1978: Farmers leaflet No. 8.

most four leaves and upper surfaces of plants regarding the percentage affected (Feeks, 1941; Large, 1954; Tarr, 1972 and ADAS, 1976a, 1976b).

2.8.3.1 Greenhouse experiment

In the greenhouse the wheat was sown in 64 compost filled pots (Area and volume of each pot = 113 cm^2 and 1300 cm^3) arranged in four completely randomized designs. The treatments were controlled droplet application (CDA), high volume sprays (HV) and untreated (CON) together with a treatment (DS) in which seeds were treated with an aqueous suspension of 58% ethirimol (1500g a.i./l) applied at the rate of 670 ml/100 kg of seeds.

Plants in each group of randomised pots were thinned to only four healthy plants and were artificially inoculated in an inoculating chamber (Appendix V Fig. 9) at the 4th growth stage (Feeks, 1941) with mildew spores from diseased leaves having a mildew infection intensity of 50 - 70%. Inoculated plants were then immediately transferred to a greenhouse with a mean temperature of 21°C and a relative humidity of 70%, to encourage mildew development (Last, 1963). Assessment of infection was carried out and then all plants excluding those grown with treated seed (DS) were sprayed with triadimefon fungicide. This fungicide is a relatively new wide spectrum, curative/protectant and fully systemic fungicide formulation containing 25% triadimefon [1] (Kaspers et al., 1975) with 5% special formulating oils and china clay.

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(1) triadimefon (Bayleton) is the common name for 1-(4-chlorophenoxy)-3, 3-dimthyl-1-(1,2-4-triazol-1-yl) butan-2-2 one, a compound of low mammalian toxicity with fungicidal activity against a wide range of agricultural and horticultural diseases. It is recommended and approved under the Agricultural Chemical Scheme for the control of powdery mildew etc.

A 5.5 cm toothed grooved spinning disc (Para.2.1.2b) was used with a mains supply via a power pack to control disc speed and hence droplet size for CDA treatment. Flow was standardized by a Sage Pump (Para.2.7) and at 6.4 ml/min droplets of VMD and NMD of 70 and 55 µm respectively (Appendix I Table 5 and Fig. 3) were obtained for a triadimefon fungicide applied at the rate of 250g in 8 and 2 litres of water and Ulvapron oil as for the stacked disc discussed under Para. 2.8.3.2.

For high volume application, the manufacturers' recommendation of 500g in 200 litres of water/ha was applied using an X-Pert (Hudson, 1963) (1) compression sprayer with a Tee-jet nozzle No. 8002 at 3.8 kg/cm^2 (55 lb/in^2). From a spray height of 90 cm, a VMD of 230 and an NMD of 130 µm was obtained. In order to avoid a fumigation effect due to volatility of the fungicide, control plants were kept in a separate glasshouse under similar conditions.

A second and final assessment of mildew was made at the 10.5 growth stage, i.e. after completion of heading but before the onset of ripening (Large and Doling, 1963). At this stage four leaves still remain intact and active in the absence of mildew infection thus providing accurate assessment possibilities of both intensity and severity of mildew infection.

2.8.3.2 Field experimentation

The field experiment was confined to an area of about a quarter of a hectare (2500m^2) in which there were early, medium and late sown wheat plots. The area was split into nine plots each subdivided into three subplots (a total of 27 plots) to provide a

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(1) 67322 WAX-Pert compression sprayer. Manufacturing Company General office: Chicago, Illinois, U.S.A.

split 3 x 3 latin square design for another student conducting a simulataneous study of aphid population and ecology. The plots were taken as replicates and not arranged into larger plots.

Wheat was sown on the following dates 29-9-77, 10-3-78 and 11-5-78 (A, B and C respectively (Appendix V Fig. 10). A fertilizer [(1)] of NPK 8:20:16 containing P_2O_5 of 18.2% and non-soluble P_2O_5 of 1.8% was base dressed at the rate of 5.7 g/m^2. Nitro-chalk |Calcium Nitrate, $Ca(NO_3)_2$| was also top dressed at same rate as above. Natural mildew was randomly assessed at growth stages of 6, 8 and 10.5. A multiple-disc sprayer with 15 spinning discs (Para. 2.1.2c, Fig. 2 and Plate 1) delivered CDA sprays of triadimefon formulation on mildew infected wheat in the field.

The formulation was prepared at the rate of 250g triadimefon in 8 and 2 litres of water and Ulvapron oil per hectare respectively. The sprayer was fitted with a flow regulator and with an initial pressure of 5.6 kg/cm^2 in a stainless steel tank there was a constant flow rate of 150 ml/min i.e. 10 ml/m/disc. Under field spray operations with a prevailing temperature of 21°C, and a relative humidity of 50% and with a disc speed of 8000 rev/min., a spray with a VMD and NMD of 70 and 55 μm droplet sizes was achieved as for the spinning disc in Para. 2.8.3.1.

The distribution of droplets in the field was observed by laying out Kromekote papers (Higgins, 1967) in horizontal and upright positions and in addition Saturn yellow deposits (Para. 2.2.4) were examined under ultra-violet light.

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(1) Obtained from Lindsay/Kesteven (LK), Fertilizers Ltd., Saxilby, Lincoln LN1. 2DS (Tel (0522) 37561.

As a control to assess the effectiveness of the spray randomly selected sample sub-plots (each = 0.25 m^2) within every plot were covered with polythene at the time of spraying. The covers were left on for about three days after each spray operations to avoid any fumigation effect on the unsprayed plants.

3. RESULTS

3.1 Laboratory experiments on droplet size

3.1.1 Effect of oil on droplet size (>250 μm)

This experiment examined the effect of two contrasting environmental conditions namely, low temperature and high humidity (18°C, 69% RH) and high temperature and low humidity (42°C, 18% RH) on a water spray with either 5% wetting agent or 22.5% oil with flow rates of 84 and 66 ml/min respectively.

At 200 cm below the nozzle the VMD of water droplets was reduced by 34% at 42°C and only 13% at 18°C compared with the VMD at 30 cm. The addition of oil gave a smaller reduction at both temperatures, namely, 10 and 5% at 42°C and 18% and 18°C and 69% relative humidity respectively (Table 1 and details in Appendix II Table 9).

With flow rates of 84 and 66 ml/min for water plus 5% wetting agent and water plus 20% Ulvapron oil respectively, the volume of droplets was calculated from the measurement of VMD for each formulation and showed that addition of oil reduced the change in the volume of droplets. At 42°C the volume of water droplets had decreased by 70% but with oil in the spray by only 27%. Even at the lower temperature of 18°C, the volume decreased by 35 and 12% without and with oil respectively. The percentage reduction in VMD under the same conditions was 32 and 13%, 15 and 10% respectively for the two formulations.

3.1.2 Effect of oil on droplet size (<110 μm)

The effect of the same formulations as Para. 3.1.1 was also examined with the same disc operated at two higher speeds with high and low temperatures and relative humidities (34°C, 15% RH and 12°C, 58% RH).

Table 1 Percentage decrease of VMD, NMD and calculated volume of droplets between samples at 30 and 200 cm below an 8 cm spinning disc. (Speed, 1950 rev/min).

Formulation	VMD		NMD		Calculated Volume based on VMD	
	Temp ^{o}C 18, RH % 69	Temp ^{o}C 42, RH % 18	Temp ^{o}C 18, RH % 69	Temp ^{o}C 42, RH % 18	Temp ^{o}C 18, RH % 69	Temp ^{o}C 42, RH % 18
Water plus 5% wetting agent	13	34	15	32	35	70
Water plus 22.5% Ulvapron	5	10	10	13	12	27

At a disc speed of 9,000 rev/min., a temperature of 34°C and 15% RH, the VMD of droplets containing water plus 5% wetting agent was reduced by 16%, but with water plus 22.5% Ulvapron oil, the reduction in VMD was only 9% over a distance of 170 cm. (Table 2). The percentage reduction at 12°C and 58% RH was % and 4% respectively. When the volume was considered i.e. the percentage reduction was 40% for water plus 5% wetting agent and 23% for 22.5% Ulvapron oil at 34°C and 15% RH. Similarly the percentage volume reduction was 18 and 10% for the two formulations at 12°C, 58% RH. The NMD also followed a similar trend amounting to 22 and 13% and 11 and 1.4% for water plus 5% of wetting agent and water plus 22.5 of Ulvapron oil at the higher and lower temperatures respectively. There was thus a similar reduction in the size of droplets at 200 cm below the nozzle (Tables 2 and 3 and Appendix 11 Tables 10 - 11) with the formulation containing oil as with larger droplets, but less evaporation occurred with the water spray mainly due to the lower temperature in these tests although the effect of a larger number of small droplets humidifying the air could have been a factor.

Where conditions remained the same as aobve, but at a disc speed of 12,000 rev/min., the percentage reduction in VMD with droplets of water plus 5% wetting agent and water plus 22.5% Ulvapron oil was 23 and 13% (at 34°C, 15% RH) 10 and 1.3% (at 12°C and 58% RH) respectively (Table 3).

When the volume was calculated from the VMD, the percentage reduction was higher, as mentioned above, being 54 and 33%, 25 and 5% for water plus 5% wetting agent and water plus 22.5% Ulvapron oil respectively. Concurrently the percentage reduction in NMD for the same formulations was 33 and 20%, 15 and 10% respectively.

In Para. 3.1.1 with >250 μm droplets and here in Para 3.1.2 with <110 μm droplets, the addition of oil has in both instances

Table 2 Percentage decrease of VMD, NMD and calculated volume of droplets between samples at 30 and 200 cm below A 5.5 cm spinning disc (speed, 9000 rev/min).

Formulation	V M D		N M D		Calculated volume based on VMD	
	Temp °C 12, RH % 58	Temp °C 34, RH % 15	Temp °C 12, RH % 58	Temp °C 34, RH % 15	Temp °C 12, RH % 58	Temp °C 34, RH % 15
Water plus 5% wetting agent	8	16	11	22	18	40
Water plus 22.5% Ulvapron	4	9	1.4	13	10	23

Table 3. Percentage decrease of VMD, NMD and calculated volume of droplets between sample at 30 and 200 cm below A 5.5 cm spinning disc (speed, 12000 rev/min).

Formulation	V M D		N M D		Calculated volume based on V M D	
	Temp °C 12, RH % 58	Temp °C 34, RH % 15	Temp °C 12, RH % 58	Temp °C 34, RH % 15	Temp °C 12, RH % 58	Temp °C 34, RH % 15
Water plus 5% wetting agent	10	23	15	33	25	54
Water plus 22.5% Ulvapron	1.3	13	10	20	5	33

significantly reduced the decrease in droplet size due to evaporation of the carrier liquid.

3.1.3 Effect of three different oils on droplet size

A spray study as in Para. 3.1.1. and Para. 3.1.2 was conducted with water plus 5% wetting agent and three different oils namely, Sunoco Sunspray (SSS) 7E, 11N and different concentrations of micronised Ulvapron oil employing the same disc and flow restrictor, at a speed of 15,000 rev/min., and a constant temperature of 34^{O}C and 20% RH.

Droplets were sampled at 10, 30 and 200 cm below the disc (Para. 2.4.1) and the results of analysis are shown in table 4 and details in Appendix II Table 12.

The highest percentage reduction of VMD, NMD and volume occurred with water plus 5% wetting agent, the volume decreased by 39% at 30 cm and 82% at 200 cm below the nozzle (Table 4 top row). In contrast the least percentage reduction of volume of droplets occurred with the formulation containing the greatest quantities of oil (40%). in water (bottom row) namely, 6% at 30 cm and 14% at 200 cm spray heights respectively.

An overall analysis of variance for the difference of the mean percentage droplet reduction between the 30 and 200 cm sampling points below the nozzle was significant P>.05 (t-test) (Table 4).

The addition of 20% Sun oil either as the 7E or 11N formulation had less effect on evaporation of water from droplets than 20% Ulvapron oil although droplets of water plus 20% Sun oils at 30 and 200 cm were significantly larger than those without any oil. The effect on the droplet size which occurred when the percentage oil of Ulvapron oil decreased from 40 to 20 and 15% was investigated in more detail in a latter experiment (Para. 3.1.4)

Table 4. Percentage decrease of VMD, NMD and calculated volume of droplets between samples of 10 - 30 and 30 - 200 cm below A 5.5 cm spinning disc. (speed, 15000 rev/min., Temp. 34^{o}C, 20% RH. and flow restirctor No. 4).

Formulation		VMD	NMD	Calculated percentage change in volume based on VMD.
Water + 5% wetting agent	30 200	15 43	16 45	39 82
Water + 20% Sunoco Sun spray 7E	30 200	6 23	7 21	17 55
Water + 20% Sunoco Sun spray 11N	30 200	7 18	8 13	19 44
Water + 15% Ulvapron micronised	30 200	5 16	5 15	13 33
Water + 20% Ulvapron micronised	30 200	5 9	5 8	7 26
Water + 40% Ulvapron micronised	30 200	2 5	3 8	6 14

30 cm vs 200 cm : VMD = T = P > .05

NMD = T = P > .05

Volume = T = P > .05

3.1.4 Effect of different concentration of oil on droplet size at three disc speeds.

The change in droplet size when sprays containing water plus 5% wetting agent and 5 different concentrations of oil namely, 5, 10, 15, 20 and 40% 'Ulvapron' oil in water was conducted with a 5.5 cm spinning disc as described in Para. 3.1.1, 3.1.2 and 3.1.3 at 32^{o}C, 20% RH. The disc was operated at three speeds of 5000, 10,000 and 15,000 rev/min. A No. 4 flow restirctor was used so the volume applied changed in relation to the viscosity of the spray liquid. Spray droplets were sampled at 3 levels namely, 10, 30 and 200 cm below the disc.

For the computed results and details of comparative analysis see Fig. 16a and 16b and Appendix II Table 13A, B and C. Also differences in droplet depositions between water plus 5% wetting agent and water plus 20% Ulvapron oil at three levels below the nozzle (i.e. 10, 30 and 200 cm) are shown in Appendix II Plates 1 and 2.

An increase in disc speed from 5,000 to 10,000 and 15,000 rev/min., decreased the size of droplets irrespective of the liquid applied and the level at which droplets were sampled. For example at 10 cm below the disc a VMD of 100 μm with water plus wetting agent at 5,000 rev/min., was reduced to 70 μm at 10,000 rev/min., and to 49 μm at 15,000 rev/min. Similarly, a VMD of 102 μm with water plus 5% Ulvapron oil was reduced to 71 μm and then to 49 μm at the two higher disc speeds respectively.

As the proportion of oil in water was increased, the decrease in droplet size was less but the effect of 40% oil was not much greater than with 20%. The mean percentage reduction of the VMD of droplets with water plus 5% wetting agent was 15% between the 10 and 30 cm, and 44% between the 10 and 200 cm samples below the disc at all the

Fig. 16a VMD and percentage change in VMD with different concentrations of oil in water sprayed with a 5.5 cm spinning disc.

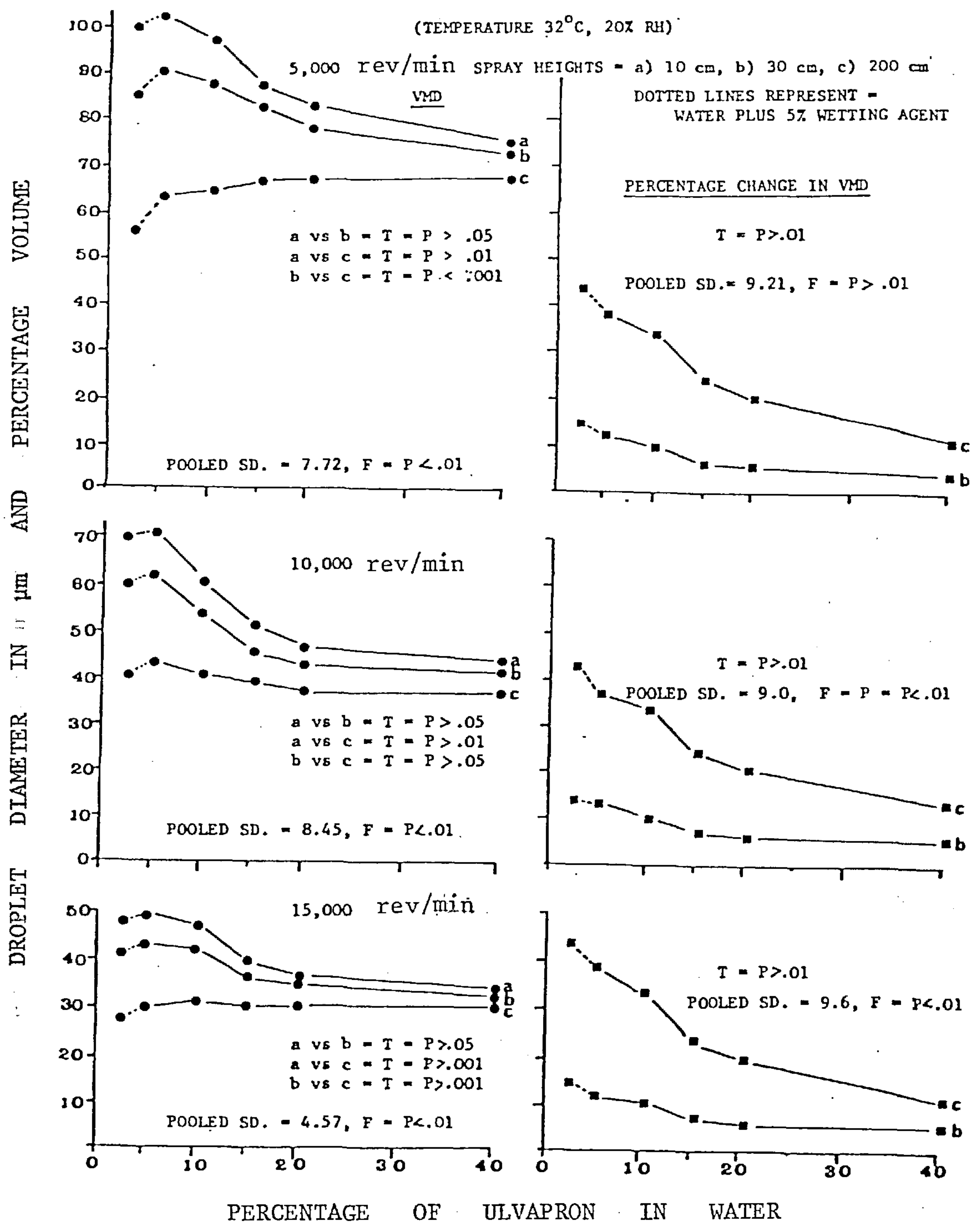
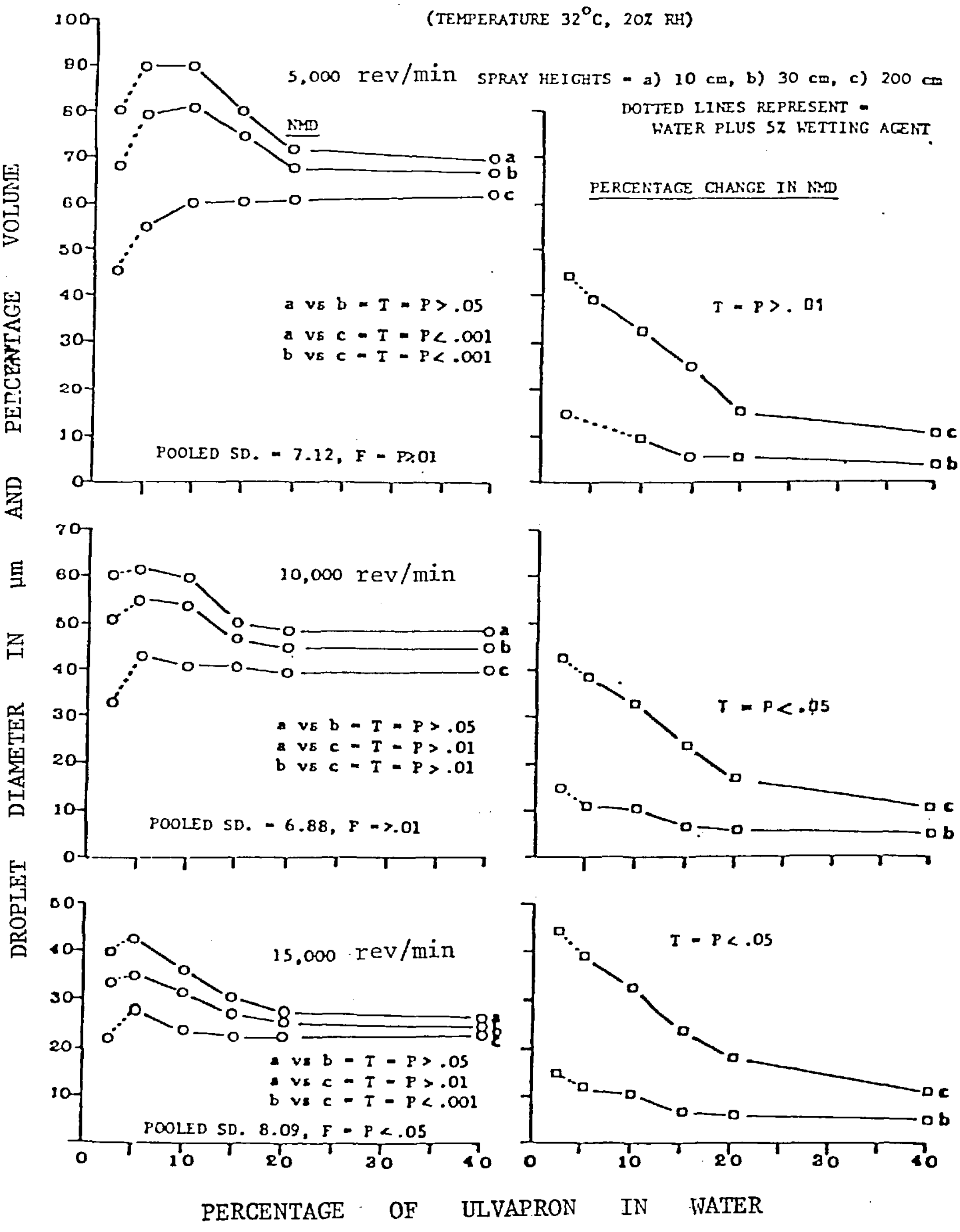


Fig. 16b NMD and percentage change in NMD with different concentrations of oil in water sprayed with a 5.5 cm spinning disc.



three disc speeds despite initially smaller droplets at the higher disc speeds. The VMD of droplets with water plus 40% Ulvapron oil, were also reduced but by an average of only 4.6 and 11.6% respectively at the same sampling heights.

The VMD of droplets with water plus 5% wetting agent was less than water plus the lowest concentration of oil, namely 5% at all three disc speeds. This initial difference in droplet size between the two formulations and subsequently with others existed despite the fact that the rate of the flow of the former was slightly higher (by 7.6%) suggesting that although the initial droplet sizes were affected by changes in surface tension and viscosity a partial evaporation of water from droplets without oil may have taken place immediately before droplets reached the nearest sampling points i.e. 10 cm below the nozzle.

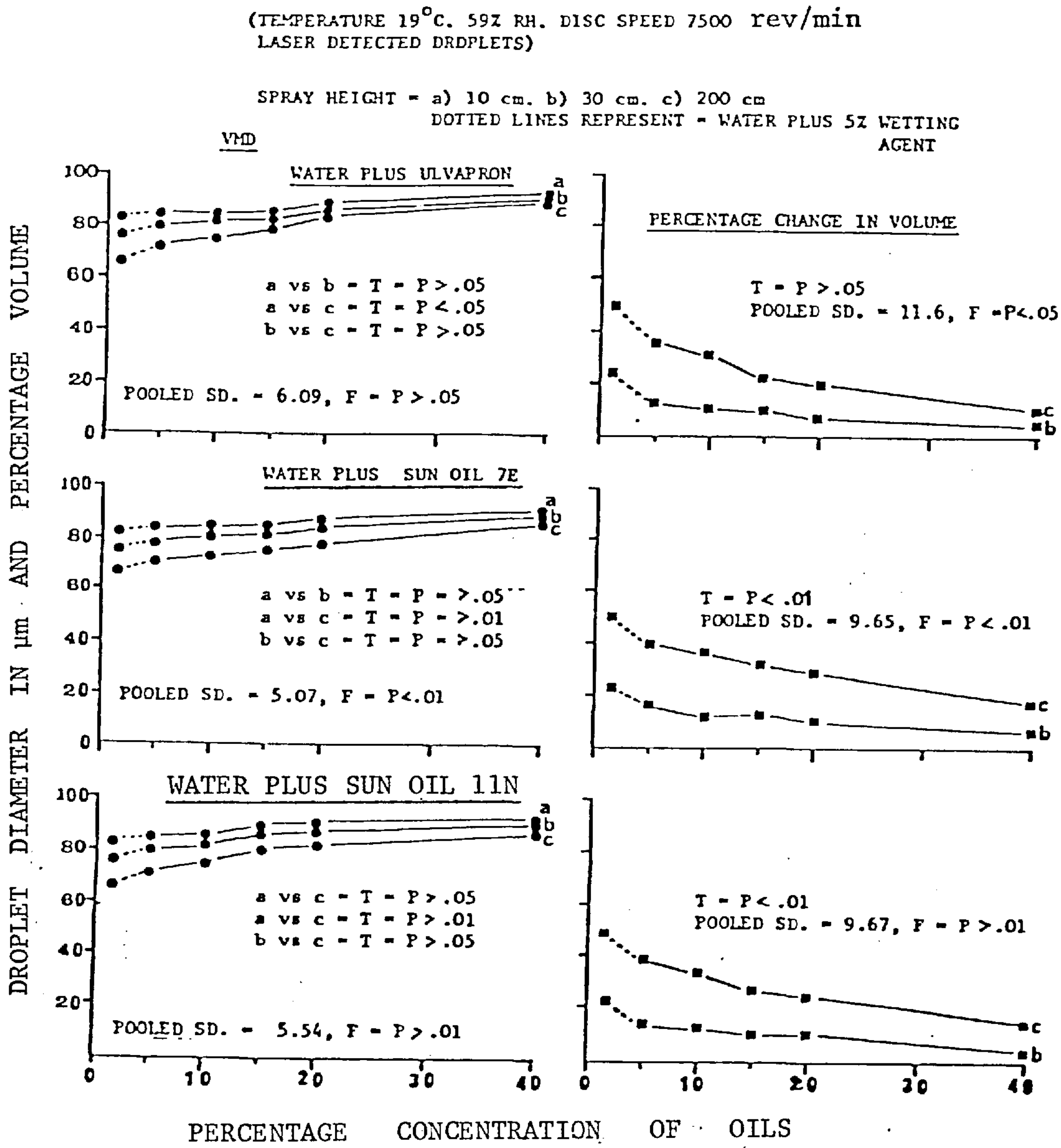
The analysis of droplet size at each level showed that the VMD decreased between the 10 and 30 cm samples ($P>0.05$), with more significant differences between either 10 and 200 cm ($P<0.01$) or 30 and 200 cm ($P>0.01$) below the nozzle.

The percentage reduction of the VMD indicated a similar trend in Fig. 16a and 16b (right columns).

3.1.5 Effect of different concentrations of three oils on droplet size (laser detected).

The results on reduction in droplet size due to evaporation of water obtained above were reassessed using a laser diffraction system to measure the droplets. A range of concentrations of oil 5, 10, 15, 20 and 40% in water was again compared with water plus wetting agent. Sprays were applied with a spinning disc mounted in a spray tower (Para. 2.4.2) maintained at a constant temperature

Fig. 17 VMD and percentage change in droplet volume when water based sprays containing concentrations of three oils were sprayed with a 5.5 cm spinning disc.



(Analysis of variance for the difference in VMD among all the three oils
Pooled SD = 5.58, F=P < .05)

of 19^{o}C and 59% RH. The disc speed was 7500 rev/min. In these tests a constant flow rate of 30 ml/min was maintained for each formulation irrespective of its viscosity in contrast to the earlier experiments.

The computed results of droplet sizes detected in the laser beam for each formulation at each sampling height are shown in Fig. 17 (Appendix II, Table 14).

The study was at a relatively low temperature and high humidity but the reduction in the size of VMD or percentage volume of each formulation is obvious except for those formulations with higher concentrations of oil (Fig. 17).

With a uniform flow rate for each formulation, an increase in the proportion of oil in water increased the size of droplets and reduced the evaporation. The change in droplet size between the 10 and 30 cm smapling points was greater for the spray without oil. The addition of oil up to 20% had a progressively greater effect on evaporation but addition of 40% oil was not significantly better than 20% in any of the water based oil formulations.

The overall analysis of variance for the difference in the size of either VMD and percentage volume reduction between any of the three oils gave a significance value of F = P>.05 and P>.05 (T - test).

3.1.6 Effect of different concentration of oil on numbers of droplets.

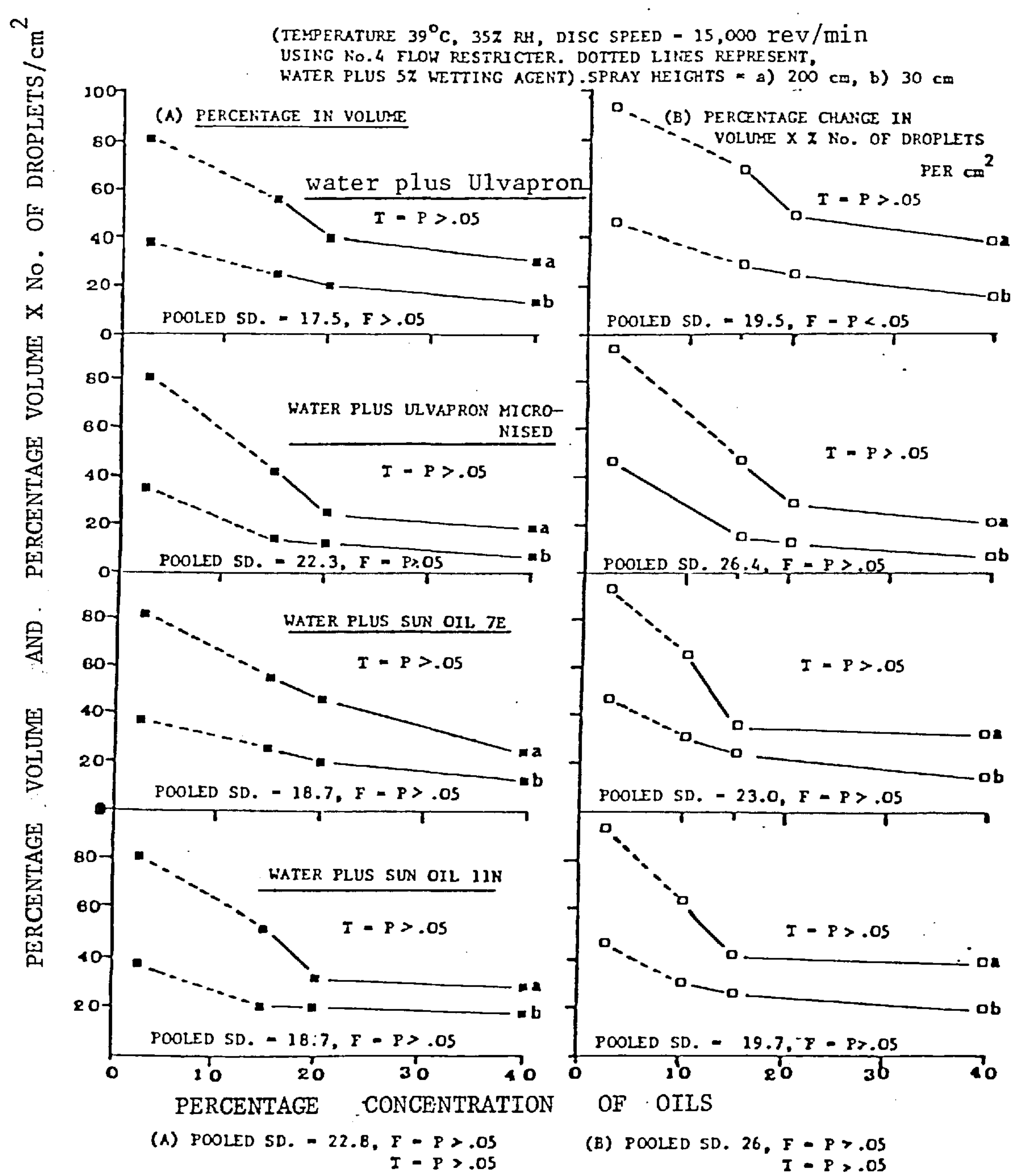
Further study of the change in droplet size due to evaporation compared the effect of different concentrations of oil (15, 20 and 40%) in water with water plus 5% wetting agent sprays to assess the number of droplets impacted on a surface. The oils used were Ulvapron oil (normal and micronised) and 7E and 11N Sun oils, all applied through a No. 4 flow restrictor, as in Para. 3.1.3 and 3.1.4, at a temperature of 39^{o}C and 35% RH.

The assessment of droplet reduction was by VMD, total volume in μm^3 and cm^3/cm^2, percentage decrease/cm^2 in volume and calculated percentage volume of VMD decrease by sampling heights. Detailed calculations are given in Appendix II and Tables 15 and 16. Droplets not only decreased in size but the number per unit area decreased too both at 30 and 200 cm below the nozzle. However, the decrease in the population of droplets per unit area was less (as in droplet volumes) as the proportion of oil in water was gradually increased from 15 to 20 and 40%. The calculated volume decrease in VMD is given in the left column (Fig. 18) and the actual percentage droplet decrease (at sampling height) multiplied by the volume calculated from VMD is given on the right column of Fig. 18.

As in Para. 3.1.3 and 3.1.4, the highest volume reduction occurred with water plus 5% wetting agent amounting to 38% at 10 cm and 82% at 200 cm below the nozzle and when the droplet number per unit area was considered, the percentage volume decrease was even higher reaching 47 and 94% respectively at the same sampling heights. The least reduction in droplets both in percentage volume and percentage X N droplets occurred with 40% Ulvapron oil reaching 7 and 19% for the former and 7 and 21% for the latter (Fig. 18). The reduction in droplet number as well as volume may be attributed to droplets affected by greater evaporation which may have become too small to reach the sampling targets, failed to impact or were not detected.

The mean percentage volume between the 30 and 200 cm below the nozzle (for each of the three formulations) gave a significant value of P>.05 (T - test). The overall analysis for the difference

Fig. 18 Effects of different concentration of oil on the change in volume of droplets and volume of spray sampled, (volume of droplets X No. of droplets/$_{cm^2}$)



in percentage volume for all the formulations gave a Pooled Standard Deviation of 22.8 and P>.05 (F - ratio) or P>.05 (T - test). Similarly the analysis of variance of the percentage change volume in cm^3/cm^2 (volume X percentage of droplets/cm^2 gave a Pooled Standard Deviation of 26 and P>.05 (F - ratio) and P>.05 (T - test) between any two groups of water based oil formulations.

3.1.7 Effect of variation of disc speed and flow rate on droplet size.

Water plus 40% Ulvapron oil was sprayed by a 5.5 cm spinning disc 10 cm above a laser beam at flow rates of 17, 38 and 56 ml/min and disc speeds of 9,500 and 11,500 rev/min., at a temperature of 17^{o}C and a relative humidity of 80%. Each flow rate was followed by 10 replicated spray tests and the computed mean results are shown in Table 5 and details in Appendix II Table 17. Fig. 8.

When the disc speed remained constant at 9,500 rev/min., the increase in flow rate from 17 to 38 and 56 ml/min increased the VMD from 59 to 70 and 79 μm and the NMD from 50 to 54 and 60 μm respectively. When the disc speed increased to 11,500 rev/min with changes in flow rates as above, the VMD increased from 52 to 60 and 69 μm with a corresponding increase in NMD from 51 to 56 and 65 μm respectively.

Analysis of variance both for VMD and NMD of the two speeds indicate that the variations in droplet sizes are significant both in F = ratio and t = Tests (Table 5 bottom).

3.1.8 Effect of spray pressure on droplet size

Deodourized kerosene (1) and water plus 20% Ulvapron oil were

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(1) Supplied by : Shell Research Ltd., Sittingbourne Research Centre, Kent.

Table 5 Laser detected droplet distributions (VMD & NMD) in relation to changes in flow rates and disc speeds of water + 20% Ulvapron sprayed by 5.5 cm spinning disc. (Temp. 18°C, 80% RH)

No.	Flow rate ml/min	Disc speed r. p. m. 8V	12V	VMD	NMD	Ratio
1	17	9500	-	59 ±5	50 ±5	1.2
2	38	9500	-	70 ±6	54 ±8	1.3
3	56	9500	-	79 ±3	60 ±7	1.3
4	17	-	11500	52 ±4	51 ±5	1.0
5	38	-	11500	60 ±6	56 ±4	1.1
6	56	-	11500	69 ±3	65 ±2	1.1

<u>95000 vs 11500 r.p.m.</u>

VMD = PSD = 9.29, F = 9.29, F = P>.01, T = P>.05

NMD = PSD = 6.15, F = 6.15, F = P>.01, T = P>.01

sprayed through an MK II Exhaust Nozzle (Para. 2.1.3) in a laboratory at 18^{0}C and 68% RH by varying the spray pressure from 0.1 to 0.2 bar. The droplets of both formulations were detected by a Malvern laser droplet detection system (Para. 2.3.3).

The summary of the results are shown in Table 6 and details in Appendix II Table 18.

At both 0.1 and 0.2 bar spray pressures a reduction in droplet size was detected between samples taken at 10 and 150 cm from the exhaust nozzle. The reduction in VMD for deodourized kerosene was less (5%) at the higher pressure than with 0.1 bar. With water plus 20% Ulvapron oil the VMD was reduced by 16 and 22% at the low and high spray pressures respectively. The greater reduction in VMD of water plus 20% Ulvapron oil compared with deodourized kerosene under similar conditions was probably due to greater evaporation of water in the formulation but the initial droplet size was also less.

Comparison of the ratio of VMD/NMD for both formulations measured with the laser technique was much greater than with the spinning disc (compare Appendix II Tables 17 and 18).

Increasing the spray pressures of the Exhaust Nozzle Sprayer decreased droplet size, however, the reduction was greater with the deodourized kerosene formulation.

3.2 Studies on drift of droplets

The distance to which droplets are carried downwind is dependent on the size of droplets, rates of evaporation and climatic conditions prevailing at the time of application. In the studies described below, droplets were sampled at different distances downwind to assess the effect of adding oil to formulations.

Table 6 Laser detected droplet distribution sprayed by an MK II exhaust nozzle sprayer.

Formulation	Operating pressure kg/cm^2	Nozzle distance from laser	VMD	NMD	Ratio	percentage decrease in VMD
Deodourized kerosene	0.1	50	111	10	11.1	100
	0.1	150	91	8	11.4	18
	0.2	50	81	14	6.8	100
	0.2	150	77	8	9.6	5
Water + 20% Ulvapron	0.1	50	90	10	9.6	100
	0.1	150	76	10	7.6	16
	0.2	50	73	7	10.4	100
	0.2	150	57	9	6.3	22

Deodourized kerosene vs water plus 20% Ulvapron oil:

50cm = VMD = PSD* = 17.2, F = P>.01, t = P<.05

150cm = VMD = PSD* = 11.8, F = P>.01, t = P<.05

(* Pooled Standard Deviation.)

3.2.1 Field sampling of droplets on MgO coated slides downwind

Three formulations namely, water plus 5% wetting agent, water plus 20% Ulvapron oil and Ulvapron oil were sprayed under field conditions with a) a hand held 5.5 cm spinning disc, b) four 5.5 cm spinning discs and the c) multiple disc (15 discs) sprayers (2.1.2a - 2.1.2c).

The nozzle of the hand-held 5.5 cm spinning cup was maintained at an approximately 90 cm, while that of 4-disc and multiple disc sprayers were kept at nearly three times this height and for each sprayer and spray formulation droplets were sampled at progressive distances of 0.25 to 128 m downwind (Para. 2.4.4 and Plate 1, and Fig. 12).

The hand held spinning cup was operated at a disc speed of 10,000 rev/min., under prevailing mean meteorological conditions of 0.5-2.7 m/s wind speed, a temperature and relative humidity of 20°C and 68%. The mean wind speed under which the 4-disc sprayer was operated was slightly higher reaching 2.3-3.4 m/s and with a temperature and relative humidity of 18°C and 57%. Although each set of tests was conducted under a different set of prevailing field conditions, an equal volume of 200 ml/disc was applied with both sprayers.

The droplets emitted by all the sprayers were sampled by MgO coated slides placed vertically. Droplets/cm^2/ml of spray were plotted in Fig. 19 and 20 and details tabulated in Appendix III Tables 19-21.

Both with a hand held spinning disc and 4-disc sprayers, relatively more droplets were sampled at each distance downwind on the vertical MgO coated slides placed 35 cm above the ground. Fewer droplets were sampled at 70 cm above ground but the distance at which droplets were sampled was similar. The recovery of droplets was minimal at 150 cm sampling height downwind for the 4-disc sprayer and very few or no droplets were recovered at this height for the hand carried sprayer (Fig. 19).

The multiple disc sprayer was used to test the effect of high and low flow rates on droplet distribution. For the former a mean wind speed of 2 - 3.1 m/s, a temperature of 24.3^{o}C and relative humidity of 50.3% prevailed and for the latter a mean wind speed of 2 - 3.4 m/s, a temperature of 21.3^{o}C and a relative humidity of 59.3% existed. For the higher flow rate, an equal tank pressure of 5 - 6 kg/cm^2 was maintained (Fig. 20) without employing a flow meter and an orifice with a valve gave flow rates of 750 ml/min (50 ml/disc) for water plus 5% wetting agent, 714 ml/min (48 ml/disc) for water plus 20% Ulvapron and 500 ml/min (33.3 ml/disc) for Ulvapron oil. For the lower flow rate a constant flow of 150 ml/min i.e. 10 ml/disc was maintained with the use of a flow meter. Both for high and low flow rates, an equal amount of 3.75 ℓ of each of the three formulations was sprayed. With the lower flow rate for the multiple disc, the maximum distance droplets of water plus 5% wetting agent recovered was 32 m from the nozzle and 16 m for water plus 20% Ulvapron oil and 8 m for Ulvapron oil alone. For the high flow rates, however, droplets of water plus 5% wetting agent and water plus 20% Ulvapron were recovered at a distance of only 16 m from the nozzle (Fig. 20).

As with the hand held and 4-disc sprayers, most droplets were recovered on MgO coated slides positioned at 35 cm above ground followed by 70 cm and lastly 150 cm when the multiple disc sprayer was used. Even with variable operational field conditions, droplets of water plus 5% wetting agent were found to have been carried away to a maximum distance of 64 m from the nozzle with both the 4-disc and the multiple disc sprayers but not with the hand held sprayer held near the ground. Traces of water plus 20% Ulvapron oil droplets were found at 32 m and 64 m downwind at 70 cm above ground with the 4-disc and 150 and 70 cm sampling heights with the multiple disc employing low flow rates. With the 4-disc sprayer a trace quantity of Ulvapron oil droplets was recovered at 32 m downwind from nozzle at all three sampling heights of 150 cm. This instance of a maximum distance at which Ulvapron oil droplets were found may be attributed to the higher mean wind speed (3 - 3.6 m/s) which prevailed at the time of Ulvapron spraying.

Under field conditions, although extremely difficult, droplet sizing by MgO coated slides was possible (Para. 2.3.2.), the main problem with these studies was that the number of droplets sampled was a function of the sampling surface. Larger droplets were found to have deposited in areas further away from the spray nozzle which may be attributed to the behaviour of air current and wind movement (Appendix III Tables 20 and 21).

An overall three-way analysis of variance (Appendix III Table 22) has given significance levels of $.05>P>.025$ between formulations, not significant for sprayers, and $P<.001$, very significant for vertical heights at which droplets were collected downwind from the various spray nozzles.

3.2.2 Comparison of droplet drift of two formulations

An equal amount of 400 ml/disc of two formulations i.e. of water plus 5% wetting agent plus 4% Fire Orange and Ulvapron oil plus 10% Saturn Yellow were released simultaneously exactly under the

Fig. 19 Droplets sampled on vertical targets at different heights to measure downwind drift of three formulations.

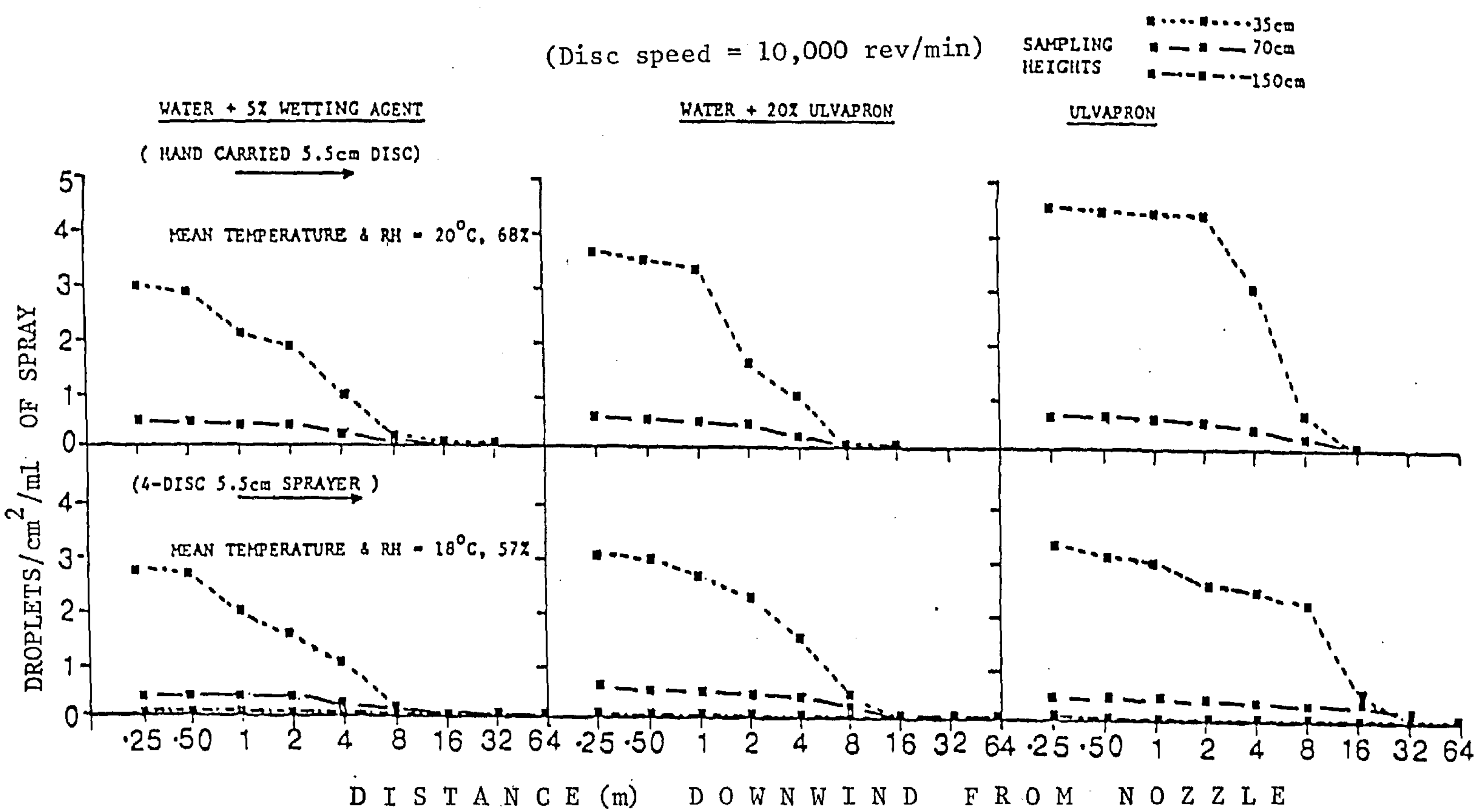
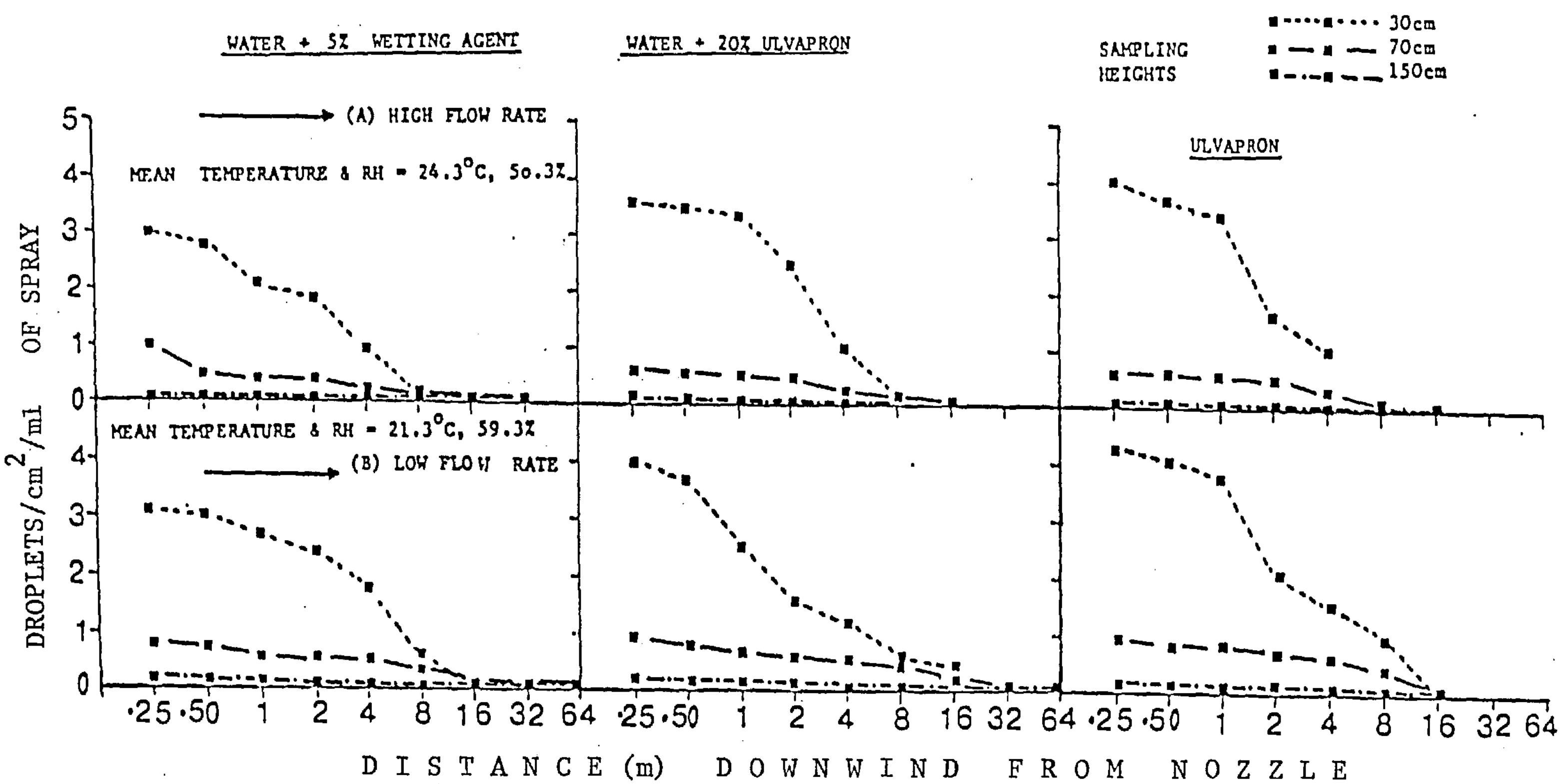


Fig. 20 Droplets sampled on vertical targets at different heights to measure downwind drift of three formulations.

(Sprayer: multiple disc; speed, 8500 rev/min.



same climatic conditions by spraying each formulation through two discs positioned diagonally. Droplets were sampled on MgO coated slides attached on stakes at 3 heights downwind as discussed in Para. 3.2.1. Detailed results of droplet recovery are given in Appendix III Table 23.

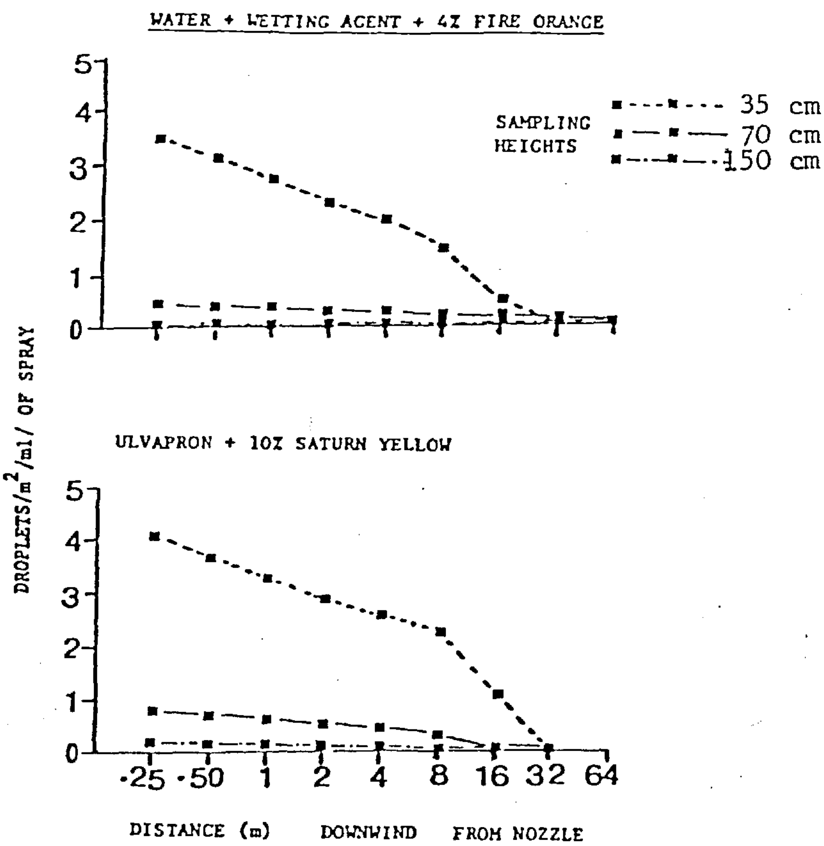
Droplets of water were recovered at a distance of 64m while that of Ulvapron was found at a distance of 32m from the spray nozzle. Droplets containing water partially evaporated so were liable to drift to a greater distance from the point of emission. Most of the droplets from either formulation were sampled mostly within 8m of the nozzle. Examination of spray area using ultra-violet-light revealed the water droplets to have impinged on grasses, leaves and stems of the surrounding hedges beyond the confines of the sampling area at higher elevations than the oil droplets which remained mainly closer to the spray nozzle and close to the ground level (Fig. 21).

A three-way analysis of variance (Appendix III Table 24) has a level of significance i.e. not significant (ns) for formulations and $P<.05$ i.e. significant for distance droplets recovered and $P<.001$ or very significant for the different vertical heights at which droplets were collected downwind from the nozzle.

3.2.3 Droplet deposition on leaves downwind

A total of 750 ml of each of water plus 5% wetting agent including 4% Fire Orange and different concentrations of Ulvapron oil (5, 10, 15, 20 and 40%) and Ulvapron oil each with 10% Saturn Yellow were sprayed by a multiple disc sprayer i.e. 15 discs (Fig. 2a - d and Plate 1) at a constant flow rate of 150 ml/min i.e. 10 ml/disc and at a speed of 8500 rev/min., a low temperature and high relative humidity ($19^{o}C \pm 2$, 60%) and a mean wind speed of 3 - 4 m/s. Branches

Fig. 21 Droplets sampled on vertical targets at different heights downwind of two formulations released simultaneously by a 5.5 cm 4-disc sprayer.



DISC SPEED - 12,000 rev/min
MEAN WIND SPEED - 3 - 3.5 M/S
TEMPERATURE & RH - 14°C, 90%

of Rhododendron Lochae Muell each 1 m high with adequate leaves were erected with a support of stakes at progressive distances similar to that used for MgO coated slides described in Para. 3.2.1 from the spray nozzle. Droplet coverage both on front and back of leaves was estimated by using a uv-lamp and standards explained by Patterson, (1963) and Pereira, (1967) (Para. 2.2.3.).

Results were plotted (Fig. 22) and details are shown in Appendix III Table 25.

Droplets of water plus 5% wetting agent and water plus 5% Ulvapron oil sprays were carried away to a maximum distance of 128 m from the spray nozzle. As the amount of oil in water was gradually increased, the distance droplets were carried away from the spray nozzle decreased in similar manner as discussed in Para. 3.2.1 and 3.2.2. For example the nearest distance Ulvapron oil droplets were carried away was 0.25 m and the furthest was 16 m downwind from the spray nozzle. A water plus 20% Ulvapron formulation gave a droplet trace coverage at a distance of 64 m from the nozzle but droplets of 10% and 15% Ulvapron oil in water were sampled at a maximum distance of 32 m. This may be attributed to the higher mean wind speed that existed at time of spraying.

The distances at which droplets were recovered on the back of Rhododendron leaves (shaded area in Fig. 22) were between 4 and 32 m with the coverage being evident at 1 m for Ulvapron oil and 2 m for water plus 20% Ulvapron oil downwind from the nozzle.

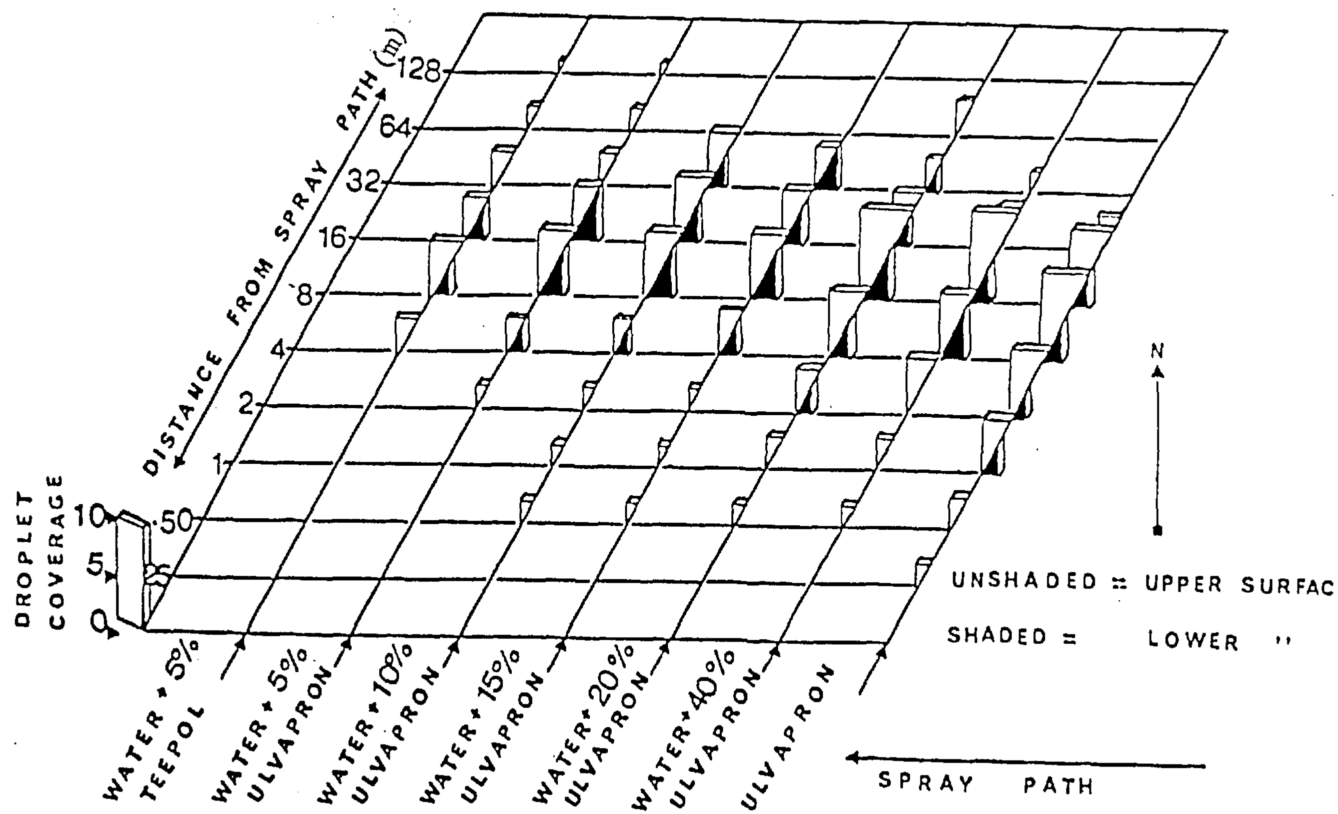
The Pooled Standard Deviation for the overall droplet coverage is 1.71 with analysis of variance for the difference in coverage between front and back of leaves being significant at $P<.001$ (T - test).

3.2.4 Effect on droplet drift of spray formulations released by Mk II exhaust Nozzle sprayer

Further studies of drift of droplets was carried out using

Fig. 22 Estimates of spray droplet deposition on (Rhododendron lochae Muell.) leaves.

(Sprayed with multiple-disc sprayer at a constant flow rate of 150 ml/min, mean temperature, 19± 1.6°C, RH 60 ± 1.1% and mean wind speed, 3 - 4 m/s).



POOLED SD. = 1.71, F = ratio = P< .01
T = P< .001

two spray formulations namely, deodourized kerosene and water plus 20% Ulvapron oil applied with an MK II Exhaust Nozzle Sprayer. Each formulation was carried separately in its twin tanks.

Under similar field conditions with a low temperature and a high relative humidity (15^{o}C, 88%), mean wind speed of 3 - 5 m/s, and a spray pressure of 0.2 bar, the above two formulations were sprayed one after the other i.e. the second was sprayed after droplets were recovered for the first formulation. Under the prevailing mean wind speed no droplets were recovered in the first six meters from the nozzle so the progressive distances adopted for the single and the multiple disc sprayers discussed in Para. 3.2.1 - 3.2.3 were altered by adding a distance of six meters to each of the consecutive distances from the nozzle (Para. 2.4.4).

The spray operation for each formulation was repeated six times and the mean droplets recovered/cm^2 up to a maximum distance of 134 m from the nozzle are shown in Table 7. All the sprays were sampled at three positions on vertically placed MgO coated slides. As with the 5.5 cm 4-disc and the multiple disc sprayers discussed in Para. 3.2.1 - 3.2.3, most of the droplets of deodourized kerosene and water plus 20% Ulvapron released by the Exhaust Nozzle Sprayer were recovered at the 35 cm sampling height at each consecutive distance downwind. A few droplets/cm^2 were recovered at every sampling height of 150 cm downwind up to 70 m from the nozzle, the droplet recovery was minimal as compared both with the 35 and 70 cm sampling heights. No droplets of deodourized kerosene were recovered at a target beyond the 70 m distance from the nozzle. But traces of droplets of water plus 20% Ulvapron oil were found at the maximum distance of 134 m downwind at sampling heights of only 35 and 70 cm.

The maximum distance at which droplets containing water

Table 7. Comparison of droplet drifts of two spray formulations sprayed by MK II Exhaust Nozzle Sprayer

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
No.	Sprayer	Temperature °C	Relative humidity	Wind speed m/s	Disc speed rev/min	Formulation & flow rate	Sampling heights	Distance (M) from spray nozzle and droplets/cm^2										
								6.25	6.50	7	8	10	14	22	38	70	134	Mean SD
1	MK II Exhaust N.S.	15	88	3 - 5	0.2 bar spray press.	5-min.spray Deodourized K	150	93	86	79	71	58	51	42	32	23	-	60.5 ±25.9
							70	231	220	199	180	160	145	128	105	50	-	157.6 ± 57.9
							35	596	560	490	470	450	410	350	280	130	-	415.0 ±144.6
2	MK II Exhaust N.S.	15	88	3 - 5	0.2 bar spray press.	5-min spray H_2O + 20% UL.	150	80	55	50	39	25	18	14	11	5	-	32.7 ± 23.4
							70	170	160	150	125	118	100	90	60	41	15	102.9 ± 51.9
							35	502	471	400	340	299	250	200	170	110	8	275.0 ±158.5

were recovered was 134 m but this may be attributed to evaporation reducing the size of the smaller droplets so that they were not sampled and were thus liable to drift beyond the furthest samplers. The height at which droplets were thrown up above the nozzle of the Exhaust Nozzle Sprayer should have also contributed to the distance to which droplets were carried away under the prevailing wind speed.

This instance of drift of droplet with a water containing formulation, agrees with the droplet recovery of a similar formulation discussed in Para. 3.2.1 - 3.2.3 in connection with sampling droplets on MgO coated slides and droplet deposition on leaves downwind.

3.2.5 Effect on droplet drift of deodourized kerosene released in still air under sheltered condition.

A study on droplet drift was conducted by spraying deodourized kerosene alone in still air under sheltered condition i.e. in a tree surrounded area and by sampling droplets on MgO coated slides positioned vertically on stakes and horizontally positioned on the ground spaced out one meter apart downwind up to a maximum of 25 m from the nozzle. Conditions of low temperature and high relative humidity (17°C, 89%), a mean wind speed of 0 - 0.1 m/s existed when spraying at a pressure of 0.2 bar for five minutes.

Although sampling surfaces were positioned up to 25 m downwind, droplets were not recovered beyond the 9 m mark from the nozzle. Horizontally positioned MgO coated slides collected more droplets/cm^2 than the vertical slides. A mean of 633$\pm$ 216/cm^2 sampled on the horizontal and 149$\pm$ 68/cm^2 on the vertical slides (Table 8 and column 11).

The analysis of variance for the difference in droplet recovery

Table 8. Comparison of vertical and horizontal depositions of deodourized kerosene sprayed by MK II Exhaust Nozzle Sprayer in still air under sheltered condition.

1	2	3	4	5	6	7	8	9	10	11	12
	Distance (m) from spray nozzle and droplets/cm^2										
Droplet Sampling position	1	2	3	4	5	6	7	8	9	Mean SD.	Percentage droplet/cm^2 (Percentage droplet inc*
Vertical MgO coat. slides	232 ± 14	220 ± 21	200 ± 16	185 ± 19	150 ± 11	130 ± 22	115 ± 27	75 ±12	30 ± 8	149 ± 68	100
Horizontal MgO coated slides	890 ± 20	800 ± 15	775 ± 31	740 ± 36	700 ±36	615 ± 9	570 ± 13	410 ± 28	200 ± 26	633 ± 216	425 (325)

(pressure : 0.2 bar)

* increase

for vertical and horizontal surfaces downwind from the nozzle gave a Pooled Standard Deviation of 160 with an F - ratio of 41.42 ($P<.01$) and a significance value of $P<.001$ (T - test).

3.2.6 Vertical projection of spray from an MK II Exhaust Nozzle Sprayer.

A five minute run of sprays of each of deodourized kerosene and water plus 20% Ulvapron were conducted alternatively both in still air under sheltered condition and in open area. Droplets sampled 1 m below the nozzle on MgO coated slides with coated faces upward and with 11 similar slides arranged on a rope above the nozzle with coated faces down. All slides were spaced out a meter apart on a rope suspended on a meteorlogical tower.

A spray pressure of 0.38 bar was maintained during each spray operation compared with 0.2 bar used for horizontal drift tests discussed earlier so as to increase the force of droplet propulsion upward from the nozzle.

For details of the variable meteorological conditions, other factors and results see Table 9.

In tree sheltered and relatively still air conditions with a mean wind speed of 0 - 0.1 m/s droplets of deodourized kerosene were recovered up to 4 m above the nozzle but the numbers recovered per cm^2 at each consecutive distance higher from the nozzle declined. Under nearly similar conditions with a mean wind speed of 0 - 0.15 m/s droplets of water plus 20% Ulvapron were recovered up to only 3 m above the nozzle. In both cases the droplets/cm^2 recovered 1 m below the nozzle on horizontally laid MgO coated slides were much higher per unit area than MgO slides positioned above the nozzle. However, the droplets of water plus 20% Ulvapron sampled at 1 m below was less by

Table 9. Samples of droplets at different heights under open and sheltered conditions when using MK II Exhaust Nozzle Sprayer.

1	2	3	4	5	6	7	8	9	10	11	12	13
No.	Temperature °C & RH.%	Condition Wind speeds M/S	Spray press. Bar	Formulation	Sprayer	Vertical (M) distance from spray nozzle & droplets/cm^2					Mean SD.	Percentage droplets collected. (%age dec)*
						1* FU	1 FD	2 FD	3 FD	4 FD		
1	18°C, 90%	Sheltered 0 - 0.1	0.38	Deodourized kerosene	MK II Exhaust Nozzle Sprayer	900 ±40	320 ±22	280 ±30	100 ±20	15 ± 5	179 ±145	100
2	17°C 89%	Sheltered 0 - 0.15	"	H_2O + 20% Ulvapron	"	656 ± 27	287 ± 19	200 ± 16	50 ± 10	-	134 ±133	75 (25)
3	16°C 89%	Open area 0.2 - 3	"	Deodourized kerosene	"	-	160 ± 35	75 ± 7	-	-	59 ±76	33 (67)
4	16°C 89%	Open area 0.2 - 3.5	"	H_2O + 20% Ulvapron	"	-	136 ± 17	55 ±11	-	-	48 ±64	27 (73)

* decrease

Time of spray run = 5 minutes, FU = Face up, FD = Face down, * 1M = below nozzle

27% than for the droplets of deodourized kerosene sampled at the same position. Under conditions with a mean wind speed of 0.2 - 3 m/s for deodourized kerosene and 0.2 - 3.5 m/s, for water plus 20% Ulvapron no droplets of either were recovered on slides positioned 1 m below the nozzle or on MgO coated slides above two meters above the nozzle.

When the mean droplets/cm^2 of those recovered above the nozzle were considered, those recovered for deodourized kerosene was higher per unit area than any of the mean spray droplets recovered under either sheltered or open conditions. Taking the deodourized kerosene droplet recovery in still air as 100%, the mean for water plus 20% Ulvapron under the same conditions was 25% less and the mean for deodourized kerosene under open conditions was 67% less. The reduction of that of water plus 20% Ulvapron under open condition was higher at 73% (Table 9 and column 13).

An overall analysis for droplet recovery above the nozzle under sheltered and open area and for the two formulations gave a Pooled Standard Deviation of 110 with an F ratio of 1.29 (P>.05). The comparison between any two spray droplet recovery was T = P>.05.

3.3 Toxicity tests of insecticides on locusts (*Schistocerca gregaria* F.)

3.3.1 Relative toxicity of three organophosphorus insecticides

The three organophosphorous insecticides namely, propetamphos, etrimfos and fenitrothion were tested on both adult (15 days after fledging) and 5th-instar hoppers. The former two insecticides were used as a 2% w/v technical grade and as a 5% w/v E.C. emulsifiable concentrate and the latter as technical grade with concentration levels of 2 and 5% of w/v each.

A total of 12 sets of tests six for adult and six for 5th-instar with means of 60 and 100 locusts per set respectively were carried out repeating each set five times. The mean of each set was analysed by a single and parallel probit computing programmes from the ULCC via ICCC computing facilities. The details of the analysis of each test both for LD50 and LD99 together with the 95% confidence intervals are given in Appendix IV Table 26.

The three graphs of Figs. 23, 24 and 25 show the relative levels of toxicities of the two concentrations of each of propetamphos, fenitrothion and etrimfos insecticides. Although the mammalian toxicities (rats) of the active ingredient of each being:

Acute LD50 on rat	Oral	Dermal
propetamphos	75 mg/kg	2300 mg/kg
fenitrothion	250 - 500	>3000 (mice)
etrimfos ♂	1800	>2000
etrimfos intra-peritoneal	710	

comparison of the trends of toxicities of each in Figs. 24 and 25 indicate that propetamphos and fenitrothion were effective and have similarities in their efficiency against the control of adult locusts, however, both were slightly less effective to 5th-instar hoppers. But etrimfos was relatively less toxic both to adult and 5th-instar hoppers compared to the above two insecticides.

3.3.2 Control of locusts with calculated field doses

Initially a spray of Shellsol-AB was carried out with a multiple disc sprayer under field conditions at a disc speed of 8,500 rev/min, a flow rate of 150 ml/min i.e. 10 ml/min/disc with a temperature and relative humidity (19^{o}C, 68%) and wind speed of 3 - 5 m/s. The droplets recovered on MgO coated slides downwind for each

Fig. 23 Toxicity of propetamphos to (A, B) adult and (C, D) 5th-instar locusts (<u>Schistocerca gregaria</u> F.)

A = w/w 2% a.i. (Technical grade)
B = w/w 5% E.C. (Emulsifiable concentrate)
C = w/w 2% a.i. (Technical grade)
D = w/w 5% E.C. (Emulsifiable concentrate)

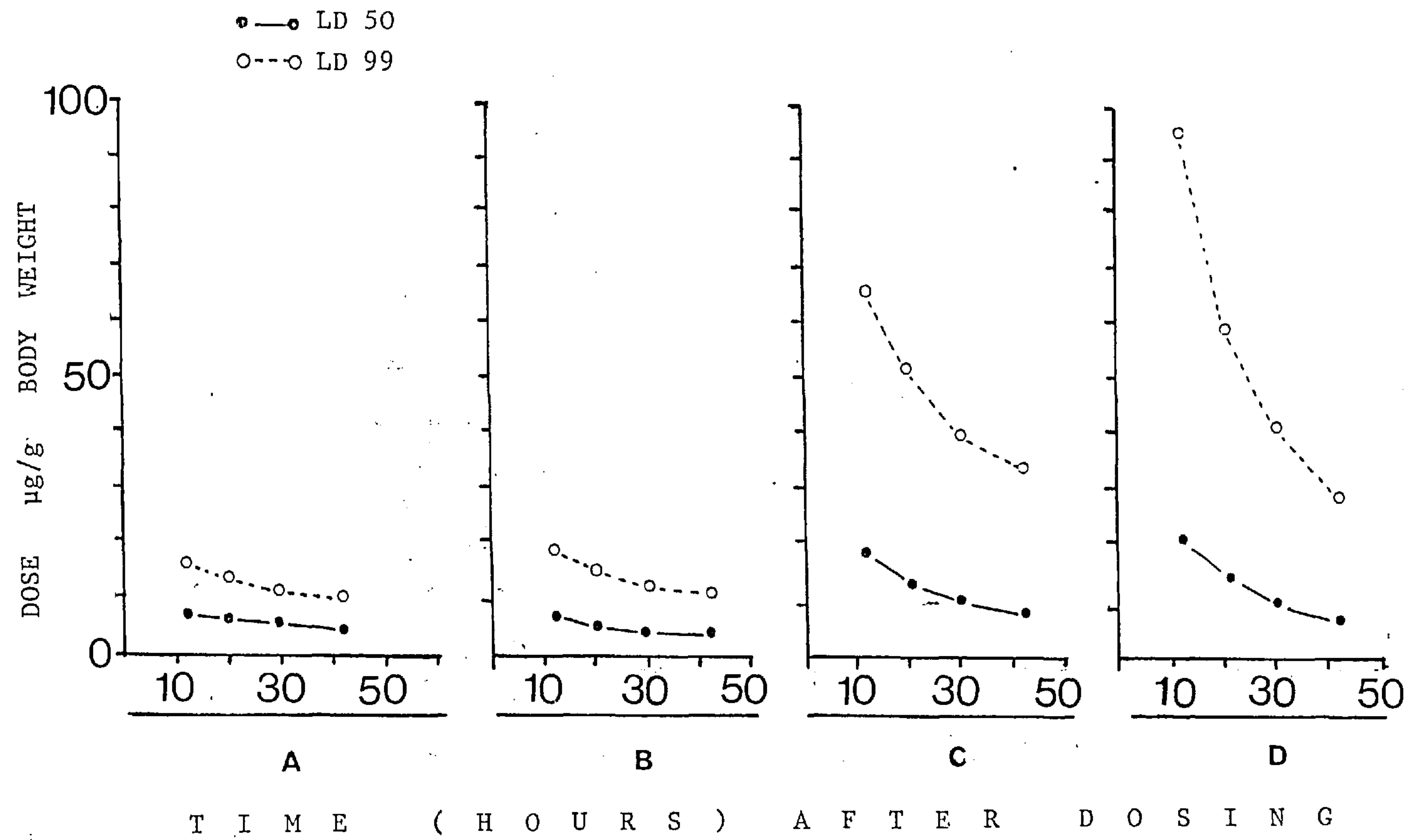


Fig. 24 Toxicity of fenitrothion to (A, B) adult and (C,D)5th-instar locusts (Schistocerca gregaria F.)

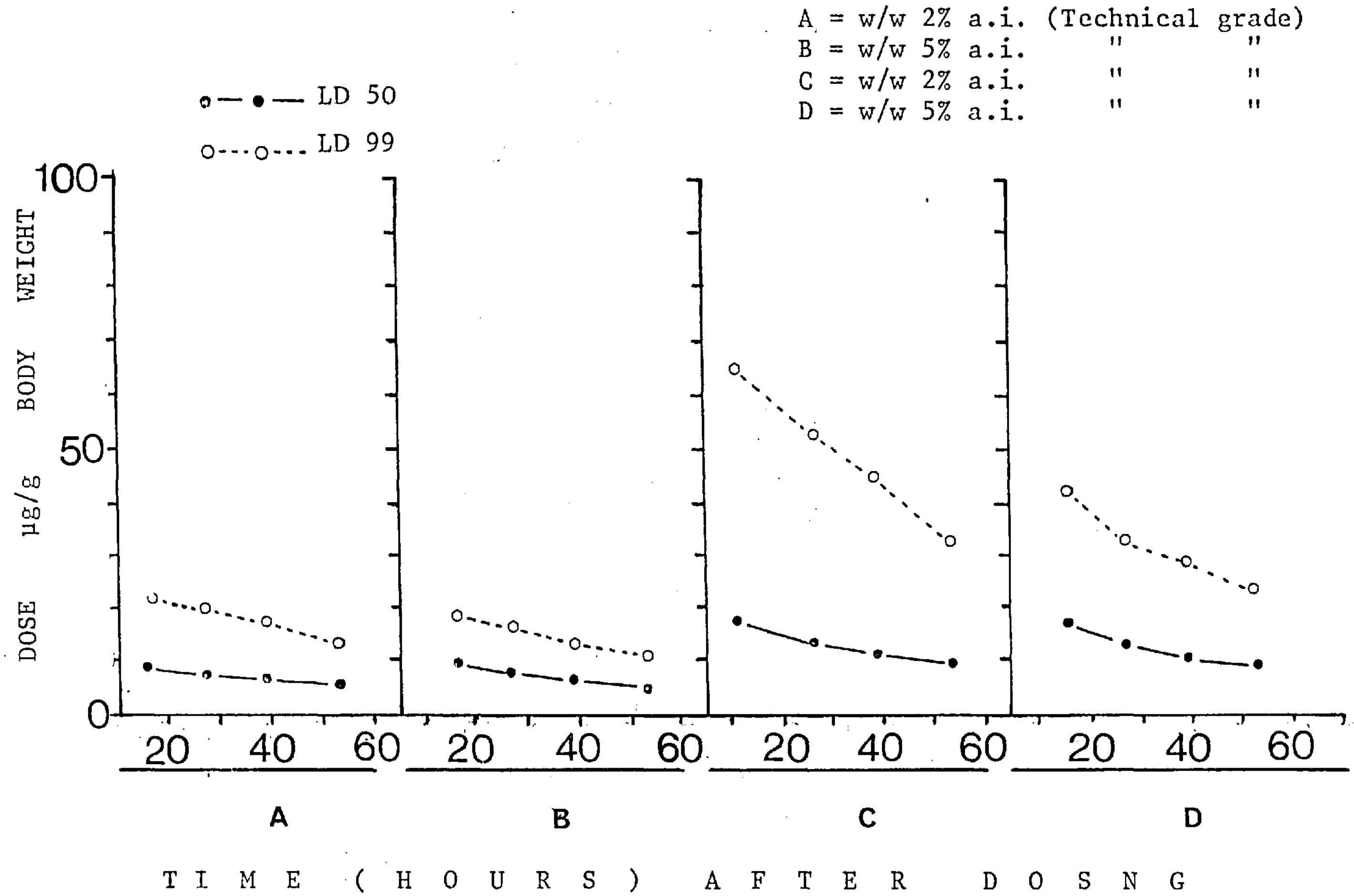
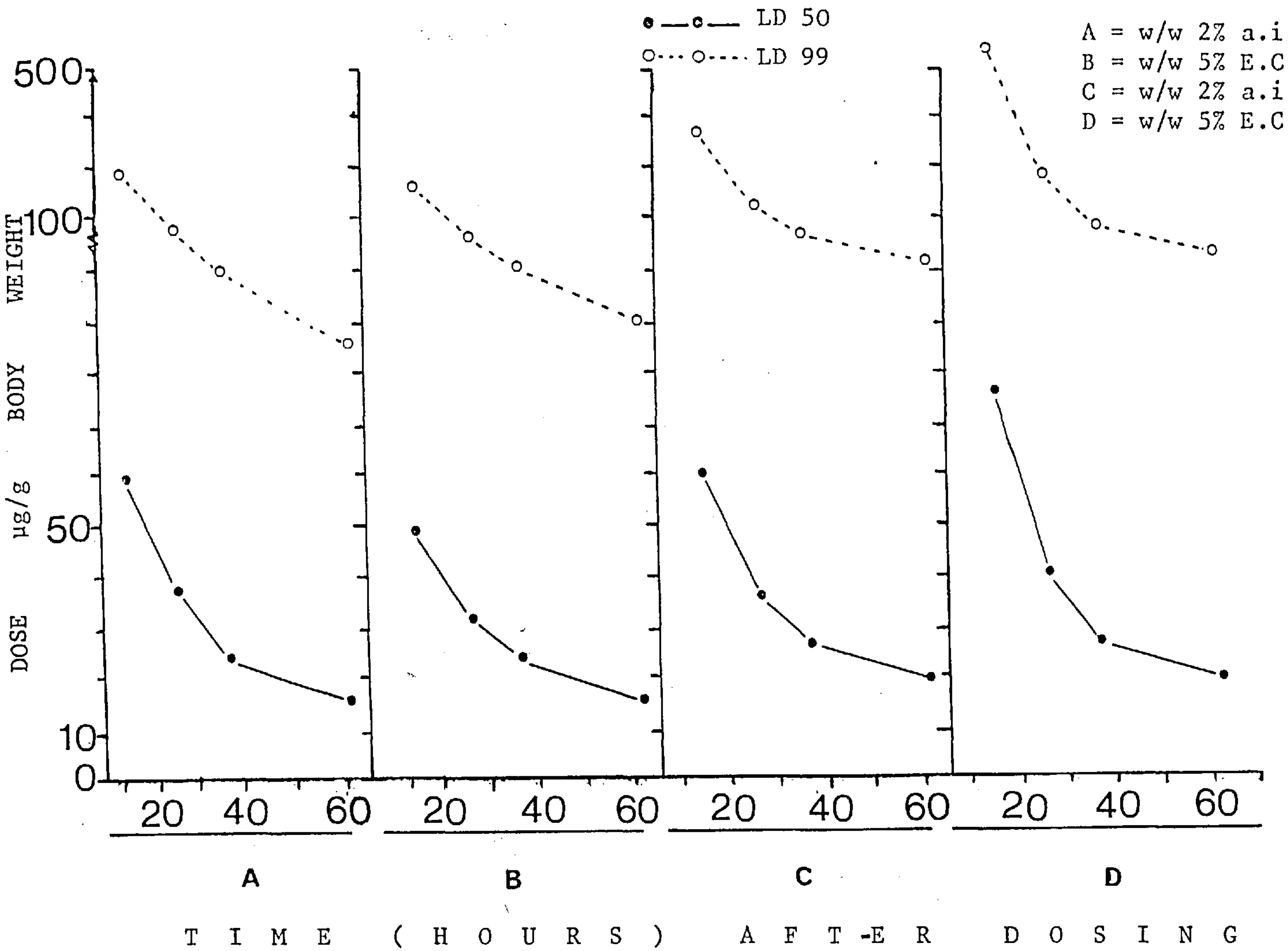


Fig. 25 Toxicity of etrimfos to (A, B) adult and (C, D) 5th-instar locusts (Schistocerca gregaria F.)



(For a.i. and E.C., refer to page 108)

progressive distance (i.e. 0.25, 0.50, 1, 2, 4, 8, 16, 32, and 64 m) from the spray nozzle was converted into ml/m^2 (i.e. 0.29, 0.58, 0.66, 0.80, 1.1, 0.34, 0.24, 0.01 and 0.0016 respectively). These quantities in ml/m^2 were further expressed in $\mu g/cm^2$ (i.e. 30, 60, 69, 83, 114, 35, 24, 1.04 and 0.17 for each of the above distance from the spray nozzle) through a series of calculations involving VMD and $droplets/cm^2$ as shown in Appendix IV, Table 27.

The calculated field doses were prepared in 2% w/v a.i. and 5% w/v (E.C.) emulsifiable concentrates and were sprayed on both adult and grass fed to hoppers with a 5.5 cm spinning disc (Para. 2.7.).

As in Para. 3.3.1, the spray was repeated four times for each level of insecticide concentration. The relative efficiency of each insecticide against the control of locusts is presented in graphs as shown Figs. 26 and 27 for adult locust and 5th-instar hoppers respectively.

The numbers within each graph indicate relative length of time in hours taken by the corresponding number of locusts (Y - axis) before being killed with a given calculated field dose of insecticide spray at each respective distance from the spray nozzle. For example, referring to Fig. 26, at a distance of 0.25 m from the nozzle, 30 $\mu g/cm^2$ of (A) propetamphos spray took 3 hours to kill a mean of 7 adult locusts whereas at a similar distance an equivalent amount of (B) fenitrothion spray took 5 hours to kill a similar mean of 7 locusts. But at such a distance an equivalent amount of etrimfos took 20 hours to kill only a mean of 2 out of a randomised group of 10 locusts. Referring to the control of 5th-instar hoppers in Fig. 27 and comparing the results with the plotted length of times i.e. within Fig. 26 the time taken before each dose-group of hoppers were killed by each insecticide was greater i.e. more time (hours) have been taken up or required by each group of randomised hoppers before they were killed.

For example at a distance of 0.25 m a 30 $\mu g/cm^2$ of (A) propetamphos took 3 hours to kill a mean of 2 hoppers as against a mean of 7 adult locusts for an equivalent amount of spray and distance from the spray nozzle and (B) fenitrothion required 5 hours to kill a mean of 3 hoppers as against a mean of 7 adults. But etrimfos took 20 hours to kill a mean of 2 hoppers similarly as against a mean of 2 adults at a similar distance and with an equivalent amount of spray. Further examination of graphs show the efficiency of either an increased or decreased dose of each insecticide compared with that mentioned above at each distance from the spray nozzle.

In conclusion, as the amount of insecticide spray was increased e.g. from 30$\mu g/cm^2$ at 0.25 m to 114 $\mu g/cm^2$ downwind to a distance of 4m from the spray nozzle, the numbers of locusts killed increased and the length of time taken by each dose group of locusts before death decreased.

Inspection of each graph at any level both in Figs. 26 and 27 show that propetamphos insecticide gave relatively better control of locusts i.e. either adult or 5th-instar at each given field spray dose followed by fenitrothion and lastly by etrimfos.

Comparing the figures in Appendix IV Tables 28 A and B, i.e. the calculated field dose at each progressive distance downwind from the spray nozzle with the LD50 of each insecticide obtained under laboratory conditions, the LD50 of that of field application exceeded in almost every instance particularly for distances up to 16 m downwind. In practice locusts move across a treated swath hence the need for an insecticide which is accumulated by the locusts.

3.3.3 Study of spectroscopy on locusts

Calculated field doses for each of the consecutive distance

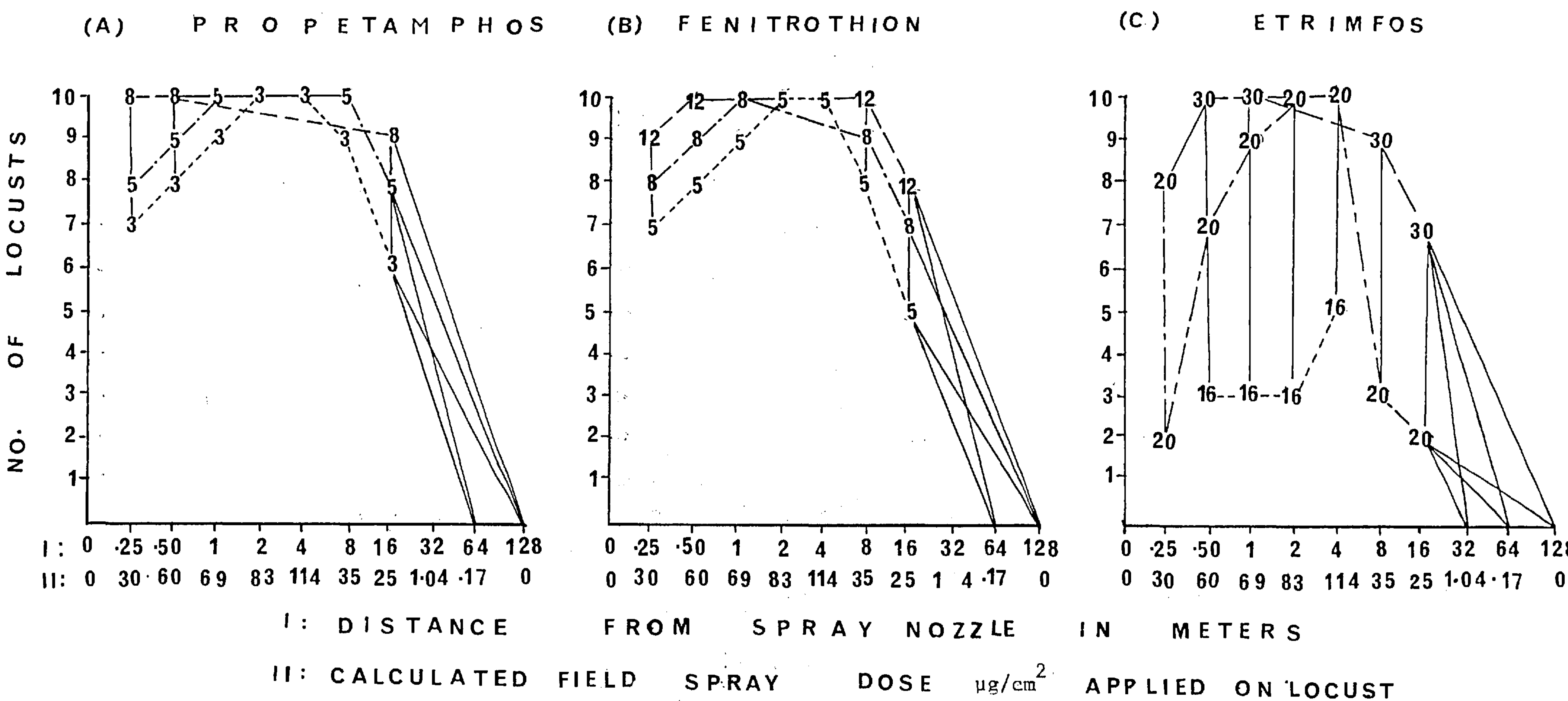


Fig. 26 Efficiency of incecticide sprays measured by distance from spray nozzle and time before death of 15 days old locusts, (<u>Schistocerca gregaria</u> F.)

(Time as hours shown by numbers on graph lines).

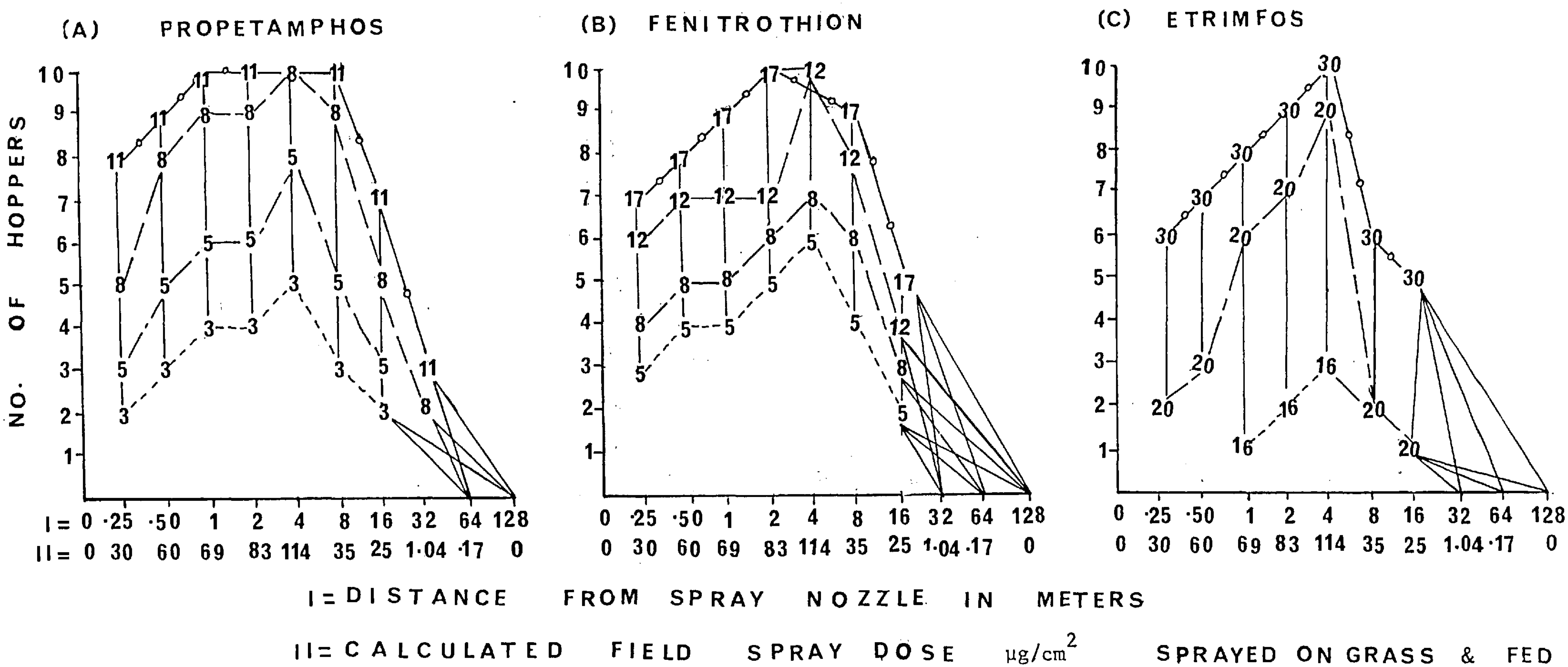


Fig. 27 Efficiency of insecticide sprays as measured by distance from spray nozzle and time before death of 5th-instar hoppers (Schistocerca gregaria F.)
(Time as hours shown by numbers on graph lines).

downwind from the spray nozzle (Para. 3.3.2 and Appendix IV Table 28A) was sprayed on two sets of each of six locusts i.e. 3 males and 3 females one set rotating and the second at a stationary position as discussed in Para. 2.7.

The absorbance for each of the spray dilutions washed off from each group of locusts was determined and the results plotted in Fig. 28 on the basis of the calibration curve in Fig. 15 discussed earlier.

Details of the results of the spectroscopy involving absorbance, percent concentration and percentage of sprays collected by each group or set of flying and non-flying are given in Appendix IV Table 29A-E and for the relevant figures see Table 10.

The mean percentages of spray solutions collected by each group of experimental locusts were analysed and compared (Appendix IV Table 30) by Friedman's (Sidney Siegel, 1956) two way analysis. The difference in droplet collection efficiency between all locusts flying and non-flying was very significant at $P<.001$. Also comparisons within each group i.e. males in flight with males stationary and females in flight with females stationary were both significant at $P<.01$.

3.4 Control of powdery mildew of wheat (*Erysiphe graminis* f. sp. tritici Marchal).

3.4.1 Laboratory experiment

Six months after sowing, the plants were harvested, hand threshed, dried to about 13% moisture content and weighed. All randomised data was analysed by a Bimodal (BMD07V) Multiple range tests (Kramer, 1957 and Duncan, 1975) and a one way Minitab analysis

Table 10 Summary of spray deposits on male and female locusts (*Schistocerca gregaria* F.) while in flight and at rest.

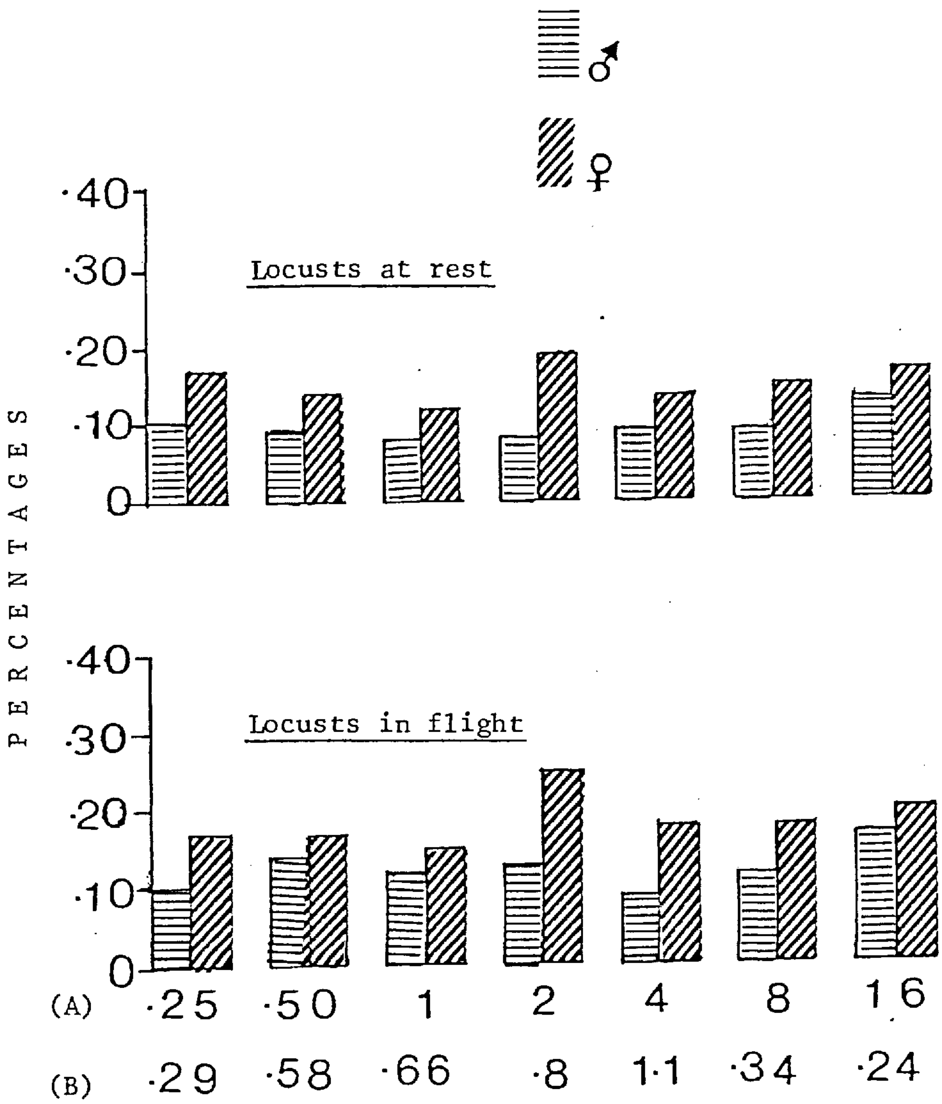
QUANTITY SPRAYED	LOCUSTS IN FLIGHT					LOCUSTS AT REST (SUSPENDED)			
ml/m²	DISTANCE (m) FROM SPRAY NOZZLE	WEIGHT IN GRAMS	PERCENT CONCENTRATION *	ABSORBANCE *	PERCENT OF SPRAY SOLUTION COLLECTED. **	WEIGHT IN GRAMS	PERCENT CONCENTRATION *	ABSORBANCE *	PERCENT OF SPRAY SOLUTION COLLECTED. **
.29	.25	2.35	3-04	.21	.10	2.36	3-04	.14	.10
.29	.25	(3.6)	(5-04)	(.36)	(.17)	(3.62)	(5-04)	(.29)	(.17)
.58	.50	2.55	8-04	.48	.14	2.59	5-04	.17	.09
.58	.50	(3.93)	(1-03)	(.63)	(.17)	(3.9)	(8-04)	(.5)	(.14)
.66	1	2.32	8-04	.53	.12	2.27	5-04	.25	.08
.66	1	(3.81)	(1-03)	(.63)	(.15)	(3.82)	(8-04)	(.5)	(.12)
.8	2	2.55	1-03	.63	.13	2.51	6-04	.11	.075
.8	2	(3.79)	(2-03)	(1.3)	(.25)	(3.38)	(1.5-3)	(.95)	(.19)
1.1	4	2.46	1-03	.63	.09	2.41	9-04	.11	.087
1.1	4	3.84	(2-03)	(1.26)	(.18)	(3.76)	(1.53)	(.95)	(.14)
.34	8	2.35	4-04	.25	.12	2.47	3-04	.19	.088
.34	8	(3.64)	(6-04)	(.38)	(.18)	(3.73)	(5-04)	(.32)	(.15)
.24	16	2.71	4-04	.23	.17	2.44	3-04	.17	.13
.24	16	(3.9)	(5-04)	(.31)	(.20)	(3.88)	(4-04)	(.25)	(.17)

Figures in parethesis refer to female locusts.
* waxoline red dye

** percentage of spray soluton collected.

Fig. 28 Comparisons of the relative percentages of waxoline red dye spray solutions collected by male and female locusts (S. gregaria F.) in flight and at rest under laboratory conditions.

(Ref. Para. 2.7 and Table 10)



(A) Distance from spray nozzle (m)

(B) Quantity of 1% of waxoline red dye solutions sprayed.

of variance. Overall means for all the replications were pooled and the 95% confidence limits calculated. The overall means for four treatments obtained (Table 11) show differences in yield (P<.01, F = test). The difference in yield between controlled droplet application and high volume sprays was significant (P<.05, T = test). No mildew infection occurred when seed was treated.

Table 11. Yields and damage assessment on wheat

No.	Treatment	Mean Mildew Percentages M%	Mean Yield g/pot	S.D.$\pm$
1	DS	0	*3.79	.334
2	CDA	10.5	3.48	.173
3	HV	10.3	3.36	.138
4	CON	35	2.86	.151
POOLED STANDARD DEVIATION				.217

$$\text{Yield kg/ha} = \frac{\dfrac{\text{ha}(10^4\text{m}^2)\ \text{X Yield/pot in grams}}{.011\text{m}^2\ \text{(pot area)}}}{10^3}$$

* 3.79 g/pot = 3445.5 kg/ha

i.e. 1 g/pot = 90.9 kg/ha

Details are in Appendix V

Tables 31 - 35 including analysis

Fig. 11 and Tables 36, 37 and 38.

Measurement of stem height, ear length and number of seeds per ear all confirmed that seed treatment provided an insurance against mildew attack (Jenkins, 1973). The retardation of growth and development of the various parts of plants observed (Appendix V, Tables 32 - 35) should be attributed to reductions of net assimilation rate caused by mildew infection (Rea and Cott, 1973).

3.4.2 Field experiment

Yields of field plots were also dried to about 13% moisture content and weighed. Results were then analysed by a Minitab one-way Anova and the 95% confidence intervals (C.I.) for treatment determined.

Despite different sowing dates, spraying of triadimefon fungicide increased yields by 7%, 14% and 21% for the early, mid and late sowing dates respectively. Although considerable improvements in yield were made by spraying, the overall yield from the second and third sowings was markedly lower than that from the first sowing. The second sowing yielded 7% less and the third 14% less but the yield differences between any sprayed and unsprayed plots were highly significant at 0.01% probability level (F = test, Table 12).

Table 12. Yield variation and mean mildew percentages with different sowing dates.

Sowing Condition	Mean Mildew Percentages M%	Sprayed Mean g/plot	Unsprayed Mean g/plot	Difference Mean g/plot
(A) Early	5.4	* 96.6 ±1.0	89.6 ±1.7	7.0 ±1.0
(B) Medium	10.0	91.9 ±2.07	79.3 ±5.42	12.5 ±3.6
(C) Late	15.2	87.0 ±1.0	68.3 ±2.8	18.7 ±2.0

$$\text{Yield kg/ha} = \frac{\dfrac{\text{ha}(10^4\text{m}^2) \times \text{Yield/sample plot in g.}}{0.25\text{m}^2 \ \ (\text{Area of sample plot})}}{10^3}$$

*96.6 g/plot=3864 kg/ha
i.e. 1g/plot=40 kg/ha.

± = 95% Confidence Intervals

3.5 Discussion and conclusion

3.5.1 Droplet sampling surfaces

Artificial targets have been used extensively to sample spray droplets as they provide a more uniform surface for droplet collection but they cannot duplicate in any significant way the size and surface characteristics, geometry or the biological characteriestics of the target whether it is an insect, plant or other surface (Himel, 1969b and Himel and Moore, 1969). With adequate care and handling, magnesium oxide coated slides were found to be useful both under laboratory and field conditions for sampling and determining droplet sizes as opposed to other methods such as Kromekote papers or cards (Higgins, 1967). Sampling papers are variable in their spread factor particularly with respect to droplet sizes and spray formulations (Hurting et al, 1956).

Most of the droplet assessments reported here were made with magnesium oxide coated slides which not only provided a uniform surface but also one spread factor would be used for the different spray liquids over a range of droplet sizes. With the MgO method a factor of 0.86 times the diameter of the crater (May, 1950) was used for all size droplet calculations above 20 µm size or 0.8 and 0.7 for droplets between 15 - 20 and 10 - 15 µm respectively (Matthews, 1975) irrespective of types of spray liquids used. This was important when both water and oils were applied in sprays and the variation in surface tension and viscosity would influence the spread factor on other surfaces such as Kromekote cards. Thus the use of MgO coated slides provided a satisfactory means of sizing the droplets sampled.

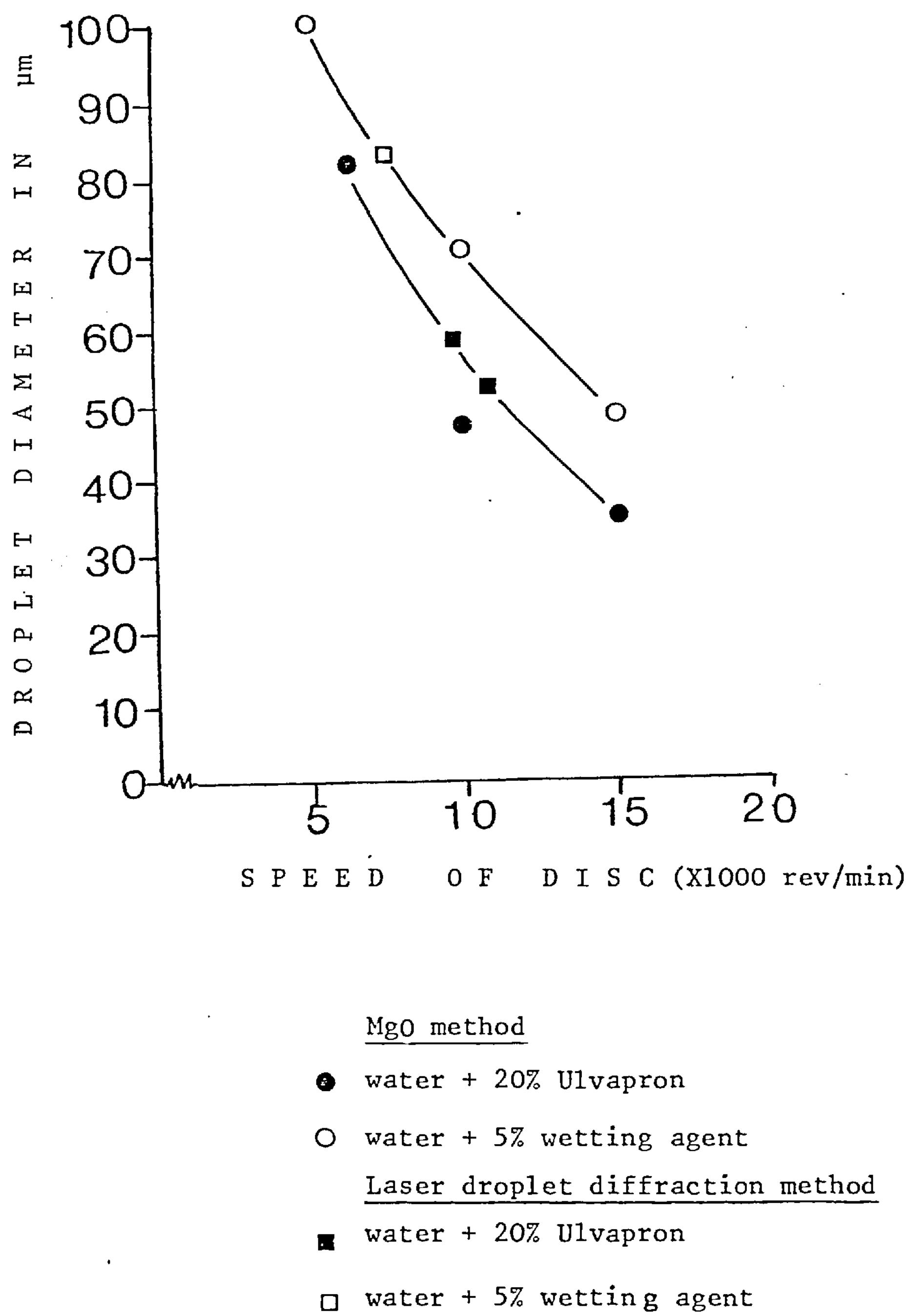
Unfortunately the size, shape and position of standard slides significantly affect the proportion of droplets collected in any given size range.

In the laboratory slides were placed horizontally so collection of droplets was by sedimentation. Sufficient time was provided to allow even the smallest droplets to sediment on the slides when sampling was within an enclosed controlled temperature environment. In the experiment measuring the change in size of droplets during transfer from a nozzle to the target, the samples were taken in the absence of air movement other than convective currents so were sufficiently representative to indicate the effect of oil on droplet size. The alternative system to using slides in the laboratory was the light diffraction system using a laser (Swithenbank et al., 1977). Although this method provided measurement of large populations of droplets close to the nozzle, the technique is not suitable when there are few droplets. It was possible to measure samples of droplets with a sufficient degree of accuracy from 10 - 30 cm away from the nozzle. The results from these two methods of sampling were compatible as indicated by the droplet size for water plus wetting agent at 10 cm from the disc operated at different speeds. (Fig. 29).

The main disadvantage in using MgO coated slides was when sampling in the field. Apart from the problems of avoiding handling the coated surface, droplet velocity affected the collection of droplets. Undoubtedly the smallest droplets were not sampled sufficiently as they were carried by air movement around the slides. Improved recovery was obtained by rotating the slides (Thornhill, 1979a) compared with stationary and horizontal slides but the air movement created by the rotating slides provides a different environment to that on vegetation and other surfaces. Droplet populations estimated

Fig. 29 Comparison of droplet sizes determined on MgO coated slides and a laser droplet diffraction system when sampling at 10 cm below a 5.5 cm spinning disc at different speeds.

(Ref. Appendix II, Tables 13 (A) & (B); Table 14, No. 1 and Table 17, No. 1 and 4).



from rotating slides are therefore, unrepresentative compared with their depositions on leaves.

Studies of the use of Rotorods (Asai, 1960; Barksdale, 1967; Edmonds, 1972; Lee, 1974; Matthews, 1975 and Johnstone et al., 1977) and Cascade impactors (May, 1945) have received some attention, but their practical use for droplet sampling under our field conditions was not comparable with the MgO coated slide method discussed above.

The use of a matrix (WHO, 1971) for sampling aqueous droplets >250 µm was limited to laboratory conditions. Sampled droplets should be covered immediately with a layer of 1 - 2 mm thin oil (e.g. risella oil) so as to prevent evaporation of droplets. Owing to difficulties in handling and the possibility of a reduction in droplet size before the layer of oil could cover the droplets only a few samples could be taken during any sampling trials.

The employment of a uv-tracer method (Sharp, 1955; 1973; 1974; Liljedhal et al., 1959; Staniland, 1951, 1960 and 1969; Courshee and Ireson, 1961: Patterson, 1963; Pereira, 1967 and Himel, 1965 and 1969b) with the aid of a uv-lamp makes it possible to make a subjective assessment of both the intensity and extent of droplet coverage either on natural or artificial targets within or beyond the confines of spray areas. This method provides accurate assessment of spray distribution in the field by visual estimates in relation to the type of spray formulations and spray machines employed.

3.5.2 Reduction in spray droplet size

Sayer (1964) reported that aqueous droplets <120 µm applied on cotton in Ethiopia lost 80 - 90% of their volume. Droplets of water emulsions decrease many fold in size between formation and impaction (Himel, 1969a). Johnstone (1971) noted that aqueous sprays of 200 μm VMD were reduced to 100 μm i.e. 50% less under severe tropical conditions of 32°C and 46% RH.

The initial experiments in contrasting temperature and relative humidity conditions confirmed the considerable decrease in the size of water droplets falling over a distance of only 10, 30 and 200 cm and the addition of oil could significantly decrease the effect of evaporation, especially under drier conditions. The effect of adding oil to the spray not only affected droplet size by influencing evaporation but also by the viscosity changing flow rate. For most farmers with a fixed orifice controlling the flow rate on their sprayer, the addition of oil decreased flow rate and consequently smaller droplets were produced. In contrast where flow rate was constant, the increase in viscosity resulted in larger droplets for a given disc speed. These interacting factors are important in machinery design to insure that the operator can easily adjust the flow rate or disc speed to compensate for variation in droplet size due to the formulation. The amount of oil in water based sprays determines the rate and extent of evaporation. Each additional amount of oil in water relatively decreases the effect of evaporation on the reduction in droplet size until the total amount of oil reaches 20% but further increase in the oil content of a spray has significantly less effect. The different oils used in this study have similar characteristics in their tendency to decrease the change in droplet size. Assuming that each droplet of water (in a water based formulation) was enveloped with a thin film of oil, the oil might limit the rate of evaporation. Droplets still decrease in size as the volatile fraction is lost so the effect of oil is primarily to ensure that after evaporation, there remains a liquid droplet and not a dry particle.

Changes in disc speed and flow rates alter droplet sizes whenever rotary nozzles are employed (Bals, 1970b; Johnstone, and Johnstone, 1976 and Matthews, 1979). Similarly changes in spray pressure such as with the Exhaust Nozzle Sprayer have comparable trends affecting droplet sizes. An increase of spray pressure of the exhaust nozzle by 100% e.g. from 0.1 to 0.2 bar not only reduced the droplet size but also projected the droplets much higher above the nozzle tip so these effects result in a spray more liable to drift. The ratio of VMD/NMD of spray droplets emitted with an MK II Exhaust Nozzle Sprayer is much greater than droplets released with any of the spinning disc nozzles tested.

3.5.3 Droplet drift

Downwind movement of droplets from a nozzle is related to their size and meteorological conditions (Johnstone 1974 and 1978). In general the smaller aerosol droplets remain airborne longer and are those subject to drift outside the area being treated. The proportion that remains airborne is affected by release height and in particular the amount of air turbulence in relation to vegetation of the underlying surface (Lawson and UK, 1978). As most sprays contain a wide variation in droplet size, only a small proportion of the spray is usually effective so Johnstone (1978) has emphasized the importance of applying droplets of similar size to allow greater control of their deposition.

In a study of the effects of wind turbulence and crop characteristics on the dispersal of aerial sprays, Lawson and UK, (1978) confirmed that a wheat crop was about 70% more efficient in removing 50 μm droplets than was a ploughed fallow field. In an open area of a grass field with foliage 15 - 20 cm high, droplets of water drifted further downwind than droplets containing oil. As water droplets are liable to evaporation, the distance of their movement downwind after leaving the nozzle increases as their volume decreases. Most of the smaller droplets progressively get smaller and lighter in weight and consequently the fall velocity decreases and drifting downwind such droplets usually fail to deposit in the desired area and get carried above their intended targets.

The amount of drift is not only affected by the size of droplets produced but also their subsequent changes in size due to physical properties (Haile, 1971). Because of the magnitude of evaporation in drier climates, aqueous sprays are not particularly suitable so less volatile formulations are needed in conjunction with greater control of droplet size. The mechanism of controlling droplet size has been realized with the use of rotary nozzles. On the basis of the early work conducted with spinning discs (Walton and Prewett, 1949; Hinze and Milborm, 1950 and Bals, 1969), the use of rotary nozzles in the use of controlled droplets has received momentum and its implications in the field of spray applications is becoming significantly clear (Lake et al., 1976; Matthews, 1977a, 1977b and 1979; Lake et al., 1978 and Frost, 1978). Although the Exhaust Nozzle Sprayer (Sayer, 1959; Rainey, 1958 and Watts et al., 1976) is still widely used in desert areas for vegetation baiting against locust hoppers (with a swath width of up to 100 m with 3 - 4 m/s), it does not control the size of droplets as achieved with a rotary nozzle.

Droplets emitted from an Exhaust Nozzle Sprayer did drift further than those from a spinning disc nozzle because of the wider spectrum of sizes as well as their projection to a greater height above the nozzle. The upward projection of droplets particularly of water based formulations increases the effect of evaporation by increasing the distance of travel and decreasing the fall of velocity. As indicated earlier the distance to which such droplets drift is dependent on the surrounding vegetation i.e. open or sheltered conditions affecting drift.

Fluorescent studies of the spray applications on leaf targets confirmed that droplets of a formulation containing oil were not carried so far downwind as droplets of water without oil. Most droplets collected close by the nozzle were larger owing to the effect of the oil in reducing the effect of evaporation. Although the grass in the field used in this study did not provide such a good filtering surface as in a wheat field, more droplets were collected on leaves at ground level and closer to the ground than when no oil was added to the spray.

The collection efficiency of a target in a field is indicated by the ratio of the number of droplets impacting on its surface to the number deflected around the target and varies with air stream velocity and the size of the target and droplets (May and Clifford, 1967.).

Analysis of the volume of spray of droplets recovered on vertical slides in the field (at three sampling heights namely, 35, 70 and 150 cm) showed that as a proportion of spray emitted, the addition of oil resulted in more spray being deposited close to the spray nozzle. Assuming if the amount of spray which sedimented to the ground was in a similar proportion at each distance downwind for different formulations, then the amount of spray still airborne and not sampled must be very much less as the involatile fraction of the spray, the oil, is increased. The relative percentage of droplets recovered in descending order were oil, water plus 20% oil and lastly water with 5% wetting agent (Fig. 30). Thus the addition of oil to a spray will increase the recovery of pesticide within a treated area provided the droplet size is controlled. When a single orifice is used to govern the flow of spray liquid, the addition of oil increases the viscosity so with the lower flow rate, droplet size is less and the risk of drift increased unless disc speed is also reduced.

Greater recovery of a less volatile spray on the intended target was also reported by Joyce and Beaumont (1979) who applied fenitrothion in butyl dioxytol at 1 l/ha in contrast to low volume aerial sprays at 20 l/ha using an emulsifiable concentrate formulation in water.

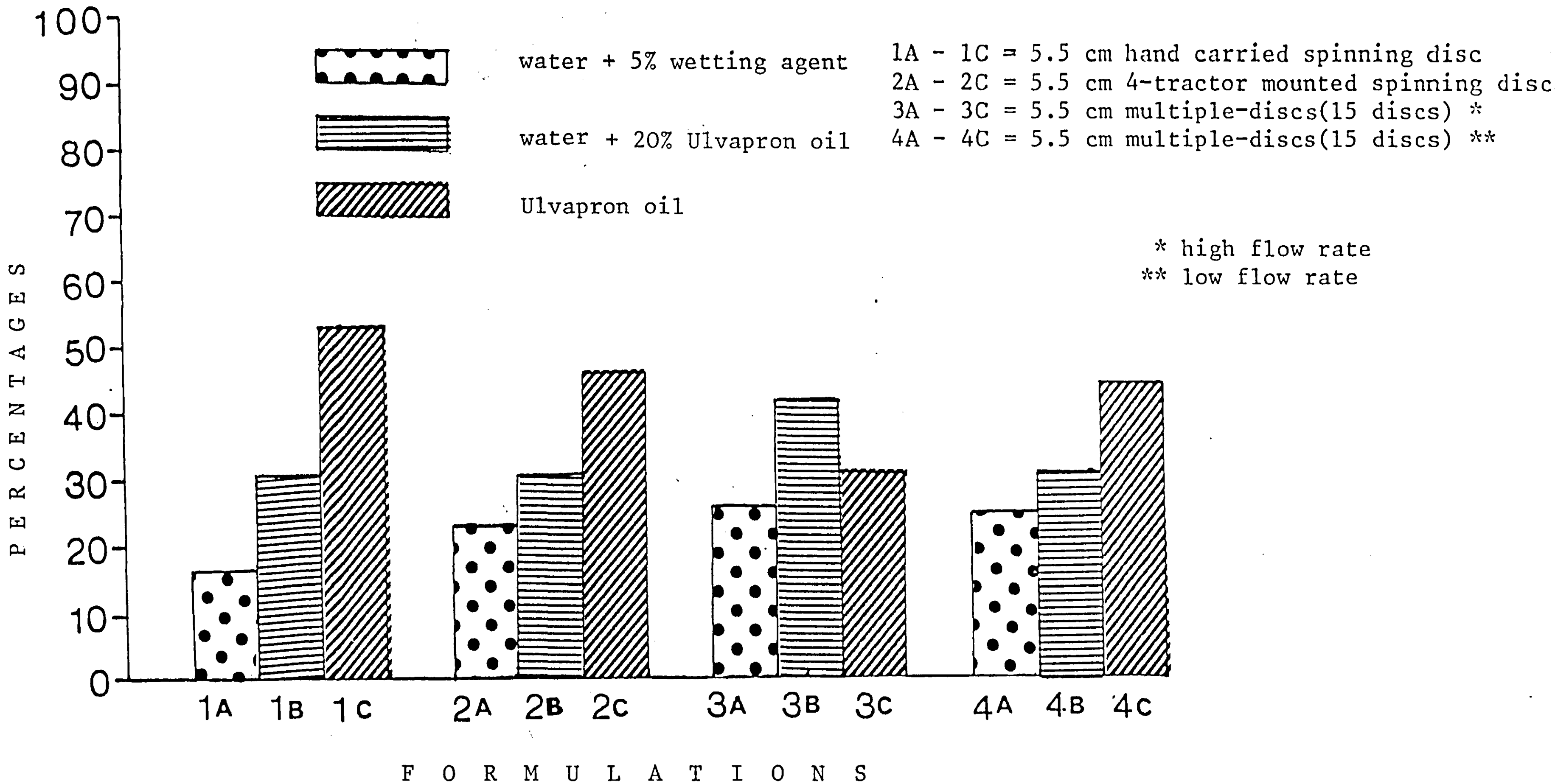
The droplet behaviour and variation in drift discussed above concurs with the findings of Bouse and Merkle (1975) in which they noted that droplets of water sprays drifted in greater proportion to a distance of 36 m downwind from a fan nozzle than paraffin oil, diesel oil, and mineral oil sprays.

This study indicates that when the formation of droplets is controlled and the minimal volume of spray per unit area is applied, the addition of 15 - 20% oil in water is adequate in any spray application. The amount of oil needs to be kept as low as possible to avoid phytotoxity and to keep the cost of treatment per unit area as low as possible.

3.5.4 Locust control experimentation

More insecticide reaches locust swarms when optimally applied than any other insect application (Rainey, 1974; Graham Bryce, 1977). in a field trial in Ethiopia for example, an application of 50 l of 96% fenitrothion in a solution gave a kill of 837,000 adult locusts/l

Fig. 30 Relative percentages of droplet recovery by volume of different formulations downwind from spray nozzles.



(Sayer, 1968). Fenitrothion is now used as an alternative to the persistent organochlorine such as dieldrin which have been widely used for locust control. As a possible alternative to fenitrothion, propetamphos and etrimfos were evaluated and on the basis of the amount of toxicant which would be deposited by vegetation baiting, propetamphos was the most promising and further field evaluation is recommended. It should also be compared with synthetic pyrethroids such as bioresmethrin and NRDS 119 (cesmethrin) particularly with respect to safety, persistence and speed of action. Presently the use of pyrethroids do not seem to be economical to use in the field particularly as bioresmethrin is more than 25 times the cost of fenitrothion (MacCuaig, 1974, 1975). Permethrin has the advantage of photostability, (Elliott et al., 1973b) but it is less toxic to locusts and has some residual effect on vegetation. Its toxicity was increased by the addition of the synergist piperonyl butoxide (Pojananuwong, 1976). Depending on the cost of active ingredient and synergist, the cost of applying in the field could be reduced to an acceptable level. The synergist sesamex also improved the toxicity of permethrin (Ford and Reay, 1972; Edge and Cesmir, 1975) so these are some of the implications and comparisons in perspective in selecting a pesticide with a higher efficiency of kill.

Without the use of synergist, propetamphos is more toxic than fenitrothion which is ranked higher in its toxicity to *Locusta migratoria* L.* than dieldrin or permethrin (MacCuaig, 1975).

The tests in the field assessing downwind droplet drift suggest that vegetation baiting with a 5.5 cm multiple disc sprayer is possible up to a swath width of 32 - 64 m downwind depending on wind conditions.

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* *Locusta migratoria migratoroides* (Reiche and Fairmaire)

The greater recovery of spray deposits on flying locusts compared with those at rest confirmed earlier studies by Kennedy et al., (1948); Wootten and Sawyer, (1954) and MacCuaig, (1958). Female locusts being heavier and larger than male locusts, collected more insecticide than males even at rest. MacCuaig (1962) observed that faster flying locusts tended to pick-up slightly less spray than slower locusts but when averaged over the whole experiment the difference was just significant. However, a number of factors such as weight, angle of approach of droplets to the locusts relative to collecting area of parts of the body, size of droplets, flying speed, method of attachment to the flight balance and the chemical and physical sprays of each contribute to the efficiency of pick-up of spray droplets. (MacCuaig, 1962).

3.5.5 Use of CDA in powdery mildew (*Erysiphe graminis* DC) control

Vegetation baiting (Courshee, 1959; Courshee and McDonald, 1963) is achieved by depositing a toxic dose of a stomach poison on plants (mainly grass) which locusts would have to eat. This was achieved by drifting spray droplets downwind under the influence of prevailing wind speeds. Similarly fungicides can be released in 60 - 70 μm droplets which are collected on the crop to control foliar diseases.

In the laboratory assessment using triadimefon, CDA sprays with 70 μm droplets gave higher yields than obtained with a high volume application on mildew infected wheat but less than when seed treated with fungicide was sown. In the field the effect of CDA treatment gave significantly higher yields than the control plots, but yields varied in relation to the dates of sowing. Autumn sown wheat responded best to the fungicide treatment, followed by the Spring sown. The response of the last sown wheat indicated the role that sowing date has on the effect of mildew infections on plant growth and yield. The higher yield obtained when wheat plants were protected from the time of sowing was significant to indicate that for optimum use of sprays, they must be applied at the onset of disease infection.

The greatly reduced yield of the control treatment in this experiment agrees with the suggestion (Last, 1962 and Paulech, 1969) that in greenhouse experiments the effect of mildew is likely to be more.

The improved control of mildew with the controlled droplet application at half the dose of fungicide used at high volume is important in reducing the total usage of fungicides. The field trial confirmed that a substantial yield increase over untreated wheat was obtained at the lower dosage of active ingredient (Para. 3.4.2, Table 12). On a field scale not only was dosage reduced but by the reduction of volume, the speed of application was greatly increased thus facilitating the correct timing of sprays. Further experiments should indicate whether the low dosage would be effective under other climatic conditions. In orchard spraying as little as 10% of the recommended dosage of fungicide has given adequate control (Cooke _et al._, 1976; Morgan, 1974; Jones and Morgan, 1974).

3.5.6 General discussion

The efficiency of spray application depends on moving droplets from the nozzle to the biological targets with minimum of loss to non-target areas (Himel, 1969a). The size of spray droplets is determined largely by the design of the nozzle and the properties of spray fluid.

In the past droplet formation has been poor so most sprays contained a wide range of droplet sizes. But advances in the design and equipment are making possible to achieve greater control of the droplet spectrum. Thus ultra-low-volume applications of pesticides are possible with smaller droplets (Johnstone et al., 1977). The development of a range of battery operated portable sprayers has been followed by the introduction of improved equipment suitable for mounting on a tractor. The degree of spray coverage achieved is determined by the volume applied and the droplet size. A reduction in volume necessitates smaller droplets to maintain coverage. This is achievable with centrifugal atomization which gives a much narrower range of droplet size than is possible with hydraulic nozzles (Hinze and Milborn, 1950). Larger droplets (>150 μm) and volume (>15 l/ha) have been used for herbicide application (Taylor & Merritt, 1975) where downwind movement of droplets must be avoided to reduce the risk of phytotoxicity on plants susceptible to the spray chemical. The practicability for such needs has been demonstrated on field trials with herbicides (Cussans & Taylor, 1976; Evans & Kitchen, 1976; O'Keeffe et al., 1976; Bailey & Smartt, 1976). Thus with the use of centrifugal energy nozzles there is a choice of droplet spectrum by the adjustment of disc speed (Johnstone, 1971).

By selecting the appropriate droplet size for a given target, a higher proportion of the emitted chemical by the sprayer should be utilized so lower dosages compared with conventional spraying should be effective. This was confirmed in this test by the control of powdery mildew of wheat involving CDA. Uniformity of droplet size is an essential feature of controlled-droplet-application and is indicated by the ratio between volume median (VMD) and number median (NMD) (Matthews, 1975; Bals, 1970b; Frost, 1978 and Johnstone, 1978).

More recently with a toothed, grooved disc (120 mm in diameter, 75mm deep with 180 teeth 'Micron Micro-max') it was possible to incorporate design features to avoid two adjacent ligaments joining together so as to achieve complete ligament formation and control of droplet size with higher flow rates of a range of rotational speeds (Heijne, 1979). Similarly a multiple disc spray system was developed to apply sufficient volume from an aeroplane, vehicle or a tractor moving faster than an individual walking through the field. Further improvements in the structural design should enable these newer spinning nozzles to withstand rugged and difficult operating ground conditions of tropical areas. Gunn (1978) noted that a spinner needs to be robust to withstand bumpy and dusty ground as it is necessary to avoid deterioration of vehicle engines due to increased back pressure from an Exhaust Nozzle Sprayer.

Formulation is as important as the spray machine so efforts should be made therefore, to incorporate those properties which will improve deposition on the target and movement of the active ingredient to the site of action. Pesticides are biologically active in extremely small quantities (Matthews, 1979) so the chemical needs to be formulated to meet these requirements without hazardous risks to the operator and environment. The use of oils in spray application minimizes the hazard to drift by reducing the effect of evaporation, an advantage which allows a reduction of droplet sizes to achieve better coverage.

In utilizing smaller oil based droplets in the field, there is a risk that with variable wind conditions the spray operators would be exposed to greater contamination. As the addition of an oil may result in an increase in dermal toxicity due to more rapid penetration of the active ingredient through the skin, it will be essential for protective clothing to be worn and the use of the more toxic pesticides avoided. Operators should be provided with appropriate protective clothing in relation to the pesticide used and risk of exposure to toxic hazards. Nevertheless, with increased deposition of spray on the target, the addition of oil makes it possible to reduce the total dosage of pesticide applied so reducing the risk of toxicity to non-target organisms.

On balance with the increased cost of the active ingredient in pesticide, the use of less volatile formulations at minimal volume rates of application should lead to more gradual use of lower dosages of pesticide.

3.6 SUMMARY

1. Magnesium oxide coated slides were used in the laboratory and outside in fields to sample droplets.
2. Studies on the period between coating the slides and their use in droplet sampling had to be kept as short as possible to avoid solidification of the coated surface.
3. Aqueous droplets >250 μm were sampled in a matrix but owing to difficulties in handling the samples, this technique was used only under laboratory conditions.
4. Droplet sizes were also measured with a laser light diffraction system.
5. Spray droplets produced with 8 and 5.5 cm spinning discs under laboratory conditions were sampled at different distances from the nozzle. The decrease in size of droplets was measured under low and high temperatures at different humidities and the greatest reduction in droplet size occurred as expected under high temperature and low relative humidity conditions.
6. An increase in the proportion of an oil in water, decreased the effect of evaporation on droplet size.
7. The change in droplet size was less with an oil known as Ulvapron compared with other oils tested namely, 7E and 11N Sun oils.
8. When using a spinning disc nozzle, water droplets with 5% wetting agent travelled further downwind than those containing any amount of oil as detected on vertical slides at 35, 70 and 150 cm above a grass field.
9. Subjective assessment of droplet deposition with a UV-tracer confirmed that water droplets were carried further downwind before impacting on target leaves.

10. A gradual increase in the proportion of oil in water reduced droplet trajection and increased deposition closer to the nozzle suggesting that:

    a) as aqueous spray droplets evaporate so rapidly in flight between the sprayer and target surface that they become more susceptible to drift,

    b) smaller droplets with non-volatile carriers maintain their size and are therefore, more efficiently deposited on targets.

11. The greater recovery of spray droplets closer to the target indicate that the use of less volatile formulations together with controlled droplet application should lead to more efficient use of a pesticide.

12. Droplets of deodourized kerosene and water with 20% oil travelled to a greater distance when released with an MK II Exhaust Nozzle Sprayer than when spinning discs were used. This was due to the greater height to which droplets were projected above the sprayer and the wider spectrum of droplets produced. The distance over which droplets travelled was reduced when the sprayer was in a sheltered position such as close to a hedgerow.

13. Toxicity tests of three organophosphorous insecticides were carried out on S. gregaria F. both on adult and 5th-instar hoppers using a micro-applicator to assess both contact and stomach action respectively.

14. Insecticide application for the control of locusts (S. gregaria F.) by vegetation baiting based on calculated field doses determined from the droplet studies confirmed that propetamphos would give control over a 32 - 64 m swath width with 70 μm droplets. Propetamphos was effective both to adult and 5th-instar locusts under

laboratory and field conditions.

15. Spectroscopic measurements of spray deposition showed that female locusts collected more droplets than male locusts whether in flight or stationary. Locusts of both sexes collected more droplets in flight than at rest.

16. Drift spraying of a field crop indicated that application of half dose of triadimefon fungicide on winter wheat with CDA gave better control of powdery mildew and a higher yield than high-volume-application but less than when seed was treated prior to sowing.

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References

ADAS (Agricultural Development and Advisory Service), 1976. Cereal growth stages (two set of cards), Key No. 11

ADAS, 1976. Wheat mildew (Erysiphe graminis f. sp. tritici, Marchal). Assessment Key No. 1.1.2

Akesson, N. B. and Yates, W. E., 1964. Problems relating to application of agricultural chemicals and resulting residues. A. Rev. Ent. 9, 285 - 318

Amsden, R., 1962. Reducing the evaporation of sprays. Agric. Aviat. 4, 88 - 93

Arnold, A., 1979. (Personal communication).

Asai, G. N., 1960. Intra - and - inter - regional movement of uredospores of black stem rust in the upper Mississippi valley. Phytopath, 50, 535 - 41

Bailey, R. J. and Smartt, A., 1976. The results of controlled droplet application technique for herbicides in cereals. Proc. 13th Br. Crop Prot. Counc. Conf. 2, 383 - 89

Baker, E. J., 1970. The effect of oils on plants. Pollut. 1, 27 - 44

Bals, E. J., 1969. The principle of and new development of ULV spraying. Proc. 5th Br. Insectic. Fungic. Conf. 183 - 193

Bals, E. J.. 1970a. Ultra - low - volume and ultra - low - dosage spraying. Cott. Grow. Rev. 47, 217 - 21

Bals, E. J., 1970b. Rotary atomisation. Agric. Aviat. 12 (3), 85 - 90

Bals, E. J., 1973. Some observation and basic principles involved in ultra - low - volume spray applications. PANS (2), 193 - 200

Bals, E. J., 1975a. Development of CDA herbicide hand sprayer. PANS 21 (3), 345 - 48

Bals, E. J., 1975b. The importance of controlled droplet application. Proc. 8th Br. Insectic. Fungic. Conf. 153 - 60

Bals, E. J., 1977. A new rotary disc nozzle. Proc. 9th Br. Crop Prot. Conf. Pests and Diseases 2, 523 - 25

Barksdale, T. H., 1967. Spread of rice blast in small fields. Pl. Dis. Reptr. 51, 243 - 47

Barnett, N.J. and Timbrell, V., 1962. An apparatus for pesticide measurement and analysis of particulate pharmaceutical materials. The Pharm J. 180, 379 - 81

Beeden, P., 1974. ULV techniques on cotton in the Northern States of Nigeria. Br. Crop Prot. Counc. Monogr. 11, 197 - 203

Bennett, L. P. and Symmons, P. M., 1972. A review of estimates of the effectiveness of certain control technique. Anti - locust Bull. No. 50

Bouse, L. M. and Merkle, M. G., 1975. Comparisons of recoveries from a tower mounted dual sprayer. Trans. ASAE 18 (3), 467 - 70

Breese, M. H., 1977. The potential for pyrethroids as agricultural, veterinary and industrial insecticides. Pestic. Sci. 8, 264 - 69

Breese, M. H. and Searle, R. J. G., 1977. Why the newer synthetic pyrethroids show promise. SPAN 20 (1), 18 - 20

Bullivant, M. J. and Pattenden, G., 1971. Photochemical decomposition of chrysanthemic and its alkyl esters. Pyrethrum Post 11 (2), 72

Clayphon, J. E., 1974. The evaluation of a motorised knapsack mistblower for conventional and ULV rates of pesticide application. PANS 20 (3), 351 - 57

Collins, P., 1978. Locusts: Vigilance still needed. Nature 273, 180

Cooke, B. K., Herrington, P. J., Jones, K. G. and Morgan, N. G., 1976. Pest and disease control with low doses of pesticides in low and ultra low volumes applied to intensive apple trees. Pestic. Sci. 7, 30 - 34

Courshee, R. J., 1950. Locust spray trials. Tech. Memor. Nat. Inst. Agric. Engng. No. 38

Courshee, R. J., 1952. Drift spraying for locust control with ground machines. Tech. Memor. Nat. Inst. Agric. Engng. No. 50

Courshee, R. J., 1955. Further trials of drift spraying for locust control. Tech. Memor. Nat. Inst. Agric. Engng. No. 54

Courshee, R. J., 1959. Drift spraying for vegetation baiting. Bull. Ent. Res. 50, 355 - 69

Courshee, R. J. and Ireson, M. J., 1961. Experiments on the subjective assessment of spray deposits. J. Agric. Engng. Res. 6, 175 - 82

Courshee, R. J. and McDonald, D. J., 1963. Control of hoppers by insecticides applied to vegetation. Pakistan and India, 1962. UNSF Desert Locust Project. Progress Report. No. UNSF/DC/OP/2, 13 pp. Memo.

Cussans, G. W. and Taylor, W. A., 1976. A review of research on " controlled - droplet - application" at the ARC', Weed Research Organization. Proc. 13th Br. Crop Prot. Conf. Weeds 3, 885 - 894

Dombrowski, N. and Lloyd, T. L., 1974. Atomisation of liquids by spinning cups, Tech. Engng. J. 8, 63 - 8,

Duncan, D. B., 1975. "Multiple range tests for correlated and Heteroscedastic means". Biometrics 13 (2) 164 - 76

Edge, V. E. and Casimir, M., 1975. Toxicity of insecticides to adult Australian plague locust Chrtoicetes terminifera (Orthoptera: Acrididae). J. Aust. Ent. Soc., 14, 321

Edmonds, R. L., 1972. Collection efficiency of Rotorod samplers for sampling fungus spores in the atmosphere. Pl. Dis. Reptr. 56, 704 - 708

Elliot, M., Farnham, A. M. Janes, N. F. Needham, P. H., Pulman D. A., and Stevenson, J. H., 1973a. A photostable pyrethroid. Nature 246, 169 - 70

Elliot, M., Farnham, A. W., Janes, N. F. Needham, P. H., Pulman, D. A., Stevenson, J. H., 1973b. NRDC 143 a more stable pyrethroid. Proc. 7th Br. Insectic. Fungic. Conf 2, 721 - 28

Elliot, M., 1977. Synthetic pyrethroids. Am. Chem. Soc. Symp. 42, 137 - 46

Elliot, M., Janes, N. F. and Potter, C., 1978. The future of pyrethroids in insect control. A. Rev. Ent. 23, 433 - 69

Evans, S. A. and Kitchen, R., 1976. A comparison of cereal herbicides Applied by fan jets and by CDA system. Proc. 13th Br. Crop Prot. Conf. Weeds 2, 745 - 751

Exodus 10 : 15

Feeks, W., 1941. De tarwe en haer miliew. vers. XVII Tech. Tarwe Commissie Groningen 560 - 1

Finney, D. J., 1977. Probit Analysis 3rd Ed., Cambridge University press, 333 pp.

Ford, M. G. and Reay, R. C., 1972. Toxicity of some pyrethroids to the desert locust (S. gregaria F.). Pestic. Sci., 3, 255

Fraser, R. P., 1956. Liquid atomisation and the drop size of sprays Trans. Inst. Chem. Engng. 34, 294 - 319

Fraser, R. P., 1957. The mechanics of producing sprays of different characteristics. Plant protection conference. Butterworths. Scient. Publs 237 - 77

Fraser, R. P., 1958. The fluid kinetics of application of pesticidal chemicals. New York Enter Science. In Adv. Pest. Control Res. 11, 1 - 106

Frost, A. R., 1978. Rotary atomisation. Br. Crop Prot. Counc. Monogr. 22, 7 - 21

Furmidge, G. G. L., 1954. Spray application problems. XVII The measurement of spray droplet size in the field. Long Ashton Res. St. Annual Rept. 118 - 31

Geiseke, F. A. and Jepson, L. R., 1965. Size measurement of controlled drops. J. Chem. Engng. Data 10, 350 - 53

Graham Bryce, I. J., 1977. Crop protection chemicals: A framework for future development. Med. Foc. Landboun. Rijksuniv. Gent. 42 (2), 819 - 29

Gunn, D. L., Graham, J. F., Jaques, E. C., Perry, F. C., Seymour, W. G., Telford, T. M., Ward, J., Wright, E. N, and Yeo, D., 1948a. Aircraft spraying against the desert locust (Schistocerca gregaria Forskal) in Kenya 1945. Anti. Locust Bull. No. 4,(London) 121 pp.

Gunn, D. L. et al., 1948b. Locust control by aircraft in Tanganika ALRC. London and Dept. of Agriculture Pretoria.

Gunn, D. L., 1952. Field tests of dry baiting against the desert locust. Bull. Ent. Res. 42, 675 - 90

Gunn, D. L., 1978. The background and role of controlled droplet application. Br. Crop Prot. Counc. Monogr. 22, 1 - 5

Hadaway, A. B. and Barlow, F., 1965. Studies on the deposition of oil drops. Ann. Appl. Biol. 55, 267 - 74

Haile, D. G., 1971. Wind tunnel analysis of spray drift of slow evaporating herbicide carriers. PhD dissertation. Texas A & M University Library. College St. Texas 777843

Havis, J. R., Dallyn, S. and Sweet, R. D., 1950. Herbicidal properties of petroleum hydrocarbons. Am. Chem. Soc. Symp. The agricultrual application of petroleum products, Washington 105 - 13

Heijne, C. G., 1979. A study of the effects of rotational speed and flow rate on the performance of a spinning cup for the application of pesticides. DIC Thesis, Imperial College.

Higgins, A. H., 1967. Spread factor for technical malathion spray. J. Econ. Ent. 60, 280 - 81

Himel, C. M., 1965. A new method for spray deposit assessment US forest Service Research note. P. S. W. 87

Himel, C. M., 1969a. The optimum size for insecticide spray droplets. J. Econ. Ent. 62, 919 - 25

Himel, C. M., 1969b. The fluorescent particle spray droplet tracer method. J. Econ. Ent. 62, 912 - 916

Himel, C. M. and Moore, A., 1969. Spray droplet size in the control of spruce budworm, boil weevil, bollworm and cabbage looper. J. Econ. Eng. 62 (4), 916 - 18

Himel, C. M., 1974. Analytical methodology in ULV. Br. Crop. Prot. Counc. Mongr. 11, 112 - 119

Hinze, J. O. and Milborn, H., 1950. Atomization of Liquids by means of rotary cups. J. Appl. Mech. 17, 145 - 63

Hurting, H., Mann, S.L.W., Hopwell, W.W. and Cravelles, R., 1956 A new technique for sampling and assessing aerial spray droplets. Can. J. Agric. Sci. 36, 81 - 94

Irving N.S. and Beesley, J.S.S.S., 1969a. Aircraft applications of insecticides in East Africa. XVII Airspray experiment with fenthion against *Glossina morsitans* Westw., *G. swynnertoni* Aust. and *G. pallidipes* Aust. Bull. Ent. Res. 58, 431 - 437

Irving, N.S. and Beesley, J.S.S .S., 1969b. XVII Attempted control of *Glossina pallidipes* Aust. with pyrethrum in dense thickets. Bull. Ent. Res. 59, 299 - 305

Jenkins, J.E.C., 1973. An evaluation of the control of cereal leaf disease by fungicide in England and Wales. Proc. 7th Br. Insectic. Fungic. Conf. 3, 781 - 790

Johnstone, D.R., 1971. Droplet size for low and ultra low volume spray. Cott. Gr. Rev. 48, 218 - 233

Johnstone, D.R., 1974. Physical and chemical requirements for ultra low volume applications Br. Crop Prot., Counc. Monogr. 11, 73 - 78

Johnstone, D.R., Huntington, K.A. and King, W.J., 1974. Micrometeorological and operational factors affecting ultra low volume spray applications of insecticides on to cotton and other crops. J. Agric. Met. 13, 39 - 57

Johnstone, D.R. and Huntington, K.A., 1977. Deposition and drift of ULV insecticide sprays applied to cotton by hand applicator in Northern Nigeria. Pestic. Sci 8, 101 - 109

Johnstone, D.R., Rendell, C.H. and Sutherland, 1977. The short term fate of droplets of coarse aerosol size in ultra low volume insecticide application on to a tropical field crop. J. Aerosol Sci. 8, 387 - 394.

Johnstone, D.R., 1978. The influence of physical and meteorological factors on the deposition and drift of spraying droplets of controlled size. Br. Crop. Prot. Counc. Monogr. 22, 43 - 50

Johnstone, K.A. and Johnstone, D.R., 1976. Power requirement and droplet size characteristics of a new ULV, hand carried, battery operated insecticide sprayer. ODA COPR Misc. Rept. No. 26

Jones, P.H., 1966. Rearing and breeding locusts in the laboratory. ALRC 12 pp.

Jones, K.G. and Morgan, N.G., 1974. Experimental spraying equipment for ULV application in top fruit Br. Crop. Prot. Counc. Monogr. 11, 143 - 151

Joyce, R.J.V., 1974. Operational potential of ULV Application. Br. Crop Prot. Counc. Monogr. 11, 29 - 38

Joyce, R.J.V., 1975. Sequential aerial spraying of cotton at ULV rates in Sudan Gezira as a contribution to synchronised chemical application over the area occupied by the pest population. Proc. Vth Int. Agr. Aviat. Conf., 47 - 54

Joyce, R.J.V. and Beaumont, J., 1979. Collection of spray droplets and chemical by larvae foliage and ground deposition control of pine beauty moth by fenitrothion in Scotland. 1978 Ed. Holden, A.V. and Bevan, D. Forestry Commission, 176 pp

Kantack, B.H., Berndt, W.L. and Balsbaugh, E.U., 1966. Horn fly and face fly control on range cattle with aerial application. J. Econ. Ent. 60, 1766 - 67

Kaspers, H., Grewe, F., Brandes, W., Schenpflug and Buchel, K. H., 1975. 1, 2, 4 - Triazol derivatives, a new class of protective and systemic fungicides. VIII Int. Plant Prot. Conf. Moscow, 1975. Nachrichten Bayer, 29, 267 - 80.

Kennedy, J. S., Ainsworth, A. and Toms, B. A., 1948. Laboratory studies on spraying of locusts at rest and in flight. Anti - locust Bull. No. 2, (London), 64 pp.

King, J. E., 1973. Cereal foliar surveys. Proc. 7th Br. Insectic. Fungic. Conf. 3, 771 - 80

King, J. E., 1977. The incidence and economic significance of diseases in cereals in England and Wales. Proc. 9th Br. Crop Prot. Conf. Pests and Diseases 3, 677 - 87

Kradel. J., Pommer, E. H., 1967. Some remarks and results on the control of powdery mildew in cereals. Proc. 4th Br. Insectic. Fungic. Conf. 1, 170 - 5

Kramer, C. Y., 1957. Extension of multiple range tests to group correlated adjusted means. Biometrics 13 (1), 1 -12

Lake, J.R., Frost, A. R. and Green, R., 1976. Measurement of drop size and spray distribution from the Micron Herbi disc. Proc. 13th Br. Crop Prot. Conf. Weeds 2, 399 - 405

Lake, J. R., Frost, A. R. and Lockwood, A., 1978. Drift from an ulvamast sprayer. Proc. 14th Br. Crop Prot. Conf. Weeds 2, 681 - 93

Large, E. C., 1954. Growth stages in cereals. Illustration of Feeks scale. Plant Pth. 3, 128 - 9

Large, E. C. and Doling, D. A., 1963. The measurement of cereal mildew and its effect on yield. Plant Pth. 11, 47 - 57

Last, F. T., 1955. Effect of powdery mildew on yield of spring barley. Plant. Pth. 3, 22 - 24

Last, F. T., 1962. Analysis of the effect of *Erysiphe graminis* DC. on the growth of barley. Ann. Bot. 26, 279 - 89

Last, F. T., 1963. Effects of temperature on cereal powdery mildews. Plant Pth. 10 - 12, 132 -33

Lawson, T. J. and Uk, S., 1978. The effects of wind turbulence and crop charachteristics on the dispersal of aerial sprays. Br. Crop Prot. Counc. Monogr. 22, 67 - 74

Lee, C. W., 1974. Aerial ULV sprays for Cayman Island mosquitoes. Br. Crop Prot. Counc. Monogr. 11, 190 - 6

Lhostle, J. and Piedallu, C., 1977. Control of insects in cotton crops in Africa with some pyrethroids. Pestic. Sci. 2, 254 - 57

Liljdahl, L. A. and Strait, J., 1959. Spray deposit measured rapidly. Agric. Engng. 40, 332 35

Lofgren, C. S., 1970. ULV applications of concentrated insecticides in medical and veterinary entomology. Ann. Re. Ent. 15, 321 - 42.

Lofgren, C. S., Ford, H. R., Tonn, R. J., Bang, Y.H. and Phaichitt Siribodhi, 1970. The effectiveness of ULV applications of malathion at a rate of US fluid ounces per acre in controlling *Aedes aegypti* in a large scale test at Nakhon Swan, Thailand. Bull. Wld. Hlth. Org. 42, 15 - 25

Lofgren, C. S., 1972. Control of anophelines in canal zone jungles with ULV aerial applications of fenthion. Mosquito news 32, 566 - 73

MacCuaig, R. D., 1958. Spray collecting area of locusts and their susceptibility to insecticides. Nature 182, 578 - 9

MacCuaig, R. D., 1962. The collection of spray droplets by flying locusts. Bull. Ent. Res. 53, 111 - 23

MacCuaig, R. D., 1967. Instruction on the use of insecticide testing kits. UN/FAO Ref. No. 3F/DL/6 and WS/54965

MacCuaig, R. D., 1968. Insecticide Index. ALRC, London.

MacCuaig, R. D., 1974. "Correspondence column". PANS 20, 161

MacCuaig, R. D., 1975. Insecticide Index - 1974 supplement (FAO/Rome).

MacCuaig, R. D. and Watts, W. S., 1967. A simple technique for applying small measured quantities of insecticides to insects. Bull. Ent. Res. 57, 549 - 52

MacCuaig, R. D. and Yeates, M. N. D. B., 1972. Theoretical studies on the efficiency of insecticidal sprays for the control of flying locust swarms. Anti - locust Bull. No. 49, 34 pp.

Martin, H., 1973. The scientific principles of crop protection. 6th Ed. Edward Arnold, London. 423 pp.

Matthews, G. A., 1973a. Nozzles for pesticide application in the tropics. PANS 19 (4) 436 - 49

Matthews, G. A., 1973b. ULV spraying of cotton in Malawi. Cott. Grw. rev. 50, 242 - 67

Matthews, G. A., 1975. Determination of droplet size. PANS, 21 (2), 213 - 25

Matthews, G. A., 1977a. Controlled droplet application (CDA). PANS 23 (4), 387 - 94

Matthews, G. A., 1977b. The biological target. Pestic. Sci. 8, 96 - 100

Matthews, G. A., 1979. Pesticide application methods. Longman, London and New York 358 pp.

Matthews, G. A. and Mowlam, M. D., 1974. Some aspects of the biology of cotton insects and their control with ULV spraying in Malawi. Br. Crop Prot. Counc. Monogr. 11, 44 - 52

May, K. R., 1945. An instrument for sampling coarse aerosols, J. Scient. Instrum. 22, 187 - 95

May, K. R., 1949. An improved homogenous spray apparatus. J. Appl. Phys. 20, 932 - 38

May, K. R., 1950. The measurement of airborne droplet by the magnesium method. J. Scient. Instrum. 27, 128 - 30

May, K. R. and Clifford, R., 1967. The impaction of aerosol particles on cylinders, spheres, ribbons and discs. Ann. Occup. Hyg. 10, 83 - 85

Maybank, J., Yoshida, K. and Grover, K., 1974. Droplet size spectra, drift potential and ground deposition pattern of the herbicide sprays. Can. J. Pl. Sci. 54, 541 - 46

Mercer, P. C., 1976. Ultra - low -volume spraying of fungicides for the control of Cercospora leaf spot of ground nuts in Malawi. PANS, 22, 57 - 60

Morgan, N. G., 1974. Some biological requirements in the ULV spraying of top fruit. Br. Crop Prot. Counc. Monogr. 11, 59 - 66

Moseman, J. G., 1966. Genetics of powdery mildews. 4th Revision Phytopath. 4, 269 - 90

O'Keeffe, M. G., Dudley, J. and Dickson, J. W., 1976. The application of some cereal herbicides by controlled droplet application. Proc. 13th Br. Crop Prot. Conf. Weeds, 2, 377 - 81

Oliver, D.R. and Ward, S.G., 1959. Studies of viscosity and sedimentation of suspensions. Part 5, The viscosity of settling suspensions of spherical particles. Br. J. Appl. Phys. 10, 317 - 21

Pant, C. P., 1974. A large scale field trial of ULV sprays applied by a portable mistblower for the control of Aedes aegypti WHO/VBC/74.500

Patterson, D. E., 1963. The effect of Saturn yellow concentration on the visual inspection and photographic recording of spray droplets. J. Agric. Engng. Res. 8, 342 - 4

Patterson, R. S. et al., 1966. Control of the midge Glyptotendipes paripes with low volume aerial sprays of malathion. J. Econ. Ent., 59, 864 - 66

Paulech, C., 1969. Influence of Erysiphe graminis on the quantity of dry substance and on growth of vegetative organs. Biologia, Bratislava 24 (10), 709 - 19

Pereira, J. L., 1967. Uses of fluorescent tracer for assessment of spray efficiency. Kenya coffee, December issue.

Plapp. F. W. and Vinson. S.B., 1977. Comparative toxicities of some insecticides to the tobacco budworm and its Ichneumonoid parasite. Environ. Entomol. 6, 381 - 84

Pojananuwong, S., 1976. Comparisons of effectiveness of three insecticides against the migratory locust, (Locusta migratoriodes R & F). Msc. Thesis, Imperial College

Rainey, R. C., 1958. The use of insecticides against the desert locust. J. Sci. Food & Agric. 9, 677 - 92

Rainey, R. C., 1974. Flying insects as targets for ULV spraying. Proc. Br. Crop Prot. Monogr. 11, 20 - 25

Rea, B. L. and Cott, R. K., 1973. The effect of mildew (Erysiphe graminis DC) on leaf growth and yield of spring barley. Proc. 7th Br. Insectic. Fungic. Conf. 1, 29 - 37

Roberts, D. A. and Boothroyd, C. W., 1972. Foundamentals of plant pathology. Freeman, W. H. and Company 292 - 94, 402 pp.

Rosin, P. and Rammler, E. 1933. The laws governing the fineness of powdered coal. J. Inst. Fuel 7, 29 - 36

Ruscoe, C. N. E., 1977. The NRDC pyrethroids as agricultural insecticides. Pestic. Sci. 8, 236 - 42

Sayer, H. J. and Rainey, R. C., 1958. An Exhaust Nozzle Sprayer for ULV applications of persistent insecticides in locust control. ALRC Rept.

Sayer, H. J., 1959. An ULV spraying technique for the control of the desert locust, (Schistocerca gregaria Forskal) Bull. Ent. Res. 50 (2), 371 - 86

Sayer, H. J., 1964. Experimental aircraft spraying of cultivations on the Eritrean Coast. Tech. Rept. No. 19 DLCO - EA Asmara.

Sayer, H. J., 1968. Trial of using sumithion ULV against settled swarm of desert locusts. DLCO - EA, Tech. Rept. 47 pp.

Sayer, H. J. and Joyce, R. J. V., 1966. Aerial application techniques in Africa. Wld. Rev. Pest Cont. 5 (3), 124 - 31

Sharp, R. B., 1955. The detection of spray deposits using fluorescent tracers. Tech. Memor. 119, Nat. Inst. Agric. Engng. Silsoe.

Sharp, R. B., 1973. A rapid method of spray deposit measurement and its use in new apple orchards. Proc. 7th Br. Insectic. Fungic. Conf. 2, 637 - 42

Sharp, R. B., 1974. Spray measurement by fluorescence. Pestic. Sci. 5, 197 - 209

Shaw, J. M. and Timmons, F. L., 1949. Controlling submerged water weeds in irrigation systems with aromatic solvents. US Bur. Reclam., US Dept. Agric. Laboratory Rept. CH -97 (Memo)

Sidney Siegel, 1956. Non - parametric statistics for the behavioral sciences. Friedman two-way analysis of variance. McGraw - Hill Book Company, London. 166 - 172, 312 pp.

Skoog, F. E. et al., 1965. Ultra - low - volume aerial spraying of dieldrin and malathion for rangeland grasshopper control. J. Econ. Ent. 58, 559 - 65

Skoog, F. G., Hanson, T. L., Higgins, A. H. and Onsager, J. A., 1976. ULV spraying: systems evolution and meteorological data analysis. Trans. Am. Soc. Agric. 19 (1), 2 - 10

Stafford, E. M., 1969. A fluorescent pigment to measure spray coverage. J. Econ. Ent. 63 (3), 769 - 76

Staniland, L. N., 1959. Fluorescent tracer technique for the study of spray and dust deposits. J. Agric. Engng. Res. 4, 110 - 25

Staniland, L. N., 1960. Field tests of spraying equipment by means of fluorescent tracer techniques. J. Agric. Engng. Res. 5, (1), 42 - 82

Swithenbank, J., Beer, J. M., D. S., Abbot, D. and McCreath, G. C. 1977. A laser diagnostic for measurement of droplet and particle size distribution. Published in : Experimental diagnostic in gas phase combution systems, Progress in Astronautics & Aeronautics, Vol. 53, 10 pp. by Zinn, B. T.

Tarimo, C. S. et al., 1970. Aircraft application of insecticides in East Africa. XIX. A comparison of two sampling techniques for assessing the effectiveness of pyrethrum application on Glossina pallidpes Aust. Bull. Ent. Res. 60, 221 - 23

Tarimo, C. S., 1974. The control of tsetse flies by ULV spraying. Br. Crop Prot. Counc. Monogr. 11, 180 - 89

Tarr, S. A. J., 1972. The principles of plant pathology 1st Ed. The Macmillan, London 632 pp.

Taylor, R. T., 1975. A prospective study of the effect of ULV aerial application of malathion on epidemic Plasmodium talciparum malaria. J. Trop. Med. Hyg. 24, 188 - 92

Taylor, W. A. and Meritt, C. M., 1975. Some aspects of the performance of experimental equipment for controlled droplet application with herbicides. Proc. 8th Br. Insectic. Fungic. Conf. 1, 161 - 70

Thornhill, E. W., 1979a. A rotary droplet sampler. PANS (1), 68 -70

Thornhill, E. W., 1979b. (Personal communication).

Walton, W. H. and Prewett, W. C., 1949. Atomization by spinning discs. Proc. Phys. Soc. 62 (6), 341 - 50

Ware, G. W., Pesticides, An - auto - tutorial approach. W. H. Freeman and Company, San Francisco, 191 pp.

Watts, W. S., Thornhill, E. W., Davis, A. L. and Matthews, G. A., 1976. The primary evaluation of the Evers and Wall MK II Exhaust Nozzle Sprayer. ODA - COPR Misc. Rept. No. 28

Woods, A., 1972. Pest control: A survey. Mcgraw - Hill, London 404 pp.

Wootten, N. W. and Sawyer, K. F., 1954. The pick - up of spray droplets by flying locusts. Bull. Ent. Res. 45, 177 - 97

WHO, 1971. Application and dispersal of pesticides. Wld. Hlth. Org. Tech. Rept. No. 465

Yates, W. E. and Akesson, N. B., 1963. Fluorescent tracers for qualitative microresidue analysis. Trans. Am. Soc. Agric. Engrs. 6 (2), 104 - 7

Yates, W. E., Akesson, N. B. and Coutts, H. H., 1967. Drift hazards related to ultra - low -volume and diluted sprays applied by agricultural aircraft. Trans. Am. Soc. Agric. 10, 628 - 32

Yeo, D., 1961. Assessment of rotary atomisers fitted to a Cessna aircraft. Agric. Aviat. 3, 131 - 35

(I)

Appendix

METHODS AND PRELIMINARY EXPERIMENTS.

(I)

Table 1 Speed and amperage of multiple-disc nozzle at different voltages with and without liquid flow.

(Ref. Para. 2.1.2c)

Voltage	r.p.m. (without liquid flow)	Amps	r.p.m. (with liquid flow)	Amps
10	6,000	5.5	5,000	5.9
11	7,800	5.6	6,420	6.2
12	8,550	5.6	8,000	6.4
13*	8,900*	6.0	8,250*	6.5
14	9,300	5.7	8,250	6.4
15	9,400	6.0	8,250	6.4
16	11,000	6.4	8,250	6.4
17	11,500	6.7	8,250	6.4
18	12,000	7.0	8,250	6.4

* Points of unstability at which stable rotational speed begins to be unsteady.

(I)

(A)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
DESCRIPTION	NUMBER OF DAYS MgO COATED SLIDES KEPT BEFORE BEING SPRAYED ON												MEAN	STANDARD DEVIATION
	10M*	30	60	90	120	150	180	210	240	270	300	330		
VMD	52	52	49	49	48	47	47	46	46	45	42	41	46.8	± 3.5
NMD	47	47	46	46	43	43	43	43	40	39	38	35	42.5	± 3.8
VMD/NMD	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.6	1.1	-	-
16%	49	44	45	48	49	48	48	48	47	45	38	40	45.8	± 3.6
84%	55	55	51	55	54	54	55	55	54	54	48	48	55.	± 12
TOTAL NO. OF DROPLETS.	938	875	844	813	750	625	531	438	375	313	188	63	562.8	± 289.7
DROPLETS PER CM^2	150	140	135	130	120	100	85	70	60	50	30	10	90.0	± 46.4

(B)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
DESCRIPTION	NUMBER OF DAYS MgO COATED SLIDES KEPT BEFORE BEING SPRAYED ON												MEAN	STANDARD DEVIATION
	10M*	30	60	90	120	150	180	210	240	270	300	330		
VMD	53	53	53	52	52	51	50	50	49	48	47	46	50.3	± 2.4
NMD	49	49	48	47	47	46	45	44	43	42	40	39	44.9	± 3.4
VMD/NMD	1.1	1.1	1.1	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.2	1.1	-	-
16%	46	46	46	46	46	46	46	46	46	46	45	46	45.9	± 0.3
84%	64	63	63	64	64	62	65	63	66	64	68	64	64.2	± 1.6
TOTAL NO. OF DROPLETS.	1375	1250	1219	1125	1000	875	750	719	625	500	469	450	863	± 326.7
DROPLETS PER CM^2	220	200	195	180	160	140	120	115	100	80	75	72	138	± 32.3

(C)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
DESCRIPTION	NUMBER OF DAYS MgO COATED SLIDES KEPT BEFORE BEING SPRAYED ON												MEAN	STANDARD DEVIATION
	10M*	30	60	90	120	150	180	210	240	270	300	330		
VMD	44	44	44	44	43	43	43	42	42	42	42	42	42.9	± 0.9
NMD	42	42	42	42	41	40	40	40		39	38	38	40.1	± 1.5
VMD/NMD	1.3	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.3	-	-
16%	32	32	32	33	36	38	38	36	38	38	37	38	35.6	± 2.6
84%	53	52	55	54	58	58	54	58	58	58	56	58	56	± 2.3
TOTAL NO. OF DROPLETS.	1875	1844	1688	1681	1619	1500	1438	1344	1125	1063	1050	875	1425.2	± 334.0
DROPLETS PER CM^2	300	295	270	269	259	240	230	215	180	170	168	140	228.0	± 53.4

Table 2 The size and number of droplets of A) water plus 5% wetting agent, B) water plus 20% Ulvapron oil and C) Ulvapron oil sprayed with a 5.5 cm spinning disc (at 10,000 rev/min) measured on MgO coated slides kept in a slide box for a period of 10 minutes up to 330 days.

(Ref.Para. 2.3.2)

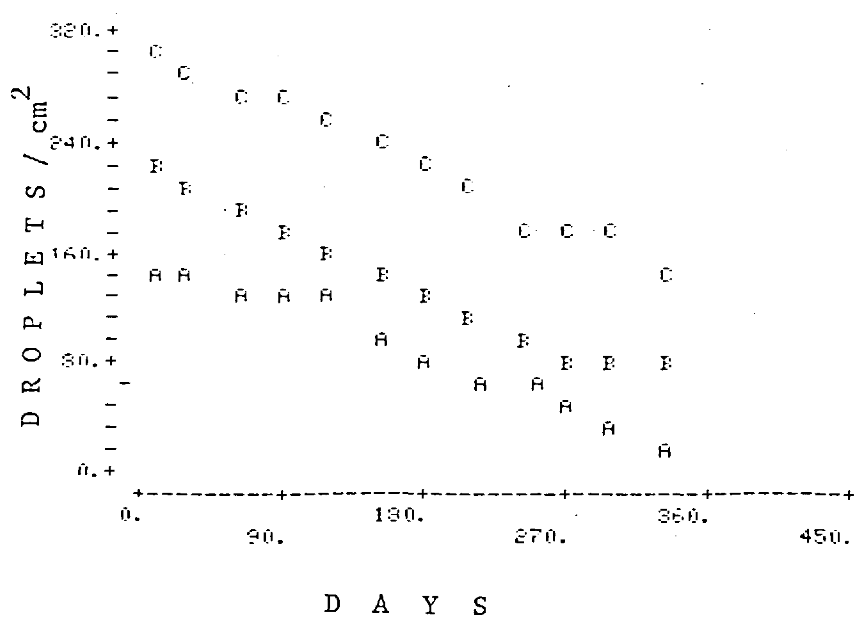
(I)

Table 3 Computer plotted table and graph (Fig. 1 below) of the relative number of droplets/cm^2 of three formulations, A) water + 5% w.a., B) water + 20% Ulvapron oil, C) Ulvapron oil, sprayed with a 5.5 cm spinning disc on MgO coated slides of different age group.

(Ref. Para. 2.3.2)

COLUMN	Droplets /cm^2	Days MgO kept	Classification	
COUNT	36	36	36	
ROW				
1	150.	10.	1.	(A)
2	140.	30.	1.	(A)
3	135.	60.	1.	(A)
4	130.	90.	1.	(A)
5	120.	120.	1.	(A)
6	100.	150.	1.	(A)
7	85.	180.	1.	(A)
8	70.	210.	1.	(A)
9	60.	240.	1.	(A)
10	50.	270.	1.	(A)
11	30.	300.	1.	(A)
12	10.	330.	1.	(A)
13	220.	10.	2.	(B)
14	200.	30.	2.	(B)
15	195.	60.	2.	(B)
16	180.	90.	2.	(B)
17	160.	120.	2.	(B)
18	140.	150.	2.	(B)
19	120.	180.	2.	(B)
20	115.	210.	2.	(B)
21	100.	240.	2.	(B)
22	80.	270.	2.	(B)
23	75.	300.	2.	(B)
24	72.	330.	2.	(B)
25	300.	10.	3.	(C)
26	295.	30.	3.	(C)
27	270.	60.	3.	(C)
28	269.	90.	3.	(C)
29	259.	120.	3.	(C)
30	240.	150.	3.	(C)
31	230.	180.	3.	(C)
32	215.	210.	3.	(C)
33	180.	240.	3.	(C)
34	170.	270.	3.	(C)
35	168.	300.	3.	(C)
36	140.	330.	3.	(C)

Fig. 1



(I)

Table 4 Two-way analysis of droplets of three formulations A) water + 5% w.a. B) water + 20% Ulvapron oil and C) Ulvapron oil, sprayed with a 5.5 cm spinning disc and collected on MgO coated slides of different age group.

(Ref. Para. 2.3.2)

ANALYSIS OF VARIANCE

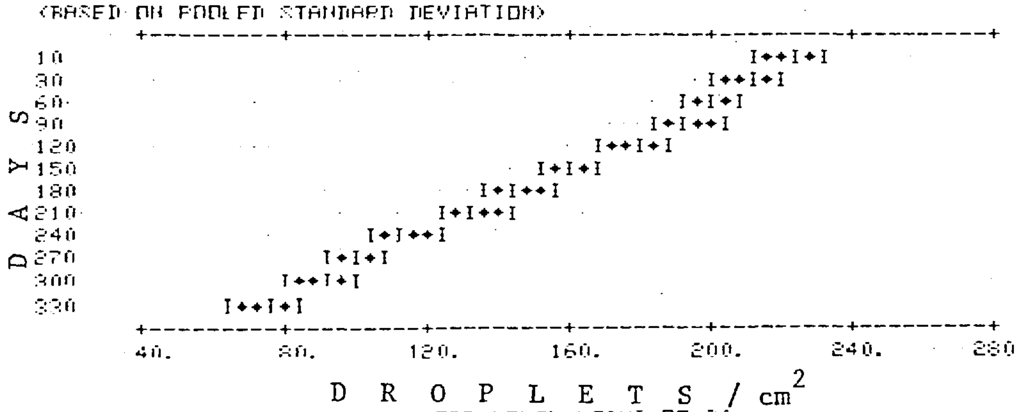
DUE TO	DF	SS	MS=SS/DF
C5	11	83593.6	7599.4
C6	2	117764.1	58882.0
ERROR	22	1519.3	69.1
TOTAL	35	202877.0	

OBSERVATIONS
ROWS ARE LEVELS OF C5 COLS ARE LEVELS OF C6

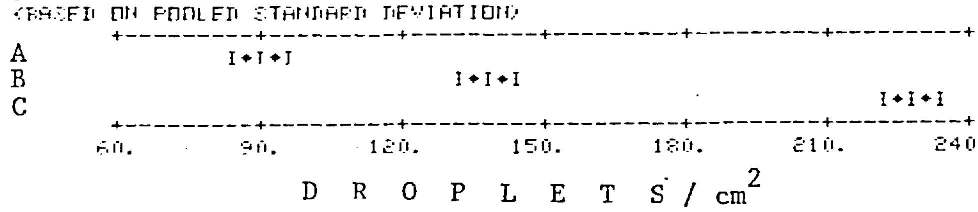
Days	A	B	C	ROW MEANS
10	150.00	220.00	300.00	223.33
30	140.00	200.00	295.00	211.67
60	135.00	195.00	270.00	200.00
90	130.00	180.00	269.00	193.00
120	120.00	160.00	259.00	179.67
150	100.00	140.00	240.00	160.00
180	85.00	120.00	230.00	145.00
210	70.00	115.00	215.00	133.33
240	60.00	100.00	180.00	113.33
270	50.00	80.00	170.00	100.00
300	30.00	75.00	168.00	91.00
330	10.00	72.00	140.00	74.00
COL. MEANS	90.00	138.08	228.00	152.03

POOLED ST. DEV. = 8.31

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS OF C5
(BASED ON POOLED STANDARD DEVIATION)



INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS OF C6
(BASED ON POOLED STANDARD DEVIATION)



c_5 and c_6 are computer reference numbers for treatment groups in days and type of spray applications.

(I)

Table 5 Droplet size analysis of droplets measured with Flemming particle size analyser.

(Ref. Para. 2.3.2)

SPRAY NOZZLE:- Mini Ulva
R.P.M./PRESSURE/- 7000
MAGNIFICATION:- X4
APPLICATION/FLOW RATE:- 6.4 ml/m
SAMPLING SURFACE:- MgO coated slides

DISTANCE:- 30 cm
TEST LIQUID:- Triadimefon fungicide formulation
RANGE:- 11 - 250um
SITE:- Laboratory
SPREAD FACTOR:- 0.86

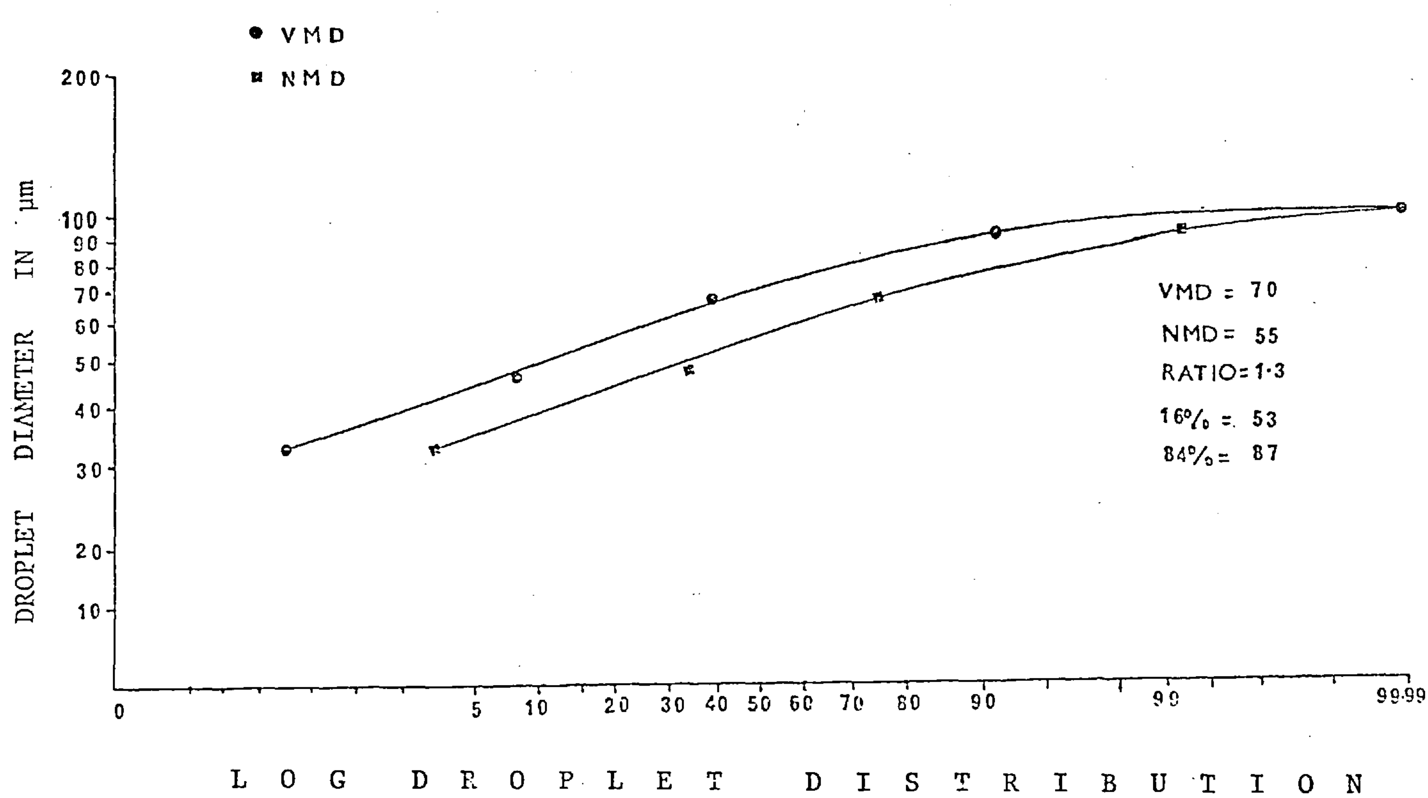
DATE:- 15th June 1978
OPERATOR:- A. WODAGENEH

Experiment No. 20 Reference No. 30 Sample No. 2

Channel Size µm	True Size d µm	Mean size dm	Number in Class N	%N	Σ %N	dm^3*	Ndm^3	% Ndm^3	Σ % Ndm^3
A 11	10	9							
B 16	14	12							
C 22	19	16							
D 31	26	23							
E 44	38	32	11	3.98	2.98	32768	360448	0.265	0.265
F 63	54	46	110	29.81	33.79	97336	10706960	7.885	8.15
G 88	76	65	152	41.19	74.98	274625	41743000	30.744	38.894
H 125	107	92	90	24.39	99.37	778688	70081920	51.617	90.511
I 177	152	129	5	1.626	99.996	2146689	12880134	9.486	99.997
J 250	214	184	-	-	-	-			
Total			369				135772462		

* Volume = $\frac{\pi d^3}{6} = \frac{4}{3}\pi r^3$.

Fig. 3 GRAPHICAL REPRESENTATION OF DROPLET DISTRBUTION OF TRIADIMEFON FUNGICIDE FORMULATION SPRAYED BY MINI ULVA



(I)

Table 6 Computer print-out from the Malvern Instrument's droplet and particle analyser:

(water plus 5% teepol sprayed from a distance (height) of 10 cm above the laser beam).

(Ref. Para. 2.3.3)

> MD= +[illegible] N= +5.7 S= 00072372 (VMD = 83, NMD = 67, and Ratio = 1.3)

D		P	R	N	C	A
D= +552.55 > +261.71		P= +0.00%	R= +100.00%	N= +0.00%	C= 0519	A= 0744
D= +261.71 > +160.29		P= +0.00%	R= +100.00%	N= +0.00%	C= 0794	A= 0858
D= +160.29 > +112.86		P= +2.08%	R= +97.92%	N= +0.31%	C= 1179	A= 1240
D= +112.86 > +84.29		P= +45.95%	R= +51.97%	N= +10.25%	C= 1591	A= 1612
D= +84.29 > +64.57		P= +37.13%	R= +14.84%	N= +34.25%	C= 1969	A= 1860
D= +64.57 > +50.29		P= +11.05%	R= +3.79%	N= +22.19%	C= 2044	A= 2047
D= +50.29 > +38.86		P= +2.90%	R= +0.88%	N= +12.47%	C= 1642	A= 1736
D= +38.86 > +30.29		P= +0.67%	R= +0.21%	N= +6.17%	C= 0975	A= 1116
D= +30.29 > +23.71		P= +0.16%	R= +0.05%	N= +3.11%	C= 0648	A= 0552
D= +23.71 > +18.57		P= +0.04%	R= +0.01%	N= +1.61%	C= 0534	A= 0372
D= +18.57 > +14.57		P= +0.01%	R= +0.00%	N= +0.83%	C= 0423	A= 0372
D= +14.57 > +11.43		P= +0.00%	R= +0.00%	N= +0.43%	C= 0324	A= 0248
D= +11.43 > +9.14		P= +0.00%	R= +0.00%	N= +0.22%	C= 0251	A= 0248
D= +9.14 > +7.14		P= +0.00%	R= +0.00%	N= +0.10%	C= 0201	A= 0186
D= +7.14 > +5.71		P= +0.00%	R= +0.00%	N= +0.07%	C= 0154	A= 0124

Legend:

D = particle diameter range,

P = associated percentage weight fraction,

R = cumulative weight fraction,

N = percentage number fraction, normalized within overall size range printed,

C = calculated best fit energy distribution normalized to 2047,

A = actual measured energy distribution also normalized to 2047.

Table 7A Viscosity in centi-poise of various oils in relation to changes in temperature.

(Ref. Para. 2.2.2)

Temperature °C	Shell-Sol AB	HLP 10	Sunoco Sun-spray 7E	HLP 40 oil	Risella	Sunoco Sun-spray 11N	Ulvapron
20	2.92	15.184	20.79	20.9	25.112	32.587	63.18
30	2.92	12.264	17.4	16.46	18.688	24.644	38.544
40	2.92	10.512	11.68	13.08	13.08	19.739	28.032
50	2.92	7.942	9.577	9.928	9.928	12.432	18.688
60	2.92	3.212	7.709	4.088	8.176	10.626	16.936

Viscosities Determined by:
(Visco Meter)
Type KP Cone and Plate Method,
at Tate & Lyle Research Centre.
Reading, Berks.

(I)

(I)

Table 7B Viscosity of water under test (1) and viscosity of water + 20% Ulvapron.

(1)

No.	Temperature °C	Total time taken in seconds by water* to pass through a visco-meter (K = 0.00046)	poise	Centipoise poise x 100
1	10	45	.02	2.0
2	16	44	.02	2.0
3	20	43	.02	2.0
4	25	42	.02	2.0
5	30	41	.02	2.0
6	35	40.5	.02	2.0
7	40	40	.02	2.0
8	50	39	.02	2.0
9	60	39	.02	2.0

* Density of tap water = 1.02 grams at 19°C

(2)

No.	Temperature °C	Total time taken in seconds by water + 20% Ulvapron to pass through a visco-meter (K = 0.00046)	poise	Centipoise (poise x 100)
1	10	21	0.010	1.0
2	20	17	0.008	0.8
3	30	15	0.007	0.7
4	40	14	0.0069	0.69

Density of water + 20% Ulvapron at 19°C = 1.04

Note: Calculation of Viscosity =

Viscosity = K x ρ x t, where K, is constant, (given by manufacturers) for a given visco-meter; ρ density of test liquid, t, time in seconds.

(Ref. Para. 2.2.2)

(I)

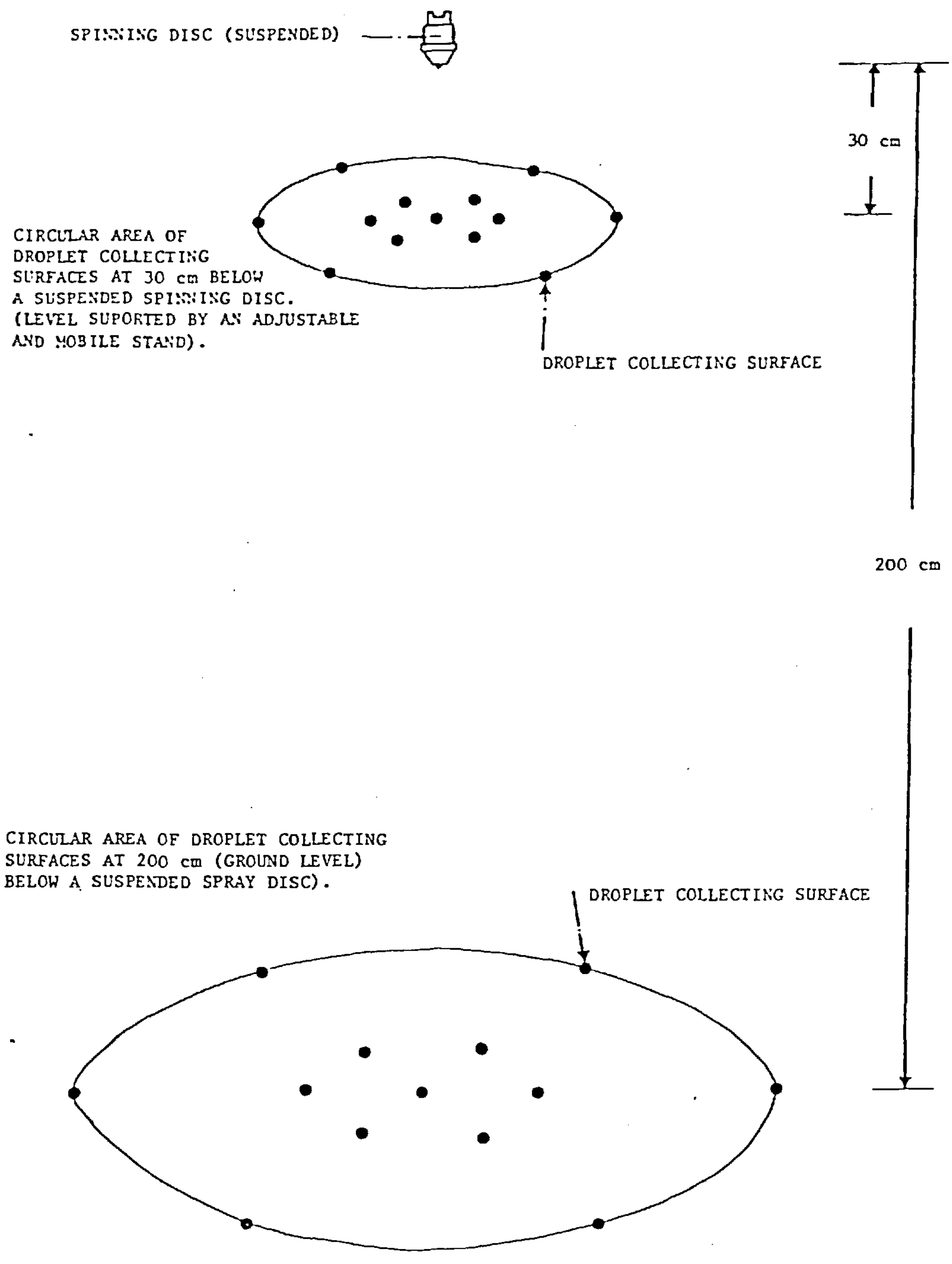


Fig. 4 Relative locations of droplet collecting surfaces below a suspended spray disc.(side view).

(Ref. Para. 2.4)

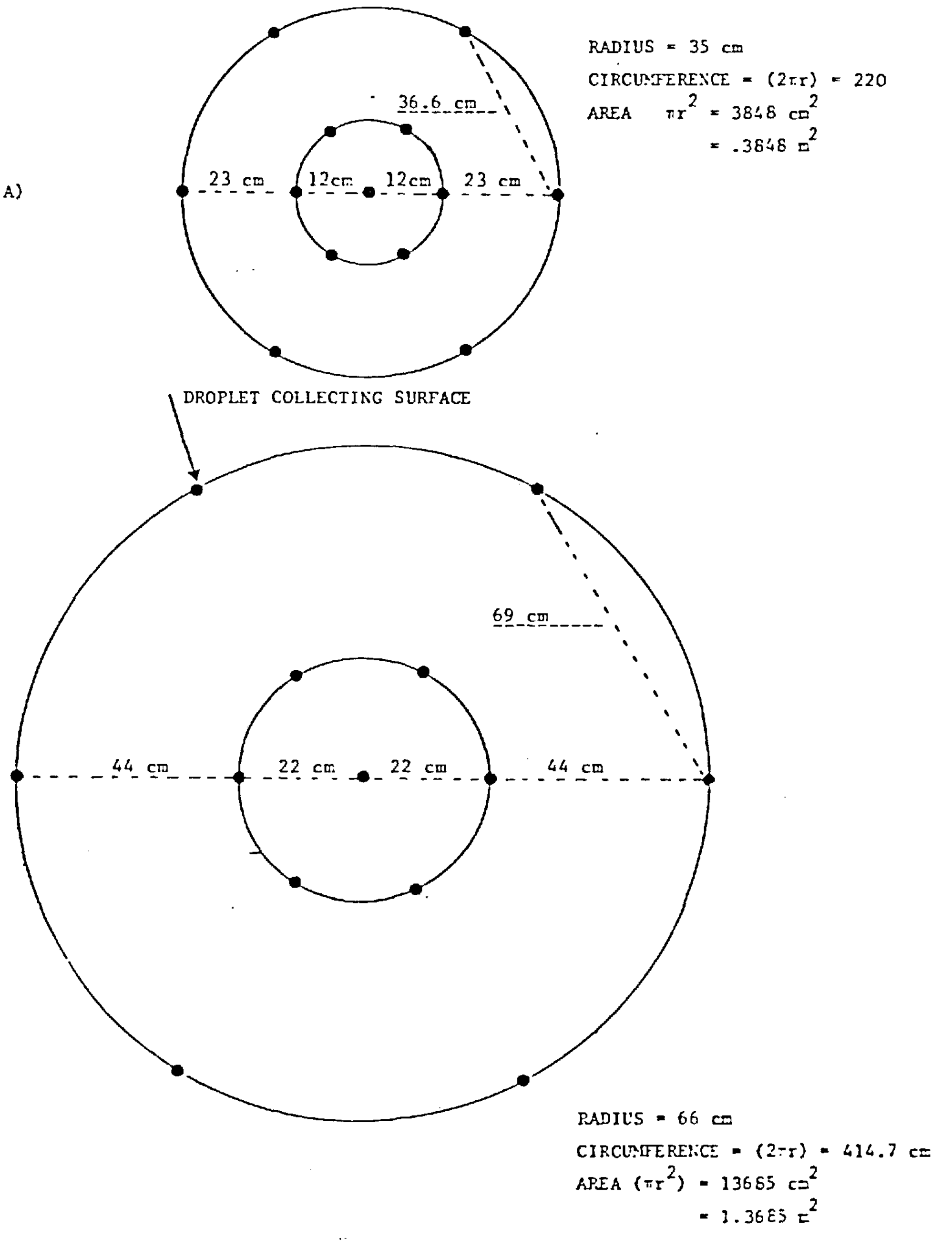
(I)

Fig. 5 Plan view of a circular arrangement and locations of droplet collecting surfaces A) 30 cm height, B) ground level i. e. 200 cm below nozzle.

(Ref. Para. 2.4)

A)

B)

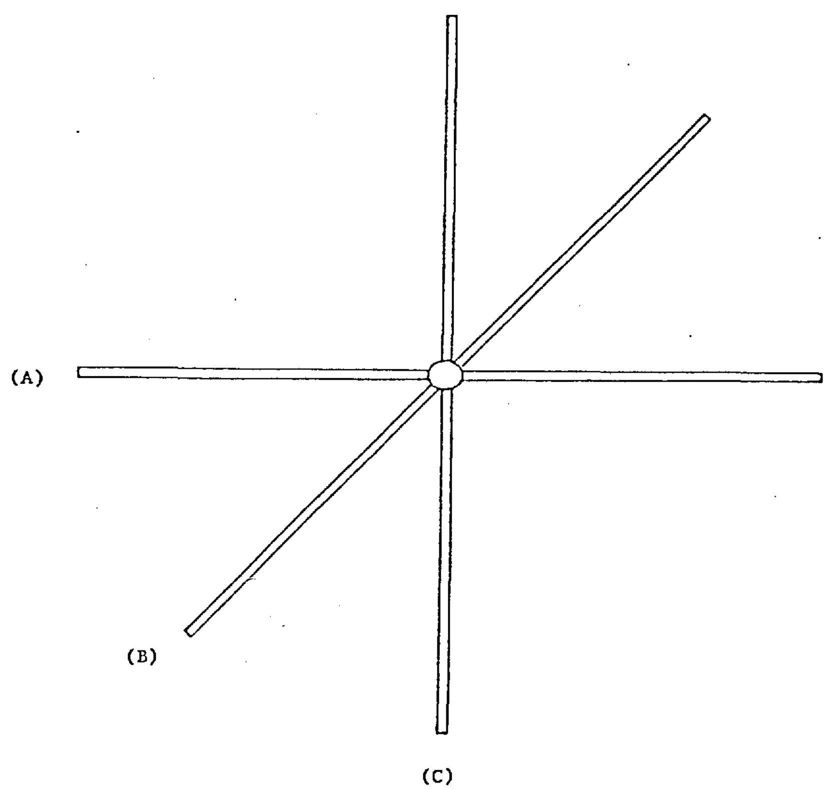


(I)

Fig. 6 Plan view of droplet collecting area (triangular aluminium bars) at three levels from which droplets were collected.

A) 10 cm height, B) 30 cm Height and C) 200 cm distance below nozzle i.e. at ground level.

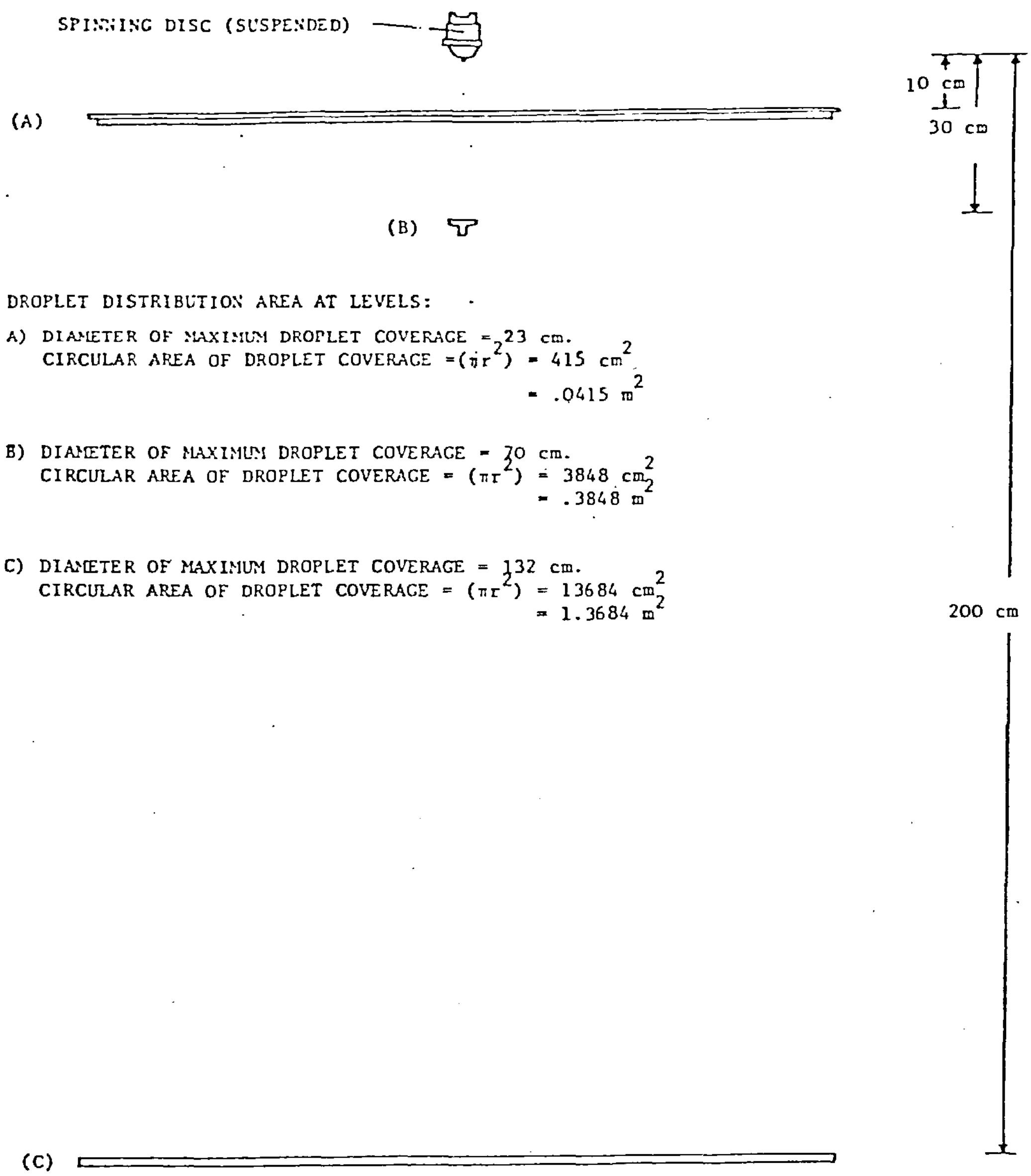
(Ref. Para. 2.4)



(I)

Fig. 7 Side view of droplet collecting areas (triangular aluminium bars) at three levels from which droplets were collected at A) 10 cm height, B) 30 cm height and C) 200 cm at ground level.

(Ref. Para. 2.4)



DROPLET DISTRIBUTION AREA AT LEVELS:

A) DIAMETER OF MAXIMUM DROPLET COVERAGE = 23 cm.
CIRCULAR AREA OF DROPLET COVERAGE = (πr^2) = 415 cm^2
= .0415 m^2

B) DIAMETER OF MAXIMUM DROPLET COVERAGE = 70 cm.
CIRCULAR AREA OF DROPLET COVERAGE = (πr^2) = 3848 cm^2
= .3848 m^2

C) DIAMETER OF MAXIMUM DROPLET COVERAGE = 132 cm.
CIRCULAR AREA OF DROPLET COVERAGE = (πr^2) = 13684 cm^2
= 1.3684 m^2

(I)

Table 8 Efficiency of different droplet collecting surfaces; a 5.5 cm spinning disc (hand carried) sprayer with a spray liquid of A.) water plus 5% w.a. and B) water plus 20% Ulvapron oil.

(Ref. Para. 2.4.3)

(A)

	2 METERS FROM SPRAY PATH					16 METERS FROM SPRAY PATH				
Description	MgO SLIDES			CASCADE IMPACTORS	Roto-Rod	MgO SLIDES			CASCADE IMPACTORS	Roto-Rod
	VR	H6D	RS	SUCTION TUBES	Rota-ting	VR	HGD	RS	SUCTION TUBES	Rota-ting
No. Slides	4	2	2	Impaction 4 Discs	2	4	2	2	Impaction 4 Discs	2
Droplet total	2920	349	2500	106	DNO	1000	250	925	DNF	DNO
Drops/ slide	730	175	1250	27	"	250	125	463	"	"
Drops/ cm^2	117	28	200	9	"	40	20	74	"	"
Drops/ rod	-	-	-	-	"	-	-	-	"	"
Drops/ CI	-	-	-	27	"	-	-	-	"	"
VMD	42	44	41	18	"	35	37	34	"	"
NMD	31	29	31	16	"	25	23	27	"	"
VMD/NMD	1.1	1.3	1.2	1.1	"	1.4	1.6	1.3	"	"
16%	32	29	32	15	"	26	23	26	"	"
84%	44	48	44	23	"	40	50	43	"	"

(B)

	2 METERS FROM SPRAY PATH					16 METERS FROM SPRAY PATH				
No. Slides	4	2	2	4	2	4	2	2	4	2
Droplet total	2900	356	2478	53	DNO	800	138	900	DNF	DNO
Drops/ slide	725	178	1239	13	"	200	69	450	"	"
Drops/ cm^2	116	29	198	4	"	32	11	72	"	"
Drops/ rod	-	-	-	-	"	-	-	-	"	"
Drops/ CI	-	-	-	13	"		-	-	"	"
VMD	45	46	42	35	"	32	44	40	"	"
NMD	27	33	30	29	"	26	27	27	"	"
VMD/NMD	1.3	1.2	1.2	1.2	"	1.2	1.3	1.2	"	"
16%	26	32	30	28	"	25	26	25	"	"
84%	40	47	42	41	"	38	40	38	"	"

Legend:

VR = vertically positioned MgO coated slides,
HGD = horizontally on ground placed MgO coated slides,
RS = rotating MgO coated slides,
DNO = droplets not observed,
DNF = droplets not found,
CI = cascade impactor.

= temperature and relative humidity (20°C, 65%),
= mean wind speed = 2.3 - 3.5 m/s.

(II)

Appendix

DISPERSAL AND BEHAVIOUR OF DROPLETS OF VARIOUS FORMULATIONS UNDER DIFFERENT AND CONTROLLED LABORATORY CONDITIONS.

Table 9 Droplet diameter and volume of VMD in relation to temperature and relative humidity of water plus 5% wetting agent and water plus 22.5% Ulvapron oil sprayed with an 8 cm spinning (Herbi) disc.

(Ref. Para. 3.1.2)

Temperature °C (Relative Humidity)	Spray height in cm.	Formulation at (Flow rate) ml/m	rpm 1950 Drop diameter in µm					Volume of droplet based on VMD in μm^3 ($4/3\ r^3$) $X10^6$	Volume of droplet based on VMD in cm^3 (μm^3-1.-12cm^3) X0.0-05	Percentage decrease in volume relative to sample at 30cm.
			VMD	NMD	Ratio VMD/NMD	16%	84%			
18 (69)	30	water + 5% (teepol) (84ml/min)	320 ± 6	230 ± 7	1.4	230	420	17.0	1.7	-
"	200	"	278 ± 8	195 ± 5	1.4	193	360	11.0	1.1	35
42 (18)	30	"	272 ± 9	196 ± 5	1.4	193	357	10.5	1.05	-
"	200	"	180 ± 6	133 ± 4	1.4	124	232	3.1	0.31	70
18 (69)	30	water + 22.5% Ulvapron (66ml/min)	250 ± 6	180 ± 7	1.4	180	330	8.2	0.82	-
"	200	"	238 ± 7	162 ± 2	1.5	138	297	7.0	0.7	12
42 (18)	30	"	245 ±11	177 ± 5	1.4	176	328	7.7	0.77	-
"	200	"	221 ±10	154 ± 8	1.4	144	279	5.6	0.56	27

(II)

Table 10 Droplet diameter in relation to temperature and relative humidity when water plus 5% wetting agent and water plus 22.5% Ulvapron oil were sprayed with a 5.5 cm spinning disc at speeds of 9,000 and 12,000 rev/min.

(Ref. Para. 3.1.2)

Temperature °C and (Relative humidity %)	Spray height in cm.	Formulation and (Flow rates) ml/min.	R.P.M. 9,000 Drop diameter in μm						R.P.M. 12,000 Drop diameter in μm					
			VMD	NMD	VMD/NMD	16%	84%	Percentage decrease in VMD	VMD	NMD	VMD/NMD	16%	84%	Percentage decrease in VMD
12 (58)	30	water + 5% teepol (84ml/min)	105 ± 5	90 ± 4	1.2	65	120	-	90 ± 6	78 ± 3	1.2	56	102	-
"	200		97 ± 4	80 ± 3	1.2	50	113	8	81 ± 3	66 ± 5	1.2	38	93	10
34 (15)	30		94 ± 8	77 ± 5	1.2	48	110	-	77 ± 7	63 ± 4	1.2	33	90	-
"	200		79 ± 6	60 ± 7	1.3	17	96	16	59 ± 5	42 ± 7	1.4	13	73	23
12 (58)	30	water + 22.5% Ulvapron (66ml/min	83 ± 4	71 ± 4	1.2	51	94	-	71 ± 3	61 ± 4	1.2	44	80	-
"	200		80 ± 3	70 ± 3	1.2	47	93	4	70 ± 2	55 ± 3	1.3	39	79	1
34 (15)	30		75 ±10	61 ± 5	1.2	37	86	-	61 ± 7	50 ± 4	1.2	28	71	-
"	200		68 ± 8	53 ± 4	1.3	15	79	9	53 ± 6	40 ± 2	1.3	10	63	13

(II)

Table 11 Changes in the calculated volume based on VMD in relation to temperature and relative humidity of water plus 5% wetting agent and water plus 22.5% Ulvapron oil sprayed with a 5.5 cm spinning disc at (A) 9,000 and (B) 12,000 rev/min respectively.

(Ref. Para. 3.1.2).

(A)

Temperature °C	Relative humidity %	Spray height in cm.	Formulation at (Flow rate) ml/m	rpm 1950 Drop diameter in μm					Percentage of VMD	Percentage NMD decrease	Percentage decrease in VMD
				VMD	NMD	Ratio VMD/NMD	16%	84%			
18	69	30	water + 5% (teepol) (84ml/min)	320 ± 6	230 ± 7	1.4	230	420	100	160	–
"	"	200	"	278 ± 8	195 ± 5	1.4	193	360	87	15	13
42	18	30	"	272 ± 9	196 ± 5	1.4	193	357	100	100	–
"	"	200	"	180 ± 6	133 ± 4	1.4	124	232	66	32	34
18	69	30	water + 22.5% Ulvapron (66ml/min)	250 ± 6	180 ± 7	1.4	180	330	100	100	–
"	"	200	"	238 ± 7	162 ± 2	1.5	138	297	95	10	5
42	18	30	"	245 ±11	177 ± 5	1.4	176	328	100	100	–
"	"	200	"	221 ±10	154 ± 8	1.4	144	279	90	18	10

(B)

Temperature °C and (Relative humidity %)	Spray Height in cm.	Formulation and (Flow rates) ml/min.	VMD	Volume of VMD in mm³ ($^4/_3 r^3$) X10⁶	Volume of VMD in cm³ (μm³=1.-12cm³) 0.0–05	Percentage Volume	Percentage decrease in volume
18 (69)	30	water + 5% teepol (84ml/min)	320 ± 6	17.0	1.7	100	–
"	200	"	278 ± 8	11.0	1.1	65	35
42 (18)	30	"	272 ± 9	10.5	1.0	100	–
"	200	"	180 ± 6	3.1	0.03	30	70
18 (69)	30	water + 22.5% Ulvapron (66ml/min)	250 ± 6	8.2	0.08	100	–
"	200	"	238 ± 7	7.0	0.07	88	12
42 (18)	30	"	245 ±11	7.7	0.077	100	–
"	200	"	221 ±10	5.6	0.056	73	27

(II)

Table 12 Droplet data for various formulations sprayed with a 5.5 cm spinning disc in a spray hut employing No.4 flow restrictor at a temperature and relative humidity (34°C, 20% RH) and a disc speed of 15,000 rev/min.

(Ref. Para. 3.1.3)

SPRAY HEIGHT IN CM	FORMULATION	FLOW RATE ML/MIN.	DROPLET DIAMETER IN μm					VOLUME (VMD) IN $\mu m^3 (4/_3 \Pi^3)$ X10^3	PERCENTAGE OF (VMD) VOLUME	PERCENTAGE OF (VMD) VOLUME DECREASE
			VMD	NMD	RATIO VMD/NMD	16%	84%			
10	H_2O+5% Teepol	31.4	46	38	1.2	22	60	51.0	100	-
30			39	32	1.2	19	51	31.0	61	39
200			26	21	1.2	13	34	9.0	18	82
10	H_2O+20% Sunoco Sun-spray 7E	30.0	47	42	1.1	23	62	54.4	100	-
30			44	39	1.1	20	55	45.0	83	17
200			36	33	1.1	16	44	24.4	45	55
10	H_2O+20% Sunoco Sun-spray 11N	27.0	45	40	1.1	26	61	48.0	100	-
30			42	37	1.1	24	57	39.0	81	19
200			37	35	1.1	19	44	27.0	56	44
10	H_2O+15% Ulva-pron Micro-nised	27.5	44	40	1.1	27	60	45.0	100	-
30			42	38	1.1	26	57	39.0	87	13
200			37	34	1.1	21	47	27.0	60	33
10	H_2O+20% Ulva-pron Micro-nised	25.0	43	40	1.1	25	58	42.0	100	-
30			41	38	1.1	24	55	39.0	93	7
200			39	37	1.1	21	49	31.1	74	26
10	H_2O+40% Ulva-pron Micro-nised	23.5	41	39	1.2	20	50	36.0	100	-
30			40	38	1.2	19	49	34.0	94	6
200			39	36	1.1	18	47	31.0	86	14

Table 13 Droplet data for water plus 5% w.a. and different concentration of Ulvapron oil sprayed with a 5.5 cm spinning disc in a spray hut at a temperature and relative humidity (32°C, 20%) and disc speeds of 5,000, 10,000 and 15,000 rev/min.

(Ref. Para. 3.1.4)

(A)

Temperature °C	Relative humidity %	Spray height in cm.	Formulation and (Flow Rate) ml/m	R.P.M. 5,000 drop diameter in µm					R.P.M. 10,000 drop diameter in µm					R.P.M. 15,000 drop diameter in µm				
				VMD	NMD	VMD/NMD	16%	84%	VMD	NMD	VMD/NMD	16%	84%	VMD	NMD	VMD/NMD	16%	84%
32	20	10	H_2O + 5% teepol (33.4m./min)	100	80	1.3	48	120										
"	"	30		85	68	1.3	41	102										
"	"	200		56	45	1.2	27	67										
32	20	10							70	60	1.2	35	95					
"	"	30							60	51	1.2	28	85					
"	"	200							40	34	1.2	18	56					
32	20	10												48	40	1.2	30	75
"	"	30												41	34	1.2	26	64
"	"	200												27	22	1.2	17	42
32	20	10	H_2O + 5% ulvapron (29ml/min)	102	90	1.1	40	125										
"	"	30		90	79	1.1	35	110										
"	"	200		63	55	1.1	25	77										
32	20	10							71	62	1.1	35	96					
"	"	30							62	55	1.1	31	84					
"	"	200							41	36	1.1	22	59					
32	20	10												49	42	1.2	31	76
"	"	30												43	37	1.2	27	67
"	"	200												30	26	1.3	19	47

(B)

Temperature °C	Relative humidity %	Spray height in cm.	Formulation and (Flow Rate) ml/min.	R.P.M. 5,000 drop diameter in µm					R.P.M. 10,000 drop diameter in µm					R.P.M. 15,000 drop diameter in µm				
				VMD	NMD	VMD/NMD	16%	84%	VMD	NMD	VMD/NMD	16%	84%	VMD	NMD	VMD/NMD	16%	84%
32	20	10	H_2O + 10% ulvapron (27ml/min)	97	90	1.0	35	100										
"	"	30		87	81	1.0	32	90										
"	"	200		64	60	1.0	24	67										
32	20	10							60	55	1.1	30	85					
"	"	30							54	50	1.1	27	77					
"	"	200							40	36	1.1	20	57					
32	20	10												47	36	1.2	28	68
"	"	30												42	32	1.2	25	61
"	"	200												31	24	1.1	19	45
32	20	10	H_2O + 15% ulvapron (26ml/min)	87	80	1.1	30	95										
"	"	30		82	75	1.1	28	89										
"	"	200		66	60	1.1	22	71										
32	20	10							51	46	1.0	26	80					
"	"	30							46	41	1.1	24	75					
"	"	200							39	35	1.1	19	60					
32	20	10												39	30	1.1	24	70
"	"	30												35	28	1.3	23	66
"	"	200												30	23	1.3	18	53

(C)

Spray height in cm.	Formulation and (Flow Rate) ml/min.	R.P.M. 5,000 drop diameter in µm					R.P.M. 10,000 drop diameter in µm					R.P.M. 15,000 drop diameter in µm				
		VMD	NMD	VMD/NMD	16%	84%	VMD	NMD	VMD/NMD	16%	84%	VMD	NMD	VMD/NMD	16%	84%
10	H_2O + 20% ulvapron (22ml/min)	82	72	1.1	31	95										
30		77	68	1.1	29	89										
200		66	61	1.1	25	79										
10							47	43	1.1	22	74					
30							43	40	1.1	21	70					
200							37	34	1.1	19	62					
10												37	28	1.1	21	57
30												35	26	1.1	20	54
200												30	23	1.1	18	48
10	H_2O + 40% ulvapron (15ml/min)	75	70	1.0	26	82										
30		72	67	1.1	25	79										
200		67	62	1.1	23	73										
10							44	39	1.1	22	69					
30							42	37	1.1	21	66					
200							38	34	1.1	20	61					
10												34	27	1.1	20	52
30												32	26	1.1	19	50
200												30	24	1.1	18	47

In Table (C) temperature and relative humidity is same as in (A) and (B) above.

(II)

Plates 1 and 2 Droplets collected on MgO coated slides A) 10 cm B) 30 cm and 200 cm below a 5.5 cm spinning disc sprayed in a hut under a temperature and relative humidity (32°C, 20%) and disc speed of 10,000 rev/min.

(Ref. Para. 3.1.4)

A B C

Plate 1 Droplets of water plus 5% wetting agent

Plate 2 Droplets of water plus 20% Ulvapron oil

(II)

Table 14 Results of laser analysis of droplet sizes, VMD and NMD of water plus 5% w.a. and different concentration of three oils sprayed with a 5.5 cm spinning disc, at a temperature and relative humidity (19^{o}C, 59%) with a constant flow rate of 30 ml/min and a disc speed of 7,500 rev/min.

(Ref. Para. 3.1.5)

No.	Spray formulation	Spray height	Droplet diameter in µm VMD	NMD	VMD/NMD	Volume in μm^3 X10^4	Percentage volume based on VMD	Percentage volume decrease
1	H_2O + 5% w.a.	10 30 200	83 76 66	67 62 56	1.2 1.2 1.2	30.0 23.0 15.1	100 77 50	- 23 50
2	H_2O + 5% Ulvapron	10 30 200	84 80 72	79 75 68	1.1 1.1 1.1	31.0 27.0 20.0	100 87 65	- 13 35
3	H_2O + 10% Ulvapron	10 30 200	85 82 75	77 74 68	1.1 1.1 1.1	33.2 29.0 22.0	100 90 68	- 10 32
4	H_2O + 15% Ulvapron	10 30 200	86 83 79	80 75 74	1.1 1.1 1.1	33.3 30.0 26.0	100 90 78	- 10 22
5	H_2O + 20% Ulvapron	10 30 200	89 87 85	86 84 83	1.0 1.1 1.0	37.0 34.5 32.3	100 93 87	- 7 13
6	H_2O + 40% Ulvapron	10 30 200	92 91 89	85 84 83	1.1 1.1 1.2	41.0 39.5 37.0	100 96 90	- 4 10
7	H_2O + 5% Sunoco SSS 7E	10 30 200	84 79 71	72 68 60	1.2 1.2 1.2	31.0 26.0 19.0	100 84 61	- 16 39
8	H_2O + 10% SSS 7E	10 30 200	85 81 73	76 72 65	1.1 1.1 1.1	32.3 29.0 20.4	100 88 63	12 37
9	H_2O + 15% SSS 7E	10 30 200	85 82 75	80 77 70	1.1 1.1 1.1	32.3 29.0 22.1	100 88 68	- 12 32
10	H_2O + 20% SSS 7E	10 30 200	88 85 81	79 77 73	1.1 1.1 1.1	36.0 32.3 29.0	100 90 81	- 10 19
11	H_2O + 40% SSS 7E	10 30 200	91 89 85	85 83 82	1.1 1.1 1.0	39.5 37.0 32.3	100 94 82	- 6 18
12	H_2O + 5% SSS 11N	10 30 200	85 81 72	72 68 61	1.2 1.1 1.2	32.3 28.0 20.0	100 87 62	- 13 38
13	H_2O + 10% SSS 11N	10 30 200	86 82 75	75 71 65	1.1 1.2 1.2	33.3 29.0 22.1	100 87 66	- 13 34
14	H_2O + 15% SSS 11N	10 30 200	89 86 80	73 71 66	1.2 1.2 1.2	37.0 33.3 27.0	100 90 73	- 10 27
15	H_2O + 20% SSS 11N	10 30 200	90 87 82	82 78 75	1.1 1.1 1.1	38.2 34.5 29.0	100 90 76	- 10 24
16	H_2O + 40% SSS 11N	10 30 200	92 91 86	86 85 81	1.1 1.1 1.1	41.0 39.5 33.3	100 96 81	- 4 15

(II)

Table 15 Droplet data for various formulations sprayed with a 5.5 cm spinning disc employing No. 4 flow restrictor in a spray hut at a temperature and relative humidity (39°C, 35%) and a disc speed of 15,000rev/min.

(Ref. Para. 3.1.6)

Spray Height in cm.	Formulation	Flow rate ml/min	Droplet Diameter in μm					
			VMD	NMD	Ratio VMD/NMD	16%	84%	
10	H_2O + 5%	32	40	36	1.1	19	50	
30	Teepol	32	34	31	1.1	15	43	
200		32	22	20	1.3	12	28	
10	H_2O + 15%	27	45	40	1.1	22	51	
30	Ulvapron	27	41	38	1.1	20	47	
200		27	34	30	1.1	16	38	
10	H_2O + 20%	25	44	40	1.1	23	53	
30	Ulvapron	25	41	38	1.0	21	50	
200		25	37	34	1.1	17	44	
10	H_2O + 40%	23	42	38	1.1	21	55	
30	Ulvapron	23	40	36	1.1	20	53	
200		23	37	34	1.1	17	48	
10	H_2O + 15%	28	43	40	1.1	20	52	
30	Ulvapron	28	41	38	1.1	18	49	
200	Micronised	28	36	34	1.1	15	44	
10	H_2O + 20%	26	45	41	1.1	23	54	
30	Ulvapron	26	43	39	1.1	21	52	
200	Micronised	26	41	37	1.1	18	47	
10	H_2O + 40%	24	43	39	1.1	22	56	
30	Ulvapron	24	42	38	1.1	21	55	
200	Micronised	24	40	36	1.1	18	52	
10	H_2O + 15%	32	42	38	1.1	20	58	
30	Sunoco	32	38	35	1.1	17	53	
200	Sunspray 7E	32	32	27	1.2	13	42	
10	H_2O + 20%	31	44	40	1.1	22	57	
30	Sunoco	31	41	37	1.1	19	53	
200	Sunspray 7E	31	36	30	1.2	15	43	
10	H_2O + 40%	25	46	42	1.1	20	53	
30	Sunoco SS	25	44	40	1.1	18	50	
200	7E	25	42	36	1.2	15	46	
10	H_2O + 15%	29	45	42	1.1	21	54	
30	Sunoco	29	41	38	1.0	18	49	
200	Sunspray 11N	29	35	32	1.0	14	42	
10	H_2O + 20%	28	44	41	1.1	20	56	
30	Sunoco	28	41	38	1.0	18	52	
200	Sunspray 11N	28	39	34	1.1	14	49	
10	H_2O + 40%	26	46	41	1.1	22	58	
30	Sunoco SS	26	43	39	1.1	20	55	
200	11N	26	41	37	1.1	16	50	

(II)

(Ref. Para. 3.1.6)

1	2	3	4	5	6	7=(4x6)	8=(7x1÷12)	9	10	11
SPRAY HEIGHT IN CM.	FORMULATION	VMD IN µm	VOLUMN OF VMD $^4/_3\pi r^3$) IN μm^3 X10^3	PERCENTAGE (VMD) VOLUME	NO. OF DROPLETS PER CM^2	VOLUME OF SPRAY PER CM^2 = VOLUME X N IN μm^3 X10^4	VOLUME OF FRAY/CM^2 IN CM^3 ($1\mu m^3$=1.-12cm^3) ($1\mu m$=0.0001cm^3) X1-05	PERCENTAGE VOLUME/CM^2	PERCENTAGE VOLUME DECREASE/ CM^2	PERCENTAGE OF (VMD) VOLUME DECREASE
10	H_2O + 5%	40	34.0	100	2725	9265.0	9.3	100	-	-
30	Teepol	34	21.0	62	2316	4864.0	4.9	53	47	38
200		22	6.0	18	1526	916.0	0.62	6	94	82
10	H_2O + 15%	45	48.0	100	4336	20,813.0	21.0	100	-	-
30	Ulvapron	41	36.0	75	4075	14,670.0	15.0	71	29	25
200		34	21.0	44	3252	6,829.2	6.8	32	68	56
10	H_2O + 20%	44	45.0	100	3528	15,876.0	16.0	100	-	-
30	Ulvapron	41	36.0	80	3317	11,941.2	12.0	75	25	20
200		37	27.0	60	2999	8,097.3	8.1	51	49	40
10	H_2O + 40%	42	39.0	100	3292	12,839.0	13.0	100	-	-
30	Ulvapron	40	34.0	87	3160	10,744.0	11.0	85	15	13
200		37	27.0	69	2930	7,911.0	7.9	61	39	31
10	H_2O + 15%	43	42.0	100	2720	11,424.0	11.0	100	-	-
30	Ulvapron	41	36.0	86	2584	9,302.4	9.3	85	15	14
200	Micronised	36	24.0	57	2400	5,760.0	5.6	53	47	43
10	H_2O + 20%	45	48.0	100	3600	17,280.0	17.0	100	-	-
30	Ulvapron	43	42.0	88	3456	14,515.2	15.0	88	12	12
200	Micronised	41	36.0	75	3240	11,664.0	12.0	71	29	25
10	H_2O + 40%	43	42.0	100	3376	14,179.2	14.0	100	-	-
30	Ulvapron	42	39.0	93	3308	12,901.2	13.0	93	7	7
200	Micronised	40	34.0	81	3105	10,557.0	11.0	79	21	19
10	H_2O + 15%	42	39.0	100	2896	11,294.4	11.0	100	-	-
30	Sunoco	38	29.0	74	2635	7,642.0	7.6	69	31	26
200	Sunspray 7E	32	17.2	44	2285	3,730.2	3.9	35	65	56
10	H_2O + 20%	44	45.0	100	2944	13,248.0	13.0	100	-	-
30	Sunoco	41	36.0	80	2738	9,857.0	9.9	76	24	20
200	Sunspray 7E	36	26.4	54	2237	5,905.7	5.9	45	35	46
10	H_2O + 40%	46	51.0	100	3200	16,320.0	16.0	100	-	-
30	Sunoco	44	45.0	88	3040	13,680.0	14.0	86	14	12
200	Sunspray 7E	42	39.0	76	2752	11,000.0	11.0	69	31	24
10	H_2O + 15%	45	48.0	100	3776	18,125.0	18.0	100	-	-
30	Sunoco	41	36.1	80	3436	12,440.0	12.0	69	31	20
200	Sunspray 11N	35	22.4	47	2945	6,597.0	6.6	36	64	53
10	H_2O + 20%	44	45.0	100	4160	18,720.0	19.0	100	-	-
30	Sunoco	41	36.0	80	3869	13,928.4	14.0	74	26	20
200	Sunspray 11N	39	31.0	69	3786	11,737.0	11.0	59	42	31
10	H_2O + 40%	46	51.0	100	2920	14,892.2	15.0	100	-	-
30	Sunoco	43	42.0	82	2745	11,529.0	12.0	80	20	18
200	Sunspray 11N	41	36.0	71	2540	9,144.0	9.1	61	39	29

Table 16 Percentage volume distribution in relation to droplets of various formulations sprayed with a 5.5 cm spinning disc employing No. 4 flow restrictor and at a temperature and relative humidity (39°C, 35%) and a disc speed of 15,000 rev/min.

Table 17 VMD and NMD determined by using the laser diffraction method in relation to changes in flow rate and disc speed using water plus 20% Ulvapron oil sprayed with a 5.5 cm spinning disc in a laboratory hut at a temperature of 17°C and relative humidity of 80%.

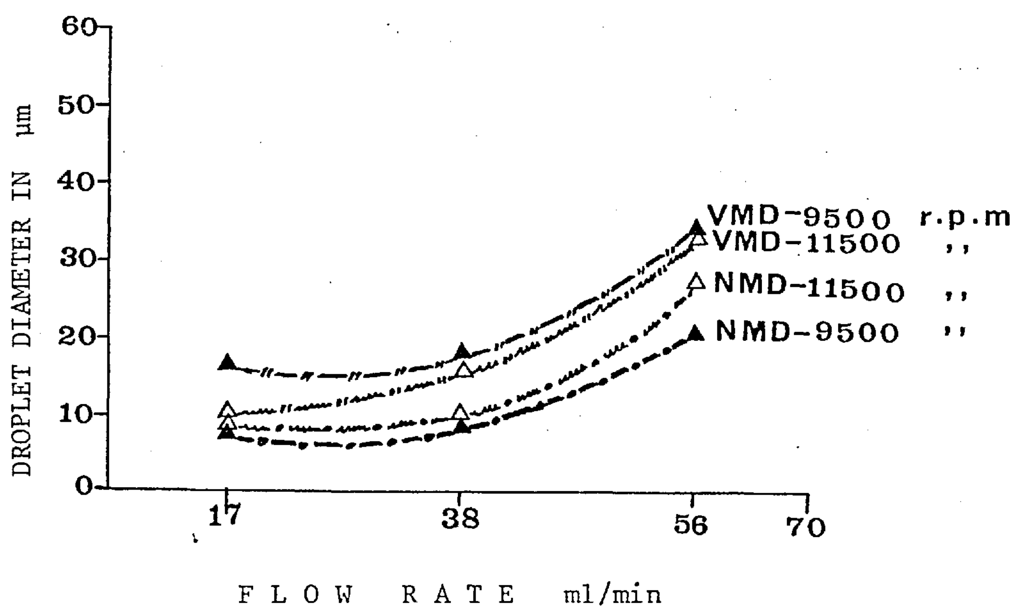
(Ref. Para. 3.1.7)

NO.	FLOW RATE	DISC SPEEDS r.p.m.		VMD	NMD	RATIO: VMD/NMD	% DROPLET FLUCTUATIONS IN RELATION TO FR. & DISC SPEEDS		% VMD/NMD DECREASE OR INCREASE AS DISC SPEEDS INCREASED.**	
		AT 8V	AT 12V				VMD	NMD	VMD	NMD
1	17	9500	-	59 ± 5	50 ± 3	1.2	16.0	7.4	-	-
2	38	"	-	70 ± 6	54 ± 8	1.3	>18.6	>8.0	-	-
3	56	"	-	79 ± 3	60 ± 7	1.3	>33.9	>20.0	-	-
4	17	-	11500	52 ± 4	51 ± 5	1.0	10.0	9.0	<12.0	>2.0
5	38	-	"	60 ± 6	56 ± 4	1.1	<15.4	>10.0	<14.3	>4.0
6	56	-	"	69 ± 3	65 ± 2	1.1	<32.7	>27.0	<12.7	>8.3

(II)

Fig. 8 Changes in droplet diameter in relation to flow rates.

(Ref. Para. 3.1.7)



(II)

Table 18 The VMD and NMD of two formulations sprayed with an MK II Exhaust Nozzle Sprayer at a temperature of 18^{o}C and relative humidity of 68% and measured using a laser diffraction system.

(Ref. Para. 3.1.8)

Temp. °C (Surrounding area)	Formulation	Relative Humidity %	Operating pressure in bar	Nozzle distance from laser beam CM.	Peak	Width	VMD	NMD	VMD/NMD	Percentage VMD	Percentage VMD Decrease
18	Deoderized kerosene	79	0.1	50	135	1.9	111	10	11	100	100
"		"	0.1	150	120	1.3	91	8	11	82	18
"		"	0.2	50	94	2.5	81	14	6	100	100
"		"	0.2	150	102	1.3	77	8	10	95	5
17	Water plus 20% Ulvapron	79	0.1	50	109	1.9	90	10	9	100	100
"		"	0.1	150	91	2.0	76	10	7	84	16
"		"	0.2	50	88	1.9	73	10	7	100	100
"		"	0.2	150	71	1.7	57	9	6	78	22

(III)

Appendix

FIELD DROPLET DRIFT STUDIES AND DEPOSITIONS ON MgO COATED SLIDES AND ON LEAVES.

(III)

Table 19 Droplets/cm^2/ml sampled on vertical targets at different heights to measure downwind drift (A) water + 5% w.a., (B) water + 20% Ulvapron oil and (C) Ulvapron oil.

(Ref. Para. 3.2.1)

(A)

No	SPRAYER	TEMPERATURE oC	RELATIVE HUMIDITY %	WINDSPEED m/s	DISC SPEED R.P.M.	VOLUME RELEASED AND FLOW RATE	SAMPLING HEIGHTS CM	DISTANCE (m) DOWNWIND FROM NOZZLE AND DROPLETS / cm²/(ml) (H₂O + 5% w.a.)										
								.25	.50	1	2	4	8	16	32	64	$\bar{x}$	S.D.
1	HAND CARRIED 5.5cm DISC	20	68	.5-2.3m/s	10,000	200ml 3ml/min	150	-	-	-	-	-	.04	-	-	-	-	-
							70	0.5	.48	.45	0.43	0.26	0.12	.035	-	-	.33	0.19
							35	3	2.94	2.1	1.93	0.98	0.21	.08	.01	-	1.4	1.25
2	4 - DISC (5.5cm)	18	57	2-3.8	10,000	800ml 31ml/min/ DISC	150	.0625	.056	.04	.03	.023	.016	.011	.0087	.006	.028	.02
							70	0.45	0.45	0.44	0.43	0.28	0.155	.03	.027	.015	.253	.19
							35	2.75	2.725	1.88	1.53	1.13	0.25	0.11	.026	.01	1.156	1.13
3	MULTI-DISC (15) 5.5cm DISC	24	62	2-3.5	8500	3750ml 750/min/ml 50/ml/ DISC	150	.029	.027	.026	.016	.01	.0056	.0037	.0029	-	.23	.028
							70	1.0	.48	.45	.42	.26	.10	.04	.02	-	.35	.32
							35	3.0	2.9	2.1	1.9	.98	.21	.09	.0008	-	1.39	1.24
4	MULTI-DISC (15) 5.5cm DISC	19	70	2-3	8500	3750ml 150/min/ml 10/ml/ DISC	150	.3	.13	.09	.069	.042	.038	.027	.016	.005	.079	.091
							70	.8	.76	.59	.53	.50	.36	.08	.05	.0016	.41	.30
							35	3.0	3.0	2.7	2.4	1.8	.53	.16	.062	-	1.7	1.27

(B)

No	SPRAYER	TEMPERATURE oC	RELATIVE HUMIDITY %	WINDSPEED m/s	DISC SPEED R.P.M.	TOTAL FORMULATION AND FLOW RATE	SAMPLING HEIGHTS CM	DISTANCE (m) DOWNWIND FROM NOZZLE AND DROPLETS / cm²/(ml) (WATER + 20% ULVAPRON OIL)										
								.25	.50	1	2	4	8	16	32	64	$\bar{x}$	S.D.
1	HAND CARRIED 5.5cm DISC	25	45	.5 - 2.5	10,000	200ml 21ml/min	150	-	-	-	-	0.1	-	-	-	-		
							70	.6	0.59	0.56	.048	0.29	.03	.01	-	-	.30	.28
							35	3.6	3.53	3.44	1.56	1.0	0.1	-	-	-	2.2	1.5
2	4 - DISC (5.5cm)	18	57	2 - 3	10,000	800ml 21ml/min/ DISC	150	.063	.063	.053	.048	.028	.019	.01	-	-	.035	.019
							70	.54	.53	.52	.49	.40	.26	.074	.053	.024	.04	.02
							35	3.0	2.85	2.65	2.39	1.52	.49	.094	-	-	1.9	1.2
3	MULTI-DISC (15) 5.5cm DISC	24	49	2 - 3	8500	3750ml 714/min/ml 48/ml/ DISC	150	.034	.027	.023	.019	.013	.0027	-	-	-	.019	.01
							70	.6	.58	.56	.49	.29	.08	.0093	-	-	.043	.21
							35	3.6	3.5	3.44	1.56	1.0	.24	.014	-	-	1.9	1.38
4	MULTI-DISC (15) 5.5cm DISC	23	50	2 - 3.8	8500	3750ml 150/ml 10/ml/DISC	150	.15	.14	.11	.08	.05	.048	.02	.0056	.002	.067	.056
							70	.86	.80	.69	.64	.56	.43	.16	.0026	.0008	.46	.33
							35	4.0	3.7	3.49	1.6	1.28	.69	.46	.0008	-	2.17	1.5

(C)

No	SPRAYER	TEMPERATURE oC	RELATIVE HUMIDITY %	WINDSPEED m/s	DISC SPEED R.P.M.	TOTAL FORMULATION AND FLOW RATE	SAMPLING HEIGHTS CM	DISTANCE (m) DOWNWIND FROM NOZZLE AND DROPLETS / cm² /(ml) (ULVAPRON OIL)										
								.25	.50	1	2	4	8	16	32	64	$\bar{x}$	S.D.
1	HAND CARRIED 5.5cm DISC	24	51	.8 - 1.2	10,000	200ml 17ml/min	150	-	-	-	-	-	-	-	-	-		
							70	.65	.66	.5	.41	.41	.25	.11	-	-	.46	.22
							35	4.45	4.41	4.4	4.0	3.0	.68	0.21	-	-	3.0	1.8
2	4 - DISC (5.5cm)	18	57	1 - 3.6	10,000	800ml 17ml/min/ /DISC	150	.05	.048	.038	.034	.029	.024	.021	.0087	.006	.028	.015
							70	.47	.47	.44	.41	.39	.37	.26	.13	-	.37	.12
							35	3.25	3.06	2.9	2.5	2.4	2.2	.50	.15	-	2.12	1.17
3	MULTI-DISC (15) 5.5cm DISC	25	60	2 - 2.8	8500	3750ml 500/min/ml 33.3/ml /DISC	150	.04	.037	.03	.026	.025	.016	-	-	-	.29	.0087
							70	.64	.63	.59	.53	.37	.33	-	-	-	.48	.19
							35	4	3.7	3.5	1.7	1.1	.32	-	-	-	2.06	1.48
4	MULTI-DISC (15) 5.5cm DISC	22	58	2 - 3.4	8500	3750ml 150/min/ml 10/ml/ DISC	150	.16	.15	.15	.11	.08	.05	.008	-	-	.10	.057
							70	.96	.88	.85	.75	.64	.48	.014	-	-	.65	.32
							35	4.3	4.1	3.68	2.08	1.6	1.06	.019	-	-	2.4	1.65

Total No. of droplets/height/cm^2 = droplets/cm^2/ml X total quantities of sprays.

(III)

Table 20 Droplet total/cm^2, VMD and NMD sampled on vertical targets at three different heights (150, 70 and 35 cm) to measure downwind drift of formulations sprayed with (A) 5.5 cm hand-held spinning disc, and (B) 5.5 cm 4-spinning discs.

(Ref. Para. 3.2.1)

(A)

NO.	TEMPERATURE, RELATIVE HUMIDITY AND WINDSPEED.	SPRAYER AND SPEED (R.P.M.)	FORMULATION	FLOWRATE ML/MIN	DROPLET DESCRIPTION	DISTANCE (M) DOWNWIND FROM SPRAY NOZZLE (DROPLET SIZES IN µm) .25	.50	1	2	4	8	16	32	64	$\bar{x}$ (SD)
1A	20°C, 68%, .5 - 2.3 m/s	5.5cm SPINNING DISC 10,000	WATER PLUS 5% WETTING AGENT	31	**TD/3HTS * MD/cm^2	700 233	684 228	501 167	471 157	247 82	71 24	23 8	2 0.7	-	337 (290) 112 (96)
					16%	25	25	24	28	24	25	20	18	-	24.4 (3.2)
					84%	52	52	48	50	50	47	46	40	-	48.0 3.9
					VMD	45	44	48	46	45	42	41	36	-	43.0 3.7
					NMD	40	41	43	42	43	38	35	24	-	38.3 6.4
1B	25°C, 45%, .5 - 2.5 m/s	5.5cm SPINNING DISC 10,000	WATER PLUS 20% ULVAPRON OIL	21	**TD/3HTS * MD/cm^2	840 280	818 273	199 266	408 136	278 93	26 9	2 0.7	-	-	453(370) 151(123)
					16%	30	31	33	30	30	29	28	-	-	30.1 (1.6)
					84%	60	61	60	61	58	55	54	-	-	58.7 (3.3)
					VMD	48	48	49	50	48	47	45	-	-	47.9 (1.6)
					NMD	45	45	46	46	44	42	38	-	-	43.7 (2.9)
1C	24°C, 51%, .8 - 3.2 m/s	5.5cm SPINNING DISC 10,000	ULVAPRON OIL	17	**TD/3HTS * MD/cm^2	1026 342	1014 338	1007 336	900 300	682 227	186 62	62 21	-	-	697 (410) 232 (137)
					16%	34	33	33	35	35	31	30	-	-	33 (1.9)
					84%	62	62	63	62	62	60	60	-	-	61.6 (1.1)
					VMD	50	50	51	52	50	50	48	-	-	50.1 (1.2)
					NMD	47	47	48	48	46	45	42	-	-	46.1 (2.1)

(B)

NO.	TEMPERATURE, RELATIVE HUMIDITY AND WINDSPEED.	SPRAYER AND SPEED (R.P.M.)	FORMULATION	FLOWRATE ML/MIN	DROPLET DESCRIPTION	DISTANCE (M) DOWNWIND FROM SPRAY NOZZLE (DROPLET SIZES IN µm) .25	.50	1	2	4	8	16	32	64	$\bar{x}$ (SD)
2A	18°C, 57%, 2-3.8 m/s	5.5cm 4 - DISC 10,000	WATER PLUS 5% WETTING AGENT	31ml/MIN/DISC	**TD/3HTS * MD/cm^2	2612 871	2585 862	1884 628	1592 531	1147 382	337 112	124 41	50 17	25 8	1151(1068) 384(356)
					16%	28	27	26	30	28	30	25	22	20	26.2 (3.4)
					84%	54	54	53	56	57	56	55	50	47	35.6 (3.2)
					VMD	47	47	48	49	47	46	46	44	40	46 (2.6)
					NMD	42	42	43	43	44	42	41	40	30	40.8 (4.2)
2B	18°C, 57%, 2-3 m/s	5.5cm 4 - DISC 10,000	WATER PLUS 20% ULVAPRON OIL	21ml/MIN/DISC	**TD/3HTS * MD/cm^2	2910 970	2765 922	2574 858	2340 780	1561 520	616 205	142 47	42 14	19 6	1441(1243) 480(415)
					16%	32	32	35	34	32	31	30	29	20	30.6 (4.4)
					84%	64	64	65	66	65	63	60	55	50	61.3 (5.4)
					VMD	49	49	49	51	50	48	48	40	38	46.9 (4.6)
					NMD	46	46	47	47	46	44	43	38	30	43 (5.6)
2C	18°C, 57%, 3-3.6 m/s	5.5cm 4 - DISC 10,000	ULVAPRON OIL	17 ml/MIN/DISC	**TD/3HTS * MD/cm^2	3021 1007	2868 956	2695 898	2358 786	2224 741	2096 699	629 210	227 76	5 2	1791(1177) 597(392)
					16%	34	34	34	35	34	33	33	31	28	32.9 (2.1)
					84%	62	62	63	62	62	62	61	60	58	61.3 (1.5)
					VMD	50	50	52	50	50	50	49	49	48	49.8 (1.1)
					NMD	48	48	48	46	46	46	45	45	44	46.2 (1.5)

** TD/3HTS = Total droplets per 3 heights (35, 70 and 150 cm)

* MD/cm^2 = Mean droplets/cm^2.

Table 21 Droplet total/cm^2, VMD and NMD sampled on vertical targets at three heights (150, 70 and 35 cm) to measure downwind drift of formulations sprayed with (A) 5.5 cm multiple-discs (15 discs) (high flow rate) and (B) same sprayer (low flow rate).

(A)

NO.	TEMPERATURE, RELATIVE HUMIDITY AND WINDSPEED.	SPRAYER AND SPEED (R.P.M.)	FORMULATION	FLOWRATE ML/MIN	DROPLET DESCRIPTION	DISTANCE (M) DOWNWIND FROM SPRAY NOZZLE (DROPLET SIZES IN μm)									
						.25	.50	1	2	4	8	16	32	64	$\bar{x}$ (SD)
3A	24^oC, 62% and 2-3.5 m/s	5.5cm MULTI-DISC SPRAYER (15 - DISCS)	WATER PLUS 5% WETTING AGENT	750 ml/MIN i.e. 50 ml/DISC	**TD/3HTS	13234	12904	9536	8895	4675	1211	484	116		6382(5471)
					*MD/cm^2	4412	4301	3179	2965	1558	404	161	39	-	2127(1823)
					16%	50	50	52	50	49	48	46	44	-	48.6 (2.6)
					84%	107	107	109	95	95	93	90	85	-	97.6 (8.9)
					VMD	80	80	82	81	79	79	76	60	-	77.1 (7.1)
					NMD	62	62	66	60	58	56	52	46	-	57.8 (6.4)
3B	24^oC, 49%, and 2-3 m/s	5.5cm MULTI-DISC SPRAYER (15 - DISCS)	WATER PLUS 20% ULVAPRON OIL	714 ml/MIN i.e. 48ml/DISC	**TD/3HTS	15875	15450	15090	7788	4900	1255	96			8636(6963)
					*MD/cm^2	5292	5150	5030	2596	1633	418	32	-	-	2879(2288)
					16%	52	53	52	52	50	50	49	-	-	51.1 (1.5)
					84%	110	110	112	107	104	100	98	-	-	105.9 (5.4)
					VMD	84	84	85	83	81	81	79	-	-	82.4 (2.1)
					NMD	66	66	66	65	62	61	56	-	-	63.1 (3.8)
3C	25^oC, 40%, and 2-2.8 m/s	5.5cm MULTI-DISC SPRAYER (15 - DISCS)	ULVAPRON OIL	500 ml/MIN i.e. 33.3 ml/MIN	**TD/3HTS	17550	16500	15522	8301	5592	1760				10871(6564)
					*MD/cm^2	5850	5503	5174	2767	1864	587	-	-	-	3624(2188)
					16%	54	54	54	53	53	53	-	-	-	53.5 (0.5)
					84%	112	112	113	111	110	109	-	-	-	111.2 (1.5)
					VMD	85	86	85	84	84	84	-	-	-	67.5 (0.8)
					NMD	68	68	68	67	67	67	-	-	-	67.5 (0.5)

(B)

NO.	TEMPERATURE, RELATIVE HUMIDITY AND WINDSPEED.	SPRAYER AND SPEED (R.P.M.)	FORMULATION	FLOWRATE ML/MIN	DROPLET DESCRIPTION	DISTANCE (M) DOWNWIND FROM SPRAY NOZZLE (DROPLET SIZES IN μm)									
						.25	.50	1	2	4	8	16	32	64	$\bar{x}$ (SD)
4A	19^oC, 70%, and 2-3 m/s	5.5cm MULTI-DISC SPRAYER (15 - DISCS)	WATER PLUS 5% WETTING AGENT	150 ml/MIN i.e. 10 ml/DISC	**TD/3HTS	15000	14590	12550	11200	8810	3493	1020	492	26	7471(6234)
					*MD/cm^2	5000	4863	4183	3733	2937	1164	340	164	9	2488(2076)
					16%	36	36	37	36	36	35	34	30	28	34.2 (3.1)
					84%	54	54	53	53	52	51	50	48	48	51.4 (2.4)
					VMD	48	48	47	47	46	45	44	40	38	44.8 (3.7)
					NMD	44	44	45	43	43	42	40	38	32	41.2 (4.1)
4B	23^oC, 50%, and 2-3.8 m/s	5.5cm MULTI-DISC SPRAYER (15 - DISCS)	WATER PLUS 20% ULVAPRON OIL	150 ml/MIN i.e. 10 ml/DISC	**TD/3HTS	18790	17522	16120	8710	7110	4391	2441	34	11	8348(7454)
					*MD/cm^2	6263	5841	5373	2903	2370	1464	814	11	4	2783(2484)
					16%	37	37	38	37	35	34	33	31	30	34.7 (2.9)
					84%	56	56	55	56	54	52	51	50	49	53.2 (2.8)
					VMD	50	50	50	48	47	47	46	43	40	46.8 (3.4)
					NMD	46	46	46	44	44	43	42	40	37	43.1 (3.1)
4C	22^oC, 58%, and 2-3.4 m/s	5.5cm MULTI-DISC SPRAYER (15 - DISCS)	ULVAPRON OIL	150 ml/MIN i.e. 10 ml/DISC	**TD/3HTS	20210	19090	17350	11012	8701	6001	151			11788(7464)
					*MD/cm^2	6737	6363	5783	3671	2900	2000	50	-	-	2929(2488)
					16%	40	40	40	40	41	40	38	-	-	39.9 (0.9)
					84%	58	58	58	57	56	54	54	-	-	56.4 (1.8)
					VMD	53	53	52	52	51	51	50	-	-	51.7 (1.1)
					NMD	50	50	51	51	50	50	49	-	-	50.1 (0.7)

** TD/3 HTS = Total droplets per 3 heights (35, 70 and 150 cm)

* MD/cm^2 = Mean droplets/cm^2

Appendix III

Table 21b) Percentage volume recovered downwind from spray nozzles of water plus 5% wetting agent, water plus 20% Ulvapron oil and Ulvapron oil sprayed with a 5.5 cm spinning disc nozzles arranged as in column (2) below.

(Ref. Appendix III, Tables 20 & 21)

1	2	3	4	5	6	7
No.	Sprayer	Formulation	Mean Droplets cm^2 $\bar{X}$ (sd)	VMD µm	Volume based on VMDXN $(4/3\Pi r^3)XN/cm^2$ μm^3	Relative percentage of volume recovered downwind.
1A	5.5 cm Single disc	H_2O + 5%w.a.	112 (96)	43	46.6×10^5	16.3
1B		H_2O + 20% Ulvapron	151 (123)	48	87.4×10^5	30.6
1C		Ulvapron	232 (137)	50	15.2×10^6	53.1
Total					28.6×10^6	
2A	5.5 cm 4-disc	H_2O + 5%w.a.	384 (356)	46	19.6×10^6	23.1
2B		H_2O + 20% Ulvapron	480 (415)	47	26.1×10^6	30.8
2C		Ulvapron	597 (392)	50	39.1×10^6	46.1
Total					84.8×10^6	
3A	5.5 cm Multiple disc (15-discs) High flow rate	H_2O + 5%w.a.	2127(1823)	77	50.8×10^7	26.2
3B		H_2O + 20% Ulvapron	2879(2288)	82	83.1×10^7	42.9
3C		Ulvapron	3624(2188)	68	59.7×10^7	30.8
Total					19.4×10^8	
4A	5.5 cm Multiple disc (15-discs) Low flow rate	H_2O + 5%w.a.	2488(2076)	45	11.9×10^7	24.5
4B		H_2O + 20% Ulvapron	2783(2484)	47	15.1×10^7	31.1
4C		Ulvapron	2929(2488)	52	21.6×10^7	44.4
Total					48.6×10^7	

(III)

Table 22 An overall three-way analysis of three formulations (water plus 5% wetting agent, water plus 20% Ulvapron oil and Ulvapron oil) on droplet drifts involving droplets/cm^2/ml (Appendix III, Table 19 A, B & C).

PRIMARY

DUE TO	SOS	DF	VARIANCE ESTIMATE		F	LEVEL OF SIGNIFICANCE
(T) FORMULATION	3.0214	2	1.5107	÷ 4460	3.39	0.05>p>0.025
(G) MACHINE	1.1578	3	.3859	"	.86552	NS
(H) HEIGHT	145.3157	2	72.6579	"	162.9	p<0.001
(TG)	* .8316	6	.1386		-	
(TH)	4.4445	4	1.1111	"	2.49	NS
(GH)	* .8890	6	.1482		-	
(GHT)	* 1.4904	12	.1242		-	
TOTAL	387.3508	323			-	
DISTANCE	97.8366	8,304	12.2296		27.42	p<0.001
NEW ERROR	* 132.3638	280	.4727		-	
ERROR + INTERACTIONS *	= 135.575	304	.4460			

↗ Divide all variance estimates by this.

SUMMARY.

DUE TO	SOS	DF	VARIANCE ESTIMATE	F	LEVEL OF SIGNIFICANCE
FORMULATION (T)	3.0214	2	1.5107	3.39	0.05>p>.025
MACHINE (G)	1.1578	3	.3859	.8655	NS
HEIGHT (H)	145.3157	2	72.6579	162.9	p<0.001
DISTANCE	97.8366	8	12.2296	27.42	p<0.001
FORMULATION X HEIGHT (TXH)	4.4445	4	1.1111	2.49	NS
INTERACTIONS	3.211	24	0.1337	0.2997	NS
ERROR	132.3638	280	.4727		

(III)

NO	SPRAYER	TEMPERATURE OC	RELATIVE HUMIDITY %	WINDSPEED M/S	DISC SPEED R.P.M.	VOLUME RELEASED AND FORMULATION	SAMPLING HEIGHTS CM	DISTANCE (m) DOWNWIND FROM NOZZLE AND DROPLETS / cm²/(ml)										
								.25	.50	1	2	4	8	16	32	64	$\bar{x}$	S.D.
1	5.5cm 4 - DISC	18	90	3 - 3.5	12,000	H_2O OF 5% W.A.+ 5% FIRE ORANGE 400ml, 31ml/min	150	40 (.1)	35 (.087)	30 (.075)	24 (.06)	23 (.057)	20 (.05)	12 (.03)	9 (.02)	5 (.01)	22 (.05)	11.9 (.03)
							70	200 (.5)	191 (.47)	180 (.45)	140 (.35)	130 (.33)	110 (.275)	95 (.237)	40 (.1)	10 (.025)	121.7 (.28)	65.9 (.16)
							35	1400 (3.5)	1250 (3.1)	1100 (2.75)	900 (2.25)	800 (2.0)	600 (1.5)	200 (0.5)	25 (.062)	5 (.013)	698 (1.74)	524.5 (1.3)
2	5.5cm 4 - DISC	18	90	3 - 3.5	12,000	ULVAPRON + 10% SATURN YELLOW 400ml, 17ml/min	150	60 (.15)	50 (.125)	30 (.075)	20 (.05)	10 (.025)	8 (.02)	5 (.013)	-	-	26.1 (.065)	21.6 (.054)
							70	300 (.75)	250 (.625)	220 (.55)	190 (.475)	160 (.4)	120 (.3)	40 (.1)	20 (.05)	-	162.5 (.41)	98.4 (.25)
							35	1650 (4.125)	1420 (3.55)	1260 (3.15)	1100 (2.75)	1010 (2.525)	900 (2.25)	400 (1.0)	50 (.125)	-	973.8 (2.43)	526.9 (1.31)

Table 23 Droplets sampled on vertical targets at three different (150, 70 and 35 cm) heights to measure downwind drift of droplets of water plus 5% wetting agent and Ulvapron oil formulations released simultaneously with a 5.5 cm 4-spinning discs.

(Ref. Para. 3.2.2)

(III)

Table 24 Three-way analysis of variance of A) water plus 5% wetting agent and Ulvapron oil droplets released simultaneously with a 5.5 cm 4-spinning discs.

(Ref. Appendix III, Table 23)

```
-ZRLS  (F=THREEWA)

 DATA NOT FOUND.

? x= .1  .087  .075  .06  .057  .05  .03  .02  .01  .05  .47  .45  .35  .33  .275

?  .237  .1  .025  3.5  3.1  2.75  2.25  2.0  1.5  .5  .062  .013  .15  .125  .075

?  .05  .025  .02  .013  o  o  .75  .625  .55  .475  .4  .3  .1  .05  0  4.125  3.55

?  3.15  2.75  2.525  2.25  1.0  .125  0

?  NUMR=1  NH=9  NG=3  NT=2

?  GO
```

PRIMARY:

DUE TO	SOS		DF		VARIANCE ESTIMATE	F	LEVEL OF SIGNIFICANCE
(T) FORMULATION	.3395		1		.3395 ÷	0.7907	NS
(G) HEIGHT	37.8838		2		18.9419	44.117	p<.001
(H) DISTANCE	14.3642		8		1.7955 ÷ ERROR =	4.1818	p<.05
INTERACTIONS							
TG	.4773	÷	2		.2387		
TH	.1423	÷	8		.0178		
GH	17.2519	÷	16	= ERROR	1.0782		
GHT	.1616	÷	16		.0101		
ERROR	0		0		I		
TOTAL	70.6208		53		-		
TOTAL INTERACTIONS	18.0331		42		.4294		

SUMMARY

DUE TO	SOS	DF	VARIANCE ESTIMATES	F	LEVEL OF SIGNIFICANCE
FORMULATION (T)	.3395	1	.3395	0.7906	* p<.05 NS.
HEIGHT (G)	37.8838	2	18.9419	44.112	*** p<.001
DISTANCE (H)	14.3642	8	1.7955	4.1814	** p<.05
ERROR	18,6331	42	.4294	-	

* NS.
** SIGNIFICANT
*** VERY SIGNIFICANT

1	2		3		4		5		6		7		8		9	10	11	12
DISTANCE FROM SPRAY PATH IN M.	WATER + 5% TEEPOL		WATER + 5% ULVAPRON		WATER + 10% ULVAPRON		WATER + 15% ULVAPRON		WATER + 20% ULVAPRON		WATER + 40% ULVAPRON		ULVAPRON		$\bar{x}$	SD	$\bar{x}$	SD
	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	F	B	B
.25	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0.8	0.3	0	0
.50	0	0	0	0	2	0	2	0	2	0	2	0	3	0	1.6	1.1	0	0
1	0	0	0	0	2	0	2	0	3	0	3	0	5	2	2.1	1.8	0.8	0.3
2	0	0	2	0	2	0	2	0	4	2	5	0	6	2	3.0	2.0	0.97	0.6
4	3	0	3	2	3	2	4	2	6	3	6	4	8	3	4.7	2.0	2.3	1.3
8	5	2	6	3	6	4	6	4	8	4	8	3	7	2	6.3	0.8	3.1	0.9
16	4	3	5	4	6	3	5	3	5	2	4	0	3	0	4.6	1.0	2.1	1.6
32	3	0	3	0	5	2	4	3	3	2	2	0	0	0	2.6	1.6	1.3	1.0
64	2	0	2	0	0	0	0	0	0	0	0	0	0	0	1.0	0.6	0	0
128	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0.5	0.3	0	0

STANDARD OF ASSESSMENT IS BASED ON PATTERSON, (1963) AND PEREIRA, (1967)

Table 25 Deposition of spray droplets on Rhododendron leaves (Rhododendron lochae Muell. of seven formulations (Column 2 - 8) sprayed with a multiple-disc sprayer (Plate 1)

(Ref. Para. 3.2.3)

(IV)

Appendix

CONTROL OF ADULT AND 5TH-INSTAR LOCUSTS (*Schistocerca gregaria* F.) WITH THREE ORGANO-PHOSPHOROUS INSECTICIDES WITH REFERENCE TO:

A) TOXICITIES,
B) STUDY OF SPECTROPHOTOSCOPY OF SPRAY DILUTIONS BOTH IN FLIGHT AND AT REST (SUSPENDED).

(IV)

Table 26 Relative levels of toxicities of propetamphos, etrimfos and fenitrothion to (A) Schistocerca gregaria F. adult and (B) 5th-instar hoppers, applied with a micro-capillary applicator (Fig. 13).

(Ref. Para. 3.3.1)

(A)

No.	Insecticide	Age of locust	Test	Observation time in hours	ED µg/g body weight (in original scale) 50% → ↓	95% C.L. for E.D. lower	95% C.L. for E.D. upper	99% → ↓	95% C.L. for E.D. lower	95% C.L. for E.D. upper
1	Propetamphos (SAN 52 139) W/V 2% a.i. (technical)	15 days	Contact	12	6.4	5.3	7.7	15.7	12.1	23.4
				20	5.7	4.7	6.9	13.9	10.8	20.5
				30	4.6	3.7	5.6	11.2	8.7	16.4
				42	4.2	3.4	5.2	10.4	8.0	15.3
2	Fenitrothion W/V 2% (technical)	15 days	Contact	16	8.6	7.2	11.2	21.7	16.1	35.1
				27	8.1	6.5	10.1	19.7	14.8	31.3
				39	7.0	5.8	8.7	17.2	13.0	26.8
				53	5.8	4.9	7.1	14.3	11.1	21.8
3	Etrimfos (SAN 197 I) W/V 2% (technical)	15 days	Contact	16	59.6	37.0	132.0	297.3	133.7	1710.0
				27	35.8	26.1	63.1	183.5	93.8	821.4
				37	23.7	17.7	34.3	118.1	66.3	428.7
				62	17.3	12.5	23.6	86.1	51.4	267.7
4	Etrimfos (SAN 197 I) W/V 5% E.C.	15 days	Contact	16	49.4	31.9	99.6	275.5	126.2	1554.0
				27	32.0	23.1	53.7	178.2	89.2	855.8
				37	25.4	18.6	38.5	141.5	75.3	585.9
				62	16.2	11.2	22.8	90.5	52.2	301.9
5	Propetamphos (SAN 52 139) W/V 5% E.C.	15 days	Contact	12	6.7	5.5	8.1	18.7	14.3	27.6
				20	5.4	4.4	6.6	15.0	11.6	22.1
				30	4.6	3.6	5.7	12.7	9.6	19.1
				42	4.0	3.1	5.0	11.1	8.4	16.5
6	Fenitrothion W/V 5% (technical)	15 days	Contact	16	9.7	8.0	11.8	24.0	18.7	34.5
				27	8.6	7.0	10.5	21.2	16.6	30.3
				39	7.2	5.9	8.8	17.8	13.8	25.3
				53	6.0	5.0	7.2	14.9	11.8	20.9

(B)

No.	Insecticide	Age of locust	Test	Observation time in hours	ED µg/g body weight (in original scale) 50% → ↓	95% C.L. for E.D. lower	95% C.L. for E.D. upper	99% → ↓	95% C.L. for E.D. lower	95% C.L. for E.D. upper
7	Propetamphos (SAN 52 139) W/V 2% a.i. (technical)	5th instar 5 days	Stomach	12	15.8	11.3	24.1	67.5	39.4	183.3
				20	12.4	9.3	17.7	52.9	32.1	135.9
				30	9.9	7.6	13.5	42.4	26.7	101.6
				42	8.1	6.2	10.7	34.7	22.5	77.7
8	Fenitrothion W/V 2% a.i.	5th instar 5 days	Stomach	16	17.6	12.7	27.2	65.4	38.7	177.6
				27	14.3	10.9	20.8	53.2	32.6	137.0
				39	12.8	9.8	18.0	47.6	29.9	116.7
				53	9.8	7.7	12.9	36.4	23.8	82.9
9	Etrimfos (SAN 197 I) W/V 2% a.i.	5th instar 5 days	Stomach	16	60.9	41.6	102.1	377.5	191.2	1381.0
				27	36.9	26.4	54.2	228.6	126.8	702.1
				37	27.3	19.2	38.8	169.1	98.1	470.8
				62	19.9	13.3	28.2	123.5	74.2	314.0
10	Etrimfos (SAN 197 I) W/V 5% E.C.	5th instar 5 days	Stomach	16	75.7	46.9	145.7	544.1	243.1	2786.0
				27	39.9	28.0	61.7	286.8	146.5	1121.0
				37	27.3	18.5	40.0	195.9	106.4	661.2
				62	19.6	12.5	28.5	140.7	79.8	424.6
11	Propetamphos (SAN 52 139) W/V 5% E.C.	5th instar 5 days	Stomach	12	22.2	14.8	39.6	95.9	50.3	338.4
				20	13.9	10.4	20.8	60.1	34.8	180.5
				30	9.9	7.6	13.6	43.0	26.5	113.3
				42	7.0	5.1	9.2	30.2	19.6	70.5
12	Fenitrothion W/V 5% (technical)	5th instar 5 days	Stomach	16	19.3	13.8	31.7	74.5	42.1	228.0
				27	14.5	10.9	21.3	55.7	33.5	152.3
				39	12.9	9.6	18.4	49.7	30.6	128.9
				53	9.8	7.7	13.1	37.9	24.3	91.0

(IV)

Table 27 Spray droplet deposition of shell-sol AB oil downwind from spray nozzle.

(sprayer: multiple-disc, 8,000 rev/min, 150 ml/min i.e. 10 ml/disc/min, temperature and relative humidity (19°C, 68%) and wind speed, 3 - 5 m/s).

(Ref. Para. 3.3.2)

1	2	3	4	5	6	7	8	9	10	11	12
NO	DESCRIPTIONS	DISTANCE FROM SPRAY NOZZLE IN METERS									
		.25	.50	1	2	4	8	16	32	64	128
1	Total droplets	1008	1355	1521	1859	2535	1183	845	39	7	0
2	droplets /cm²	161	216	243	297	406	189	135	6	1	0
3	VMD	70	80	80	80	80	70	70	69	68	0
4	NMD	65	66	66	66	64	64	63	61	60	0
5	VMD/NMD	1.1	1.2	1.2	1.2	1.3	1.1	1.1	1.1	1.1	0
6	16%	64	62	66	64	59	60	60	58	56	0
7	84%	95	97	94	93	75	78	72	77	76	0
8	VOLUME: VMD (4/3 πr^3) IN μm^3	$18X10^4$	$27X10^4$	$27X10^4$	$27X10^4$	$27X10^4$	$18X10^4$	$18X10^4$	$17X10^4$	$16X10^4$	0
9	TOTAL VOLUME/ CM² (NO.2 X No. 8) IN μm^3	$29X10^6$	$58X10^6$	$66X10^6$	$80X10^6$	$11X10^7$	$34X10^6$	$24X10^6$	$10X10^5$	$16X10^4$	0
10	$\mu l/cm^2$ (NO. $9X10^{-9}$ N.B. $1\mu m^3 = 10^{-9}$ ml	2.9-02	5.8-02	6.6-02	8.-02	0.11	3.4-02	2.4-02	1.-03	1.6-04	0
11	$\mu l/m^2$ (NO. $10X10^4$)	290	580	660	800	1100	340	240	10	1.6	0
12	ml/m^2 (NO.11)/(1000)	0.29	0.58	0.66	0.8	1.1	0.34	0.24	.01	.0016	0

(Figures in No. 8, 9, and 10 were rounded off to the nearest decimal points).

(IV)

Table 28 Comparisons of LD50s (laboratory tests of insecticide toxicities on locusts, Colum 2 - 4) with field spray doses downwind (from multiple-disc nozzle, Column 2 and 5 - 14) for (A) adult and (B) 5th-instar hoppers, <u>Schistocerca</u> <u>gregaria</u> F.

(Ref. Para. 3.3.2)

(A)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
NO	INSECTICIDE	OBSERVATION TIME IN HOURS	LD50 µg/g	DISTANCE FROM SPRAY NOZZLE IN METERS.									
				.25	.50	1	2	4	8	16	32	64	128
				FIELD SPRAY DOSE µg/cm²									
				30	60	69	83	114	35	25	1.04	17	0
1	PROPETAMPHOS W/V 2%	12	6.397	> (4.7)	> (9.4)	> (10.7)	> (12.9)	> (12.8	> (5.5)	> (3.9)	< (0.2)	< (0.03)	0
		20	5.678	> (5.3)	> (10.5)	> (12.2)	> (14.6)	> (20.)	> (6.2)	> (4.4)	< (0.2)	< (0.03)	0
		30	4.582	> (6.5)	> (13.0)	> (15.1)	> (18.1)	> (24.9)	> (7.6)	> (5.5)	< (0.2)	< (0.03)	0
		42	4.231	> (7.1)	> (14.1)	> (16.3)	> (19.6)	> (26.9)	> (8.3)	> (5.9)	< (0.2)	< (0.04)	0
2	FENITROTHION W/V 2%	16	8.837	> (3.4)	> (6.8)	> (7.8)	> (9.4)	> (12.9)	> (4.0)	> (2.8)	< (0.1)	< (0.02)	0
		27	8.050	> (3.7)	> (7.4)	> (8.6)	> (10.3)	> (14.2)	> (4.3)	> (3.1)	< (0.1)	< (0.02)	0
		39	7.013	> (4.3)	> (8.6)	> (9.8)	> (11.8)	> (16.3)	> (4.9)	> (3.6)	< (0.1)	< (0.02)	0
		53	5.847	> (5.1)	> (10.3)	> (11.8)	> (14.2)	> (19.5)	> (5.9)	> (4.3)	< (0.2)	< (0.03)	0
3	ETRIMFOS W/V 2%	16	59.62	< (0.5)	(1.0)	> (1.2)	> (1.4)	> (1.9)	< (0.6)	< (0.4)	< (0.02)	< (0.003)	0
		27	36.79	< (0.8)	> (1.6)	> (1.9)	> (2.3)	> (3.1)	< (1.0)	< (0.8)	< (0.03)	< (0.005)	0
		37	23.69	> (1.3)	> (2.5)	> (2.9)	> (3.5)	> (4.8)	> (1.5)	> (1.1)	< (0.04)	< (0.0[illegible]7)	0
		62	17.27	> (1.7)	> (3.5)	> (4.0)	> (4.8)	> (6.6)	> (2.0)	> (1.4)	< (0.06)	< (0.009)	0

(B)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
NO	INSECTICIDE	OBSERVATION TIME IN HOURS	LD50 µg/g	DISTANCE FROM SPRAY NOZZLE IN METERS.									
				.25	.50	1	2	4	8	16	32	64	128
				FIELD SPRAY DOSE µg/cm²									
				30	60	69	83	114	35	25	1.04	17	0
4	PROPETAMPHOS W/V 2%	12	15.81	> (1.9)	> (3.8)	> (4.3)	> (5.2)	> (7.2)	> (2.2)	> (1.6)	< (0.07)	< (0.01)	0
		20	12.41	> (2.4)	> (4.8)	> (5.6)	> (6.7)	> (9.2)	> (2.8)	> (2.0)	< (0.08)	< (0.01)	0
		30	9.931	> (3.0)	> (6.0)	> (6.9)	> (8.4)	> (11.5)	> (3.5)	> (2.5)	< (0.1)	< (0.01)	0
		42	8.124	> (3.7)	> (7.4)	> (8.5)	> (10.2)	> (14.0)	> (4.3)	> (3.1)	< (0.1)	< (0.02)	0
5	FENITROTHION W/V 2%	16	17.61	> (1.7)	> (3.4)	> (3.9)	> (4.7)	> (6.5)	> (2.0)	> (1.4)	< (0.06)	< (0.01)	0
		27	14.34	> (2.1)	> (4.2)	> (4.8)	> (5.8)	> (7.9)	> (2.4)	> (1.7)	< (0.07)	< (0.01)	0
		39	12.83	> (2.3)	> (4.7)	> (5.4)	> (6.5)	> (8.9)	> (2.7)	> (1.9)	< (0.08)	< (0.01)	0
		53	9.800	> (3.1)	> (6.1)	> (7.0)	> (8.4)	> (11.6)	> (3.6)	> (2.6)	< (0.1)	< (1.7)	0
6	ETRIMFOS W/V 2%	16	60.92	< (0.5)	(0.9)	> (1.1)	> (1.4)	> (1.9)	< (0.6)	< (.4)	< (0.02)	< (0.003)	0
		27	36.89	< (0.8)	> (1.6)	> (1.9)	> (2.2)	> (3.1)	< (0.9)	< (.7)	< (0.03)	< (0.005)	0
		37	27.29	> (1.1)	> (2.5)	> (2.5)	> (3.0)	> (4.2)	> (1.3)	< (0.9)	< (0.04)	< (0.006)	0
		62	19.93	> (1.5)	> (3.0)	> (3.5)	> (4.3)	> (5.7)	> (1.8)	> (1.3)	< (0.05)	< (0.009)	0

e.g. <u>Dose calculation:</u>
30 µg at a distance of 0.25 m =
= µl X density of formulation X 10^3
= .029 (Appendix IV, Table 27 line No. 10) X 10^3
= 30 µg etc.

N. B. Figures in parenthesis show field dosage levels as compared with LD50 (Column 4) obtained in the laboratory with micro-capillary applicator.

(IV)

Table 29 Quantity of spray solution of 1% waxoline red dye in Shellsol-AB oil collected by both adult male and female locusts (Schistocerca gregaria F.) (A - E)

(Ref. Para. 3.3.3)

(A)

CONDITION OF SPRAY	LOCUSTS IN FLIGHT						MEAN (SD)	MEAN (SD)	LOCUSTS AT REST (SUSPENDED)						MEAN (SD)	MEAN (SD)
QUANTITY OF SPRAY	0.29 ml/m²								0.29ml/m²							
SEX	♂	♂	♂	♀	♀	♀	♂	♀	♂	♂	♂	♀	♀	♀	♂	♀
WEIGHT OF LOCUST IN GRAMS	2.16	2.60	2.30	3.80	3.30	3.70	2.35 (.22)	3.6 (.36)	2.17	2.5[illegible]	2.40	3.72	3.51	3.62	2.36 (0.17)	3.62 (0.11)
ABSORBANCE	0.19	0.25	0.19	0.38	0.32	0.38	.21 (.03)	.36 (.03)	0.12	0.19	0.12	0.32	0.25	0.32	.14 (0.04)	0.2[illegible] (0.0[illegible])
% CONCENTRATION	3÷04	4÷04	3÷04	6÷04	5÷04	6÷04	3÷04 (6÷05)	5÷04 (6÷05)	2÷04	3÷04	2÷04	5÷04	4÷04	5÷04	3÷04 (1÷04)	5÷04 (5÷05)
QUANTITY OF SPRAY	0.58 ml/m²								0.58ml/m²							
WEIGHT OF LOCUST IN GRAMS	2.55	2.71	2.38	3.95	3.85	4.0	2.55 (0.17)	3.93 (0.08)	2.60	2.75	2.42	4.0	3.9	3.8	2.59 (0.16)	3.9 (0.1)
ABSORBANCE	0.5	0.5	0.44	0.63	0.60	0.65	0.48 (3.402)	0.62 (2.5-02)	0.25	0.26	0.23	0.5	0.5	0.5	0.25 (1.5-02)	0.5 (0)
% CONCENTRATION	8÷04	8÷04	7÷04	1÷03	1÷03	1÷03	8÷04 (6÷05)	1÷03 (0)	5÷04	5÷04	5÷04	8÷04	8÷04	8÷04	5÷04 (0)	8÷04 (0)

(B)

CONDITION OF SPRAY	LOCUSTS IN FLIGHT						MEAN (SD)	MEAN (SD)	LOCUSTS AT REST (SUSPENDED)						MEAN (SD)	MEAN (SD)
QUANTITY OF SPRAY	0.66 ml/m²								0.66 ml/m²							
SEX	♂	♂	♂	♀	♀	♀	♂	♀	♂	♂	♂	♀	♀	♀	♂	♀
WEIGHT OF LOCUST IN GRAMS	2.15	2.30	2.52	3.72	3.82	3.89	2.32 (0.19)	3.81 (0.09)	2.25	2.16	2.40	3.80	3.82	3.84	2.27 (0.12)	3.82 (0.02)
ABSORBANCE	0.5	0.5	0.6	0.63	0.63	0.63	0.53 (0.06)	0.63 (0)	0.25	0.26	0.27	0.5	0.5	0.5	0.26 (1÷02)	0.5 (0)
% CONCENTRATION	8÷04	8÷04	9÷04	1÷03	1÷03	1÷03	8÷04 (6÷05)	1÷03 (0)	5÷04	5÷04	6÷04	8÷04	8÷04	8÷04	5÷04 (6÷05)	8÷04 (0)
QUANTITY OF SPRAY	0.8 ml/m²								0.8 ml/m²							
WEIGHT OF LOCUST IN GRAMS	2.50	2.60	2.55	3.92	3.96	3.50	2.55 (0.63)	3.79 (0.25)	2.41	2.50	2.62	3.70	3.15	3.30	2.51 (0.11)	3.38 (0.28)
ABSORBANCE	0.63	0.63	0.63	1.3	1.3	1.3	0.63 (0)	1.3 (0)	0.38	0.38	0.38	0.95	0.95	0.95	.38 (0)	0.95 (0)
% CONCENTRATION	1÷03	1÷03	1÷03	2÷03	2÷03	2÷03	1.03 (0)	2÷03 (0)	6÷04	6÷04	6÷04	[illegible].5÷03	1.5÷0[illegible]	1.5÷0[illegible]	6÷04 (0)	1.5-03 (0)

cont.

(IV)

Table 29 Quantity of spray solution of 1% waxoline red dye in Shellsol-AB oil collected by both adult male and female locusts (*Schistocerca gregaria* F.) (A - E)

(C)

(REf. Para. 3.3.3)

CONDITION OF SPRAY	LOCUSTS IN FLIGHT						MEAN (SD)	MEAN (SD)	LOCUSTS AT REST (SUSPENDED)						MEAN (SD)	MEAN (SD)
QUANTITY OF SPRAY	1.1ml/m²								1.1ml/m²							
SEX	♂	♂	♂	♀	♀	♀	♂	♀	♂	♂	♂	♀	♀	♀	♂	♀
WEIGHT OF LOCUST IN GRAMS	2.40	2.50	2.50	3.72	4.0	3.81	2.46 (0.06)	3.84 (0.14)	2.30	2.47	2.52	3.70	3.86	3.72	2.41 (0.11)	3.76 (.08.7
ABSORBANCE	0.63	0.63	0.63	1.26	1.26	1.26	0.63 (0)	1.26 (0)	0.44	0.-3	0.63	0.95	0.95	0.95	0.56 (01)	.95 (0)
% CONCENTRATION	1-03	1-03	1-03	2-03	2-03	2-03	1-03 (0)	2-03 (0)	7-04	1-03	1-03	1.5-03	.5-03	.5-03	9-04 (1.7-04)	.5-03 (0)
QUANTITY OF SPRAY	0.34ml/m²								0.34ml/m²							
WEIGHT OF LOCUST IN GRAMS	2.21	2.30	2.50	3.76	3.60	3.55	2.35 (.18)	3.64 (0.11)	2.40	2.50	2.52	3.81	3.74	3.65	2.47 (0.06)	3.73 (0.06)
ABSORBANCE	0.25	0.25	0.25	0.38	0.38	0.38	.25 (0)	0.38 (0)	0.19	0.19	0.19	0.32	0.32	0.32	0.19 (0)	0.32 (0)
% CONCENTRATION	4-04	4-04	4-04	6-04	6-04	6-04	4-04 (0)	6-04 (0)	3-04	3-04	3-04	5-04	5-04	5-04	3-04 (0)	5-04 (0)

(D)

CONDITION OF SPRAY	LOCUSTS IN FLIGHT						MEAN (SD)	MEAN (SD)	LOCUSTS AT REST (SUSPENDED)						MEAN (SD)	MEAN (SD)
QUANTITY OF SPRAY	0.24ml/m²								0.24ml/m²							
SEX	♂	♂	♂	♀	♀	♀	♂	♀	♂	♂	♂	♀	♀	♀	♂	♀
WEIGHT OF LOCUST IN GRAMS	2.72	2.80	2.60	4.0	3.98	3.72	2.71 (0.1)	3.9 (0.16)	2.60	2.30	2.41	4-03	3-86	3-76	2.44 (0.15)	3.88 (0.14)
ABSORBANCE	0.25	0.25	0.19	0.31	0.31	0.31	0.23 (0.03)	0.31 (0)	0.19	0.19	0.13	0.25	0.25	0.25	0.17 (0.03)	0.25 (0)
% CONCENTRATION	4-04	4-04	3-04	5-04	5-04	5-04	4-04 (6-05)	5-04 (0)	3-04	3-04	2-04	4-04	4-04	4-04	3-04 (6-05)	4-04 (0)
QUANTITY OF SPRAY	.01ml/m²								.01ml/m²							
WEIGHT OF LOCUST IN GRAMS	2.71	2.50	2.60	3.69	3.57	3.86	2.60 0.1	3.71 0.15	2.60	2.15	2.75	3.96	3.60	3.76	2.5 0.31	3.77 0.18
ABSORBANCE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% CONCENTRATION	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(E)

CONDITION OF SPRAY	LOCUSTS IN FLIGHT						MEAN SD	MEAN SD	LOCUSTS AT REST (SUSPENDED)						MEAN SD	MEAN SD
QUANTITY OF SPRAY	0.0016ml/m²								0.0016ml/m²							
SEX	♂	♂	♂	♀	♀	♀	♂	♀	♂	♂	♂	♀	♀	♀	♂	♀
WEIGHT OF LOCUST IN GRAMS	2.75	2.60	2.5	4.0	4.05	3.96	2.62 0.13	4 0.05	2.50	2.60	2.71	3.76	3.82	3.72	2.60 .11	3.77 0.05
ABSORBANCE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% CONCENTRATION	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 30 Friedman's[1] two-way analysis of variance by ranks of (Table 10, Para. 3.3.3) results of spectroscopy i.e. percentage of spray dilutions washed off from male and female locusts (S. gregaria F.) in flight and at rest.

(Ref. Para. 3.3.3 & Appendix IV, Table, 29)

NO.	DISTANCE FROM SPRAY NOZZLE (m)	SPRAY APPLICATION ml/m² (REPLICATE)	♂ IN FLIGHT	♂ AT REST (SUSPENDED)	♀ IN FLIGHT (	♀ AT REST (SUSPENDED)
1	.25	.29	.11 (2)	.10 (1)	.17 (3½)	.17 (3½)
2	.50	.58	.14 (2½)	.09 (1)	.17 (4)	.14 (2½)
3	1	.66	.12 (2½)	.08 (1)	.15 (4)	.12 (2½)
4	2	.8	.13 (2)	.075 (1)	.25 (4)	.19 (3)
5	4	1.1	.09 (2)	.087 (1)	.18 (4)	.14 (3)
6	8	.34	.12 (2)	.088 (1)	.18 (4)	.15 (3).
7	16	.24	.17 (2)	.17 (2)	.20 (4)	.17 (2)
–	–	–	(FIGURES IN PARENTHESIS ARE ROW RANKS).			
		Σ ranks	15	8	27½	19.5
		(Σr)²	225	64	756.25	380.25

1ST. STEP

NULL HYPOTHESIS IS THAT THERE IS NO DIFFERENCE BETWEEN THE COLUMNS.

$\Sigma(\Sigma r)^2 \quad 1425.5$

$$X^2 = \left(\frac{12}{NK(K+1)} \Sigma(\Sigma r^2)\right) - 3N(K+1)$$

N IS NO. OF ROWS = 7

K IS NO. OF COLUMNS = 4

12 IS A CONSTANT

$$Xr^2 = \left(\frac{12}{7\times 4\ (5)} \times 1425.5\right) - 3 \times 7\ (5)$$

$$Xr^2 = 122.186 - 105$$

$$Xr^2 = 17.186$$

$P<0.001 \quad \alpha \to 0$

VERY SIGNIFICANT ∴ REJECT NULL HYPOTHESIS

2ND. STEP

♂ IN FLIGHT	♂ AT REST	DIFFERENCES	RANKS
.11	.10	0.01	2
.14	.09	0.05	5
.12	.08	0.04	4
.13	.075	0.055	6
.09	.087	0.003	1
.12	.088	0.032	3
.17	.017	0.153	7

T = 0

P<0.01

♀ IN FLIGHT	♀ AT REST	DIFFERENCE	RANKS
.17	.17	0	1
.17	.14	0.03	2.25
.15	.12	0.03	2.25
.25	.19	0.06	7
.18	.14	0.04	6
.18	.15	0.03	2.25
.20	.17	0.03	2.25

T = 0

P<0.01

(N. B. spray dilutions used = waxoline red dye)

(1) Sidney Siegel, 1956)

Appendix

CONTROL OF POWDERY MILDEW (*Erysiphe* *graminis* DC)

(V)

Fig. 9 Inoculation chamber for powdery mildew (Erysiphe graminis DC)

(Ref. Para. 2.8.3.1)

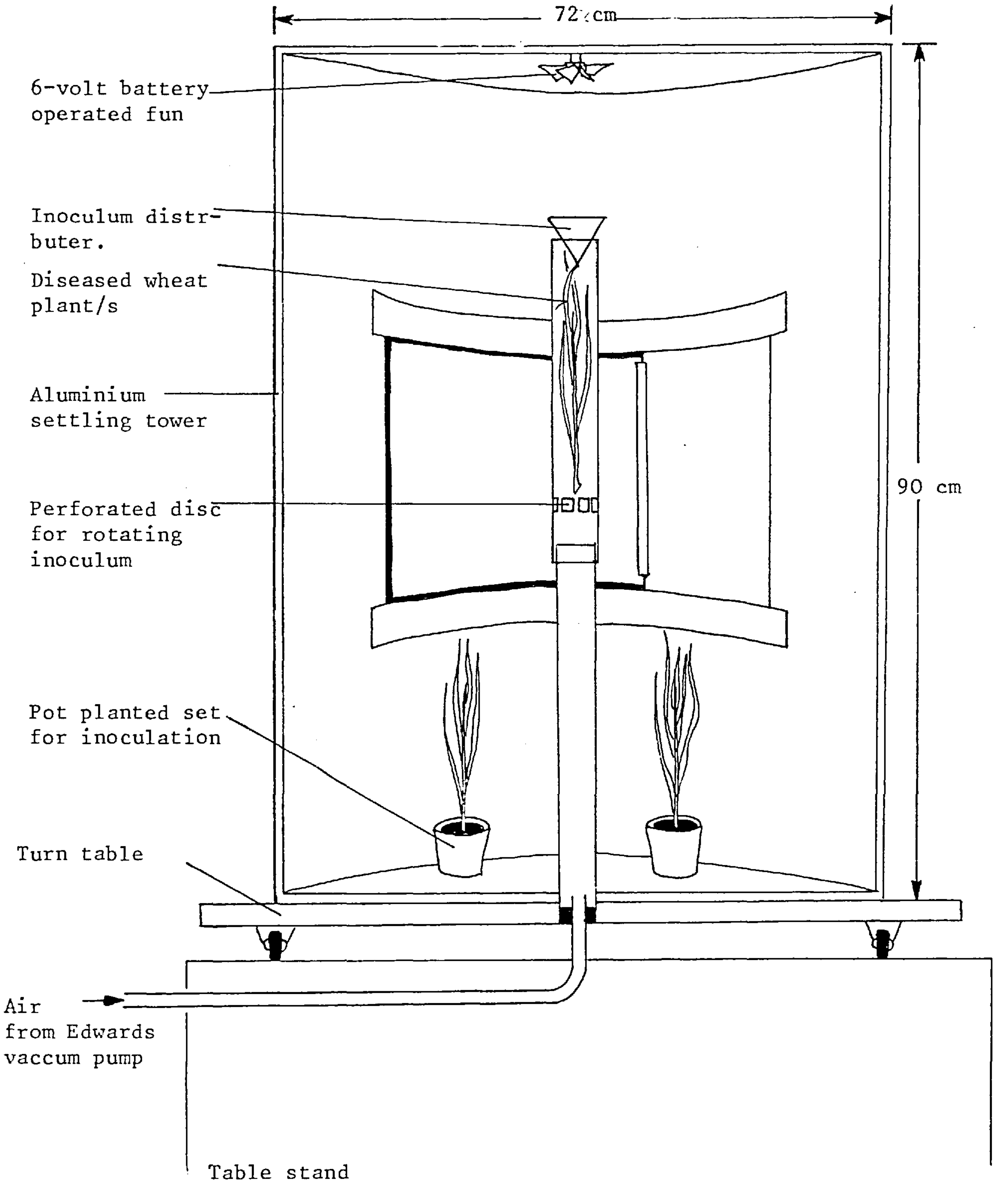
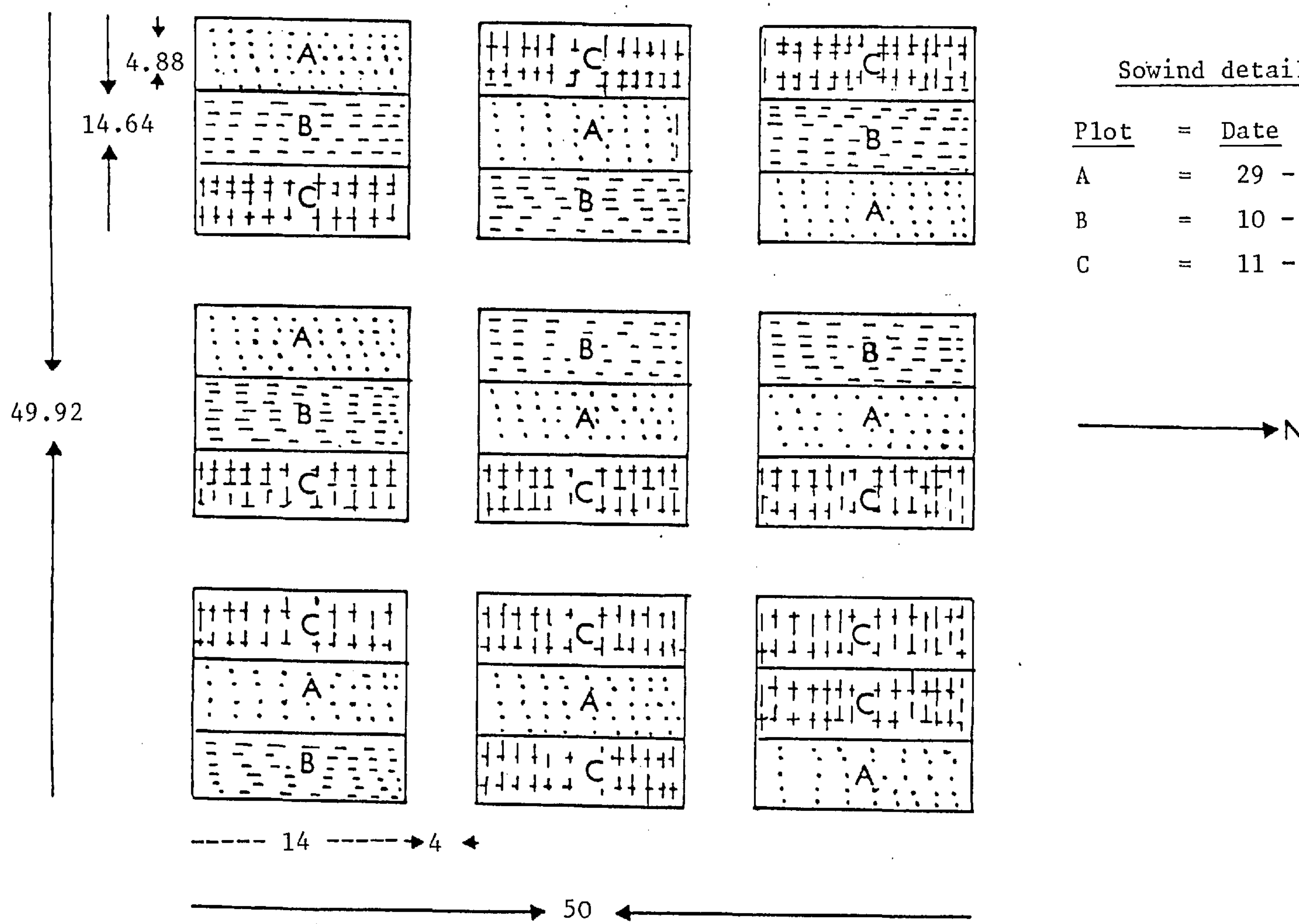


Fig. 10 Randomised field plots

(Ref. Para. 2.8.3.2)



Sowind details:

Plot	=	Date
A	=	29 - 9 - 77
B	=	10 - 3 - 78
C	=	11 - 5 - 78

(Distances are in meters)

(V)

Table 31 Summary of experimental results of relative yields of pot planted wheat cultivar Maris Kinsman treated against powdery mildew (<u>Erysiphe graminis</u> DC) with triadimefon fungicide and other methods.

(Ref. Para. 3.4.1)

	RANDOMISED - TREATMENTS			
	(A_1 - A_4) CDA M% = 13	(B_1 - B_4) DS M% = 0	(C_1 - C_4) CON M% = 33	(D_1 - D_4) HV M% = 9
I	3.3	3.8	3.0	3.2
	3.4	4.0	2.9	3.5
	3.6	4.5	3.0	3.6
	3.5	3.3	2.9	3.3
	ε = 13.8	ε = 15.6	ε = 11.8	ε = 13.6
	$\bar{x}$ = 3.5	$\bar{x}$ = 3.9	$\bar{x}$ = 2.95	$\bar{x}$ = 3.4
	CDA M% = 11	CDA M% = 10	CON M% = 35	DS M% = 0
II	3.2	3.5	3.0	3.9
	3.4	3.7	2.9	3.5
	3.5	3.8	2.6	3.9
	3.3	3.4	2.7	3.5
	ε = 13.4	ε = 14.4	ε = 11.2	ε = 14.8
	$\bar{x}$ = 3.1	$\bar{x}$ = 3.6	$\bar{x}$ = 2.8	$\bar{x}$ = 3.7
	CDA M% = 10	CDA M% = 10	HV M% = 11	DS M% = 0
III	3.6	3.6	3.5	4.0
	3.7	3.3	3.3	3.4
	3.1	3.5	3.2	4.0
	3.6	3.7	3.5	3.4
	ε = 14.0	ε = 14.1	ε = 13.5	ε = 14.8
	$\bar{x}$ = 3.5	$\bar{x}$ = 3.5	$\bar{x}$ = 3.4	ε = 3.7
	CDA M% = 9	HV M% = 11	CON M% = 37	DS M% = 0
IV	3.5	3.4	2.9	3.9
	3.4	3.3	2.8	3.4
	3.3	3.3	3.0	4.0
	3.5	3.2	2.6	4.1
	ε = 13.7	ε = 13.2	ε = 11.3	ε = 15.4
	$\bar{x}$ = 3.4	$\bar{x}$ = 3.3	$\bar{x}$ = 2.8	$\bar{x}$ = 3.9

(Yields are in grammes per pot)

(For treatment abbreviations, refer to page 17)

(V)

Table 32 Relative yields of pot planted wheat cultivar Maris Kinsman sprayed with triadimefon fungicide and other methods against powdery mildew of cereals (*Erysiphe graminis* DC).

Group I (Ref. Para. 3.4.1)

1	2	3	4	5	6	7	8	9
TREATMENT	REPLICATE	% MILDEW ERYSIPHEGRAMINIS	AVERAGE STEM LENGTH IN CM. (FOUR PLANTS/POT)	AVERAGE EAR LENGTH IN CM.	AVERAGE NO. OF SEEDS PER EAR	YIELDS PER POT** IN GRAMS	YIELDS PER POT IN KGS = (COL.7 / 10^3GRAMS*)	CALCULATED YIELD/ ha IN KGS = (ha (10^4m^2 x COL.7.) / .011m^2 (AREA OF POT) / 10^3 GRAMS *
CDA	A1	13	52.1	5	18	3.3	3.3-03	3000
	A2	15	51.4	5	18	3.4	3.4-03	3090
	A3	12	53.2	5.5	20	3.6	3.6-03	3272
	A4	12	53.1	5.8	21	3.5	3.5-03	3182
	ε	52	209.8	21.3	77	13.8	1.38-02	12544
	$\bar{x}$	13	52.5	5.3	19	3.5	3.45-03	3136
DS	B1	0	59.4	7.0	26	3.8	3.8-03	3455
	B2	0	60.6	7.5	28	4.0	4.0-03	3636
	B3	0	61.5	8.2	31	4.5	4.5-03	4091
	B4	0	58.6	6.1	22	3.3	3.3-03	3000
	ε	-	240.1	28.8	107	15.6	1.56-02	14182
	$\bar{x}$	-	60.0	7.2	27	3.9	3.9-03	3546
CON	C1	35	39.2	4.1	15	3.0	3.0-03	2727
	C2	29	43.4	3.6	13	2.9	2.9-03	2636
	C3	41	35.3	4.1	15	3.0	3.0-03	2727
	C4	26	44.5	3.5	13	2.9	2.9-03	2636
	ε	131	162.4	15.3	56	11.8	1.19-02	10726
	$\bar{x}$	33	40.6	3.8	14	2.95	2.97-03	2682
HV	D1	10	54.1	5.4	20	3.2	3.2-03	2909
	D2	9	55.0	5.8	21	3.5	3.5-03	3182
	D3	5	57.0	6.0	22	3.6	3.6-03	3272
	D4	11	53.8	5.5	20	3.3	3.3-03	3000
	ε	35	219.9	22.7	83	13.6	1.36-02	12363
	$\bar{x}$	9	55.0	5.7	21	3.4	3.4-03	3091

** POT AREA = 113.97 cm^2 = 0.011m^2
* 1kg = 1000 GRAMS

(For treatment abbreviations, refer to page 17)

(V)

Table 33 Relative yields of pot planted wheat cultivar Maris Kinsman sprayed with triadimefon fungicide and other methods against powdery mildew of cereals (Erysiphe graminis DC). (Ref. Para. 3.4.1)

Group II

1 TREATMENT	2 REPLICATE	3 % MILDEW ERYSIPHEGRAMINIS	4 AVERAGE STEM LENGTH IN CM. (FOUR PLANTS/POT)	5 AVERAGE EAR LENGTH IN CM.	6 AVERAGE NO. OF SEEDS PER EAR	7 YIELDS PER POT** IN GRAMS	8 YIELDS PER POT IN KGS = (COL.7 / 10^3 GRAMS*)	9 CALCULATED YIELD/ ha IN KGS = (ha ($10^4 m^2$ x COL.7.) / .011m^2 (AREA OF POT) / 10^3 GRAMS *)
CDA	A1	13	52.7	4.9	18	3.2	3.2-03	2909
	A2	8	55.6	5.2	19	3.4	3.4-03	3091
	A3	12	33.1	5.4	20	3.5	3.5-03	3182
	A4	10	54.0	5.1	19	3.3	3.3-03	3000
	Σ	43	195.4	20.6	76	13.4	1.34-02	12182
	$\bar{x}$	11	48.9	5.1	19	3.1	3.35-03	3046
CDA	B1	10	54.4	5.8	21	3.5	3.5-03	3182
	B2	9	55.2	5.7	21	3.7	5.7-03	3364
	B3	12	55.2	5.9	22	3.8	3.8-03	3455
	B4	10	54.5	5.6	21	3.4	3.4-03	3091
	Σ	41	219.3	23	85	14.4	1.44-02	13092
	$\bar{x}$	10	54.8	5.8	21	3.6	3.6-03	3273
CON	C1	26	44.4	4.3	16	3.0	3.0-03	2727
	C2	36	38.4	4.1	15	2.9	2.9-03	2636
	C3	39	36.6	3.7	13	2.6	2.6-03	2364
	C4	38	37.3	3.9	14	2.7	2.7-03	2455
	Σ	139	159.7	16.0	58	11.2	1.12-03	10182
	$\bar{x}$	35	39	4.0	15	2.8	2.8-03	2546
DS	D1	0	62.5	7.3	25	3.9	3.9-03	3545
	D2	0	63.4	6.5	24	3.5	3.5-03	3182
	D3	0	60.0	7.1	26	3.9	3.9-03	3545
	D4	0	61.3	6.5	23	3.5	3.5-03	3182
	Σ	-	247.4	27.4	98	14.8	1.47-02	13454
	$\bar{x}$	-	61.9	6.9	25	3.7	3.7-03	3364

** POT AREA = 113.97 cm^2 = 0.011m^2.
* 1kg = 1000 GRAMS

(For treatment abbreviations, refer to page 17)

(V)

Table 34 Relative yields of pot planted wheat cultivar Maris Kinsman sprayed with triadimefon fungicide and other methods against powdery mildew of cereals (*Erysiphe graminis* DC).

(Ref. Para. 3.4.1)

Group III

1	2	3	4	5	6	7	8	9
TREATMENT	REPLICATE	% MILDEW ERYSIPHEGRAMINIS	AVERAGE STEM LENGTH IN CM. (FOUR PLANTS/POT)	AVERAGE EAR LENGTH IN CM.	AVERAGE NO. OF SEEDS PER EAR	YIELDS PER POT** IN GRAMS	YIELDS PER POT IN KGS = (COL.7 / 10^3GRAMS*)	CALCULATED YIELD/ ha IN KGS = (ha (10^4m^2 x COL.7.) / .011m^2 (AREA OF POT)) / 10^3 GRAMS *
CDA	A1	8	55.2	6.0	22	3.6	3.6-03	3273
	A2	12	52.8	6.2	23	3.7	3.7-03	3364
	A3	9	51.0	5.2	19	3.1	3.1-03	2818
	A4	12	53.0	6.1	22	3.6	3.6-03	3273
	ε	41	212.0	23.5	86	14	1.4-03	12728
	$\bar{x}$	10	53.0	5.9	22	3.5	3.5-03	3182
CDA	B1	10	55.1	5.8	21	3.6	3.6-03	3273
	B2	13	52.4	5.5	20	3.3	3.3-03	3000
	B3	9	54.5	5.8	21	3.5	3.5-03	3182
	B4	9	54.6	5.9	22	3.7	3.7-03	3364
	ε	41	216.6	23	84	14.1	1.41-02	12819
	$\bar{x}$	10	54.0	5.8	21	3.5	3.5-03	3205
HV	C1	7	55.9	5.9	22	3.5	3.5-03	3182
	C2	12	52.8	5.6	21	3.3	3.3-03	3000
	C3	12	53.5	5.3	19	3.2	3.2-03	2909
	C4	11	52.8	5.9	21	3.5	3.5-03	3182
	ε	42	215	22.7	83	13.5	1.35-03	12273
	$\bar{x}$	11	54.0	5.7	21	3.4	3.4-03	3068
DS	D1	0	62.3	7.5	29	4.0	4.0-03	3636
	D2	0	63.1	6.1	21	3.4	3.9-03	3091
	D3	0	61.0	7.4	27	4.0	4.0-03	3636
	D4	0	59.2	6.3	22	3.4	3.4-03	3091
	ε	-	245.6	27.3	99	14.8	1.53-02	13454
	$\bar{x}$	-	61.4	6.8	25	3.7	3.83-03	3364

** POT AREA = 113.97 cm^2 = 0.011m^2

* 1kg = 1000 GRAMS

(For treatment abbreviations, refer to page 17)

(V)

Table 35 Relative yields of pot planted wheat cultivar Maris Kinsman sprayed with triadimefon fungicide and other methods against powdery mildew of cereals (Erysiphe graminis DC).

Group IV (Ref. Para. 3.4.1)

1 TREATMENT	2 REPLICATE	3 % MILDEW ERYSIPHEGRAMINIS	4 AVERAGE STEM LENGTH IN CM. (FOUR PLANTS/POT)	5 AVERAGE EAR LENGTH IN CM.	6 AVERAGE NO. OF SEEDS PER EAR	7 YIELDS PER POT** IN GRAMS	8 YIELDS PER POT IN KGS = (COL.7)/(10^3GRAMS*)	9 CALCULATED YIELD/ha IN KGS = (ha (10^4m^2 x COL.7.)/(.011m^2 (AREA OF POT) 10^3 GRAMS *)
CDA	A1	9	55.0	5.8	21	3.5	3.5-03	3182
	A2	10	54.2	5.7	21	3.4	3.4-03	3091
	A3	10	54.3	5.6	20	3.3	3.3-03	3000
	A4	8	55.1	5.9	21	3.5	3.5-03	3182
	Σ	37	218.6	23	83	13.7	1.37-02	12455
	$\bar{x}$	9	55.0	5.8	21	3.4	3.4-03	3114
HV	B1	10	54.0	5.7	20	3.4	3.4-03	3091
	B2	13	52.2	5.5	20	3.3	3.3-03	3000
	B3	10	53.8	5.6	21	3.3	3.3-03	3006
	B4	9	54.9	5.3	19	3.2	3.2-03	2909
	Σ	42	214.9	22.1	80	13.2	1.32-02	12000
	$\bar{x}$	11	53.7	5.5	20	3.3	3.3-03	3000
CON	C1	35	39.0	4.1	15	2.9	2.9-03	2636
	C2	35	39.4	4.0	15	2.8	2.8-03	2545
	C3	29	42.7	4.5	16	3.0	3.0-03	2727
	C4	48	31.2	3.3	12	2.6	2.6-03	2364
	Σ	147	152.3	15.9	58	11.3	1.13-03	10272
	$\bar{x}$	37	38.1	4.0	15	2.8	2.8-03	2568
DS	D1	0	59.2	7.2	26	3.9	3.9-03	3545
	D2	0	57.5	6.3	23	3.4	3.4-03	3091
	D3	0	60.2	7.5	27	4.0	4.0-03	3636
	D4	0	62.3	7.6	28	4.1	4.1-03	3727
	Σ	-	239.2	28.6	104	15.4	1.54-03	13999
	$\bar{x}$	-	59.8	7.2	26	3.9	3.9-03	3500

** POT AREA = 113.97 cm^2 = 0.011m^2

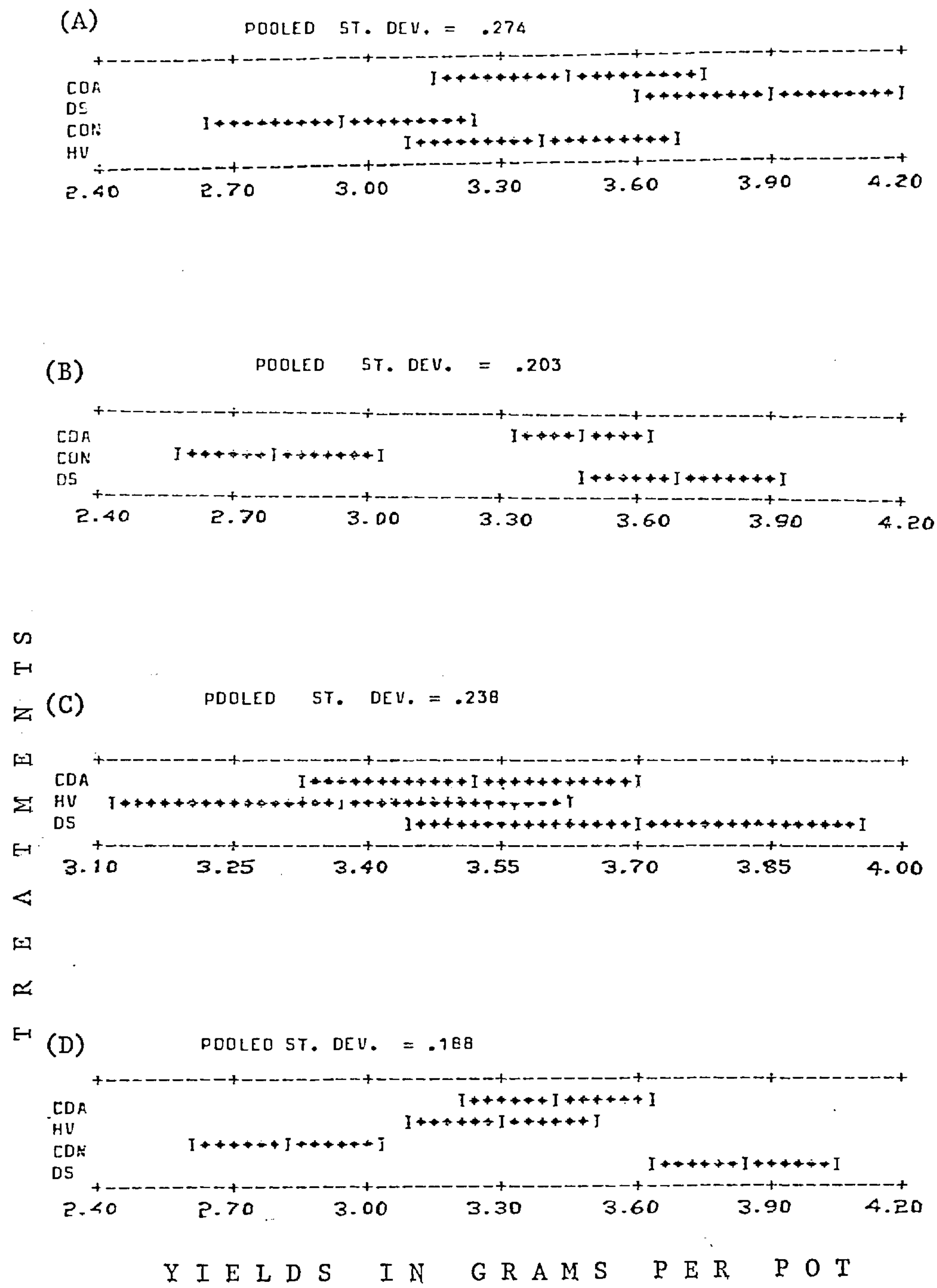
* 1kg = 1000 GRAMS

(For treatment abbreviations, refer to page 17)

(V)

Fig. 11 Histograrams of individual 95% confidence interval for level means of yields of four randomised pot planted wheat cultivar Maris Kinsman based on Pooled Standard Deviation of (A to D) i.e of four separately randomised treatments.

(Ref. Para. 3.4.1)



(V)

Table 36 One-way analysis of variance employing a Minitab computer of 64 pot planted wheat cultivar Maris Kinsman pooled according to treatment.

(Ref. Para. 3.4.1)

COLUMN	DS	CDA	HV	CON
COUNT	16	24	12	12
ROW				
1	3.80000	3.30000	3.20000	3.00000
2	4.00000	3.40000	3.50000	2.90000
3	4.50000	3.60000	3.60000	3.00000
4	3.30000	3.50000	3.30000	2.90000
5	3.90000	3.20000	3.50000	3.00000
6	3.50000	3.40000	3.30000	2.90000
7	3.90000	3.50000	3.20000	2.60000
8	3.50000	3.30000	3.50000	2.70000
9	4.00000	3.50000	3.40000	2.90000
10	3.40000	3.70000	3.30000	2.80000
11	4.00000	3.80000	3.30000	3.00000
12	3.40000	3.40000	3.20000	2.60000
13	3.90000	3.60000		
14	3.40000	3.70000		
15	4.00000	3.10000		
16	4.10000	3.60000		
17		3.60000		
18		3.30000		
19		3.50000		
20		3.70000		
21		3.50000		
22		3.40000		
23		3.30000		
24		3.50000		

? AOVO DS CDA HV CON

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	3	6.0635	2.0212	42.99
ERROR	60	2.8208	.0470	
TOTAL	63	8.8844		

LEVEL	N	MEAN	ST. DEV.
DS	16	3.788	.334
CDA	24	3.475	.173
HV	12	3.358	.138
CON	12	2.858	.151

POOLED ST. DEV. = .217

```
INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
       +---------+---------+---------+---------+---------+---------+
DS                                             I***I****I
CDA                                   I***I***I
HV                              I****I****I
CON     I****I****I
       +---------+---------+---------+---------+---------+---------+
      2.70      2.95      3.20      3.45      3.70      3.95      4.20
```

Y I L D S I N G R A M S P E R P O T

(V)

Table 37 T-test for comparisons of yield differences between any two treatments of pot planted wheat cultivar Maris Kinsman.

(Ref. Para. 3.4.1)

(A)

```
TWOS CDA HV
CDA        N = 24     MEAN =     3.4750     ST.DEV. =     .173
HV         N = 12     MEAN =     3.3583     ST.DEV. =     .138
  APPROX. DEGREES OF FREEDOM =  27

  A 95.00  PERCENT C.I. FOR MU1-MU2 IS (     .0076,      .2258)

  TEST OF MU1 = MU2 VS. MU1 N.E. MU2
 T =  2.195
 THE TEST IS SIGNIFICANT AT   .0370
```

(B)

```
TWOS DS CDA
DS         N = 16     MEAN =     3.7875     ST.DEV. =     .334
CDA        N = 24     MEAN =     3.4750     ST.DEV. =     .173
  APPROX. DEGREES OF FREEDOM =  20

  A 95.00  PERCENT C.I. FOR MU1-MU2 IS (     .1232,      .5018)

  TEST OF MU1 = MU2 VS. MU1 N.E. MU2
 T =  3.445
 THE TEST IS SIGNIFICANT AT   .0026
```

(C)

```
TWOS DS CON
DS         N = 16     MEAN =     3.7875     ST.DEV. =     .334
CON        N = 12     MEAN =     3.3583     ST.DEV. =     .138
  APPROX. DEGREES OF FREEDOM =  21

  A 95.00  PERCENT C.I. FOR MU1-MU2 IS (     .2366,      .6218)

  TEST OF MU1 = MU2 VS. MU1 N.E. MU2
 T =  4.635
 THE TEST IS SIGNIFICANT AT   .0000
```

(V)

Table 38 A Bimodal (BMD07V) multiple range test arrangement for analysis of yields per pot of wheat cultivar Maris Kinsman.

(Ref. Para. 3.4.2)

```
JOB(UMBZS13,J1)
PASSWOR(ANALSPG)
NETFILE(INPUT,RUN=ULCC,OUT=ICCC/SW)

  7/8/9 - END OF SECTION

JOB(UMBZS13,J3)
ATTACH(BMD07V,BMD07V,ID=PUBLIC)
BMD07V.

  7/8/9 - END OF SECTION

PROBLMGROUP1   40   40   0                                        NO    1
SAMSIZ       4     4     4     4
LABELS     1 CDA       2 ST        3 CON       4 HV
(4F5.0)
  3.3   3.4   3.6   3.5
  3.8   4.0   4.5   3.3
  3.0   2.9   3.0   2.9
  3.2   3.5   3.6   3.3
RANGES
PROBLMGROUP2   30   30   0                                        NO    1
SAMSIZ       8     4     4
LABELS     1 CAD       2 CON       3 ST
(4F5.0)
  3.2   3.4   3.5   3.3
  3.5   3.7   3.8   3.4
  3.0   2.9   2.6   2.7
  3.9   3.5   3.9   3.5
RANGES
PROBLMGROUP3   30   30   0                                        NO    1
SAMSIZ       8     4     4
LABELS     1 CDA       2 HV        3 ST
(4F5.0)
  3.6   3.7   3.1   3.6
  3.6   3.3   3.5   3.7
  3.5   3.3   3.2   3.5
  4.0   3.4   4.0   3.4
RANGES
PROBLMGROUP4   40   40   0                                        NO    1
SAMSIZ       4     4     4     4
LABELS     1 CDA       2 HV        3 CON       4 ST
(4F5.0)
  3.5   3.4   3.3   3.5
  3.4   3.3   3.3   3.2
  2.9   2.8   3.0   2.6
  3.9   3.1   4.0   4.1
RANGES
FINISH

  6/7/8/9 - END OF INFORMATION
```

(The figures with decimal points in four groups of 16 each are yields per pot in grammes).

(VI)

Appendix

COMPUTER PROGRAMME FOR DROPLET ANALYSIS.

A computer programme and an example of steps of droplet analysis.

```
JOB(UNBZS13,J3)
FNF(L=2,R=0,T)
LGO.


  7/8/9 - END OF SECTION


      PROGRAM DROPS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      DIMENSION N(20),SP(20),SP3(20),P(20),P3(20),CLASS(21),D(20),ND(20)
     1,ND3(20) ,TITLE(10),VOL(20)   ,CLAS(20)
      REAL ND,ND3
      READ(5,99) NTESTS
   99 FORMAT(I2)
      DO 999 NTEST=1,NTESTS
C
C     NFLAG = 1 TO READ IN CLASS VALUES..
C           = 2 TO CALCULATE CLASS VALUES AS XMAX X SPREAD   WHERE...
C      SPREAD IS  THE FRACTION OF DROP SIZE RELATIVE TO THE CRATER...
C     XMAX    = LARGEST CLASS VALUE..
C     NCLASS = THE NUMBER OF CLASSES MAXIMUM 21...
C
      READ(5,110) TITLE
  110 FORMAT(10A8)
      READ(5,100)NFLAG,NCLASS
  100 FORMAT(I1,I2)
      N1=NCLASS-1
      GO TO (1,2),NFLAG
    1 READ(5,101)SPREAD,(CLASS(I),I=1,NCLASS)
  101 FORMAT(13F6.0)
      GO TO 3
    2 READ(5,101)XMAX,SPREAD
      CONST=1./SQRT(2.0)
      CLASS(NCLASS)=XMAX
C
C    DERIVE CLASS VALUES...
C
      DO 4 I=1,N1
      J=NCLASS-I
    4 CLASS(J)=CLASS(J+1)*CONST
C
C     CALCULATE TRUE DIAMETER AS MEAN OF TWO CLASS VALUES X SPREAD...
C
    3 SUMN=0.
      SUMD3=0.
      READ(5,103)(N(I),I=1,N1)
  103 FORMAT(20I4)
      DO 15 I=1,NCLASS
   15 CLAS(I)=CLASS(I)*SPREAD
      DO 5 I=1,N1
      D(I)=(CLAS(I)+CLAS(I+1))*0.5
      VOL(I)=D(I)**3.
      ND3(I)=N(I)*VOL(I)
      SUMN=SUMN+N(I)
    5 SUMD3=SUMD3+ND3(I)
      PC=100./SUMN
      PC3=100./SUMD3
C
C     CALCULATE PERCENTAGE OF EACH COUNT AND VOLUME..
C
C     NOTE... P IS FOR PERCENT..
      DO 6 J=1,N1
```

cont... (VI)

A computer programme and an example of steps of droplet analysis.

```
      P(J)=PC*N(J)
    6 P3(J)=PC3*ND3(J)
      SP(1)=P(1)
      SP3(1)=P3(1)
      DO 8 I=2,N1
      SP(I)=SP(I-1)+P(I)
    8 SP3(I)=SP3(I-1)+P3(I)
C
C     OUTPUT OF RESULTS UNDER COLUMN HEADINGS...
C
      WRITE(6,108)NTEST
  108 FORMAT(1H1,50X,*ANALYSIS OF DATA SET *,I5//)
      WRITE(6,109)TITLE
  109 FORMAT(1H0,20X,10A8)
      WRITE(6,111)SPREAD
  111 FORMAT(1H0,* SPREAD FACTOR = *,F10.4//)
      WRITE(6,104)
  104 FORMAT(/////,16X,*TRUE*,4X,*MEAN TRUE*)
  105 FORMAT(4X,*CLASS*,11X,*D*,9X,*D*,11X,*N*,7X,*P N*,2X,*SUM P N*,5X,
     1*VOL*,7X,*N X VOLUME*,2X,*P N X VOL*,5X,*SUM P N X VOL*/)
  107 FORMAT(22X, F11.2,I11,2F7.2,2F13.2,F9.2,F14.2)
      WRITE(6,105)
      DO 7 I=1,N1
      WRITE(6,106)CLASS(I) ,CLAS(I)
  106 FORMAT(1X,2F10.4)
    7 WRITE(6,107)          D(I),N(I),P(I),SP(I),VOL(I),ND3(I),P3(I),SP3(I
     1)
      WRITE(6,106)CLASS(NCLASS),CLAS(NCLASS)
  999 CONTINUE
      STOP
      END


  7/8/9 - END OF SECTION

X4    WATER AND 0.5 PERCENT TEEPOL
2 5
 125. 0.86
   5  43 181  32
X4    WATER AND 20 PERCENT ULVAPRON
2 6
 177. 0.86
   6  42 129  81   3
X4    WATER AND 40 PERCENT ULVAPRON
2 5
 125. 0.86
   6  45 160  55
X4    ULVAPRON
2 6
 125. 0.86
   8  39  50  52 153
```

cont....

Computer print-out of droplet analysis.

ANALYSIS OF DATA SET 1

X4 WATER AND 0.5 PERCENT TEEPOL

SPREAD FACTOR = .8600

CLASS	TRUE D	MEAN TRUE D	N	P N	SUM P N	VOL	N X VOLUME	P N X VOL	SUM P N X VOL
31.2500	26.8750								
		32.44	5	1.92	1.92	34141.49	170707.46	.22	.22
44.1942	38.0070								
		45.88	43	16.48	18.39	96566.72	4152368.97	5.29	5.51
62.5000	53.7500								
		64.88	181	69.35	87.74	273131.93	49436879.47	62.99	68.50
88.3883	76.0140								
		91.76	32	12.26	100.00	772533.76	24721080.37	31.50	100.00
125.0000	107.5000								

(VI)

cont.....

Computer print-out of droplet analysis.

ANALYSIS OF DATA SET 2

X4 WATER AND 20 PERCENT ULVAPRON

SPREAD FACTOR = .8600

CLASS	TRUE D	MEAN TRUE D	N	P N	SUM P N	VOL	N X VOLUME	P N X VOL	SUM P N X VOL
31.2895	26.9089								
		32.48	6	2.30	2.30	34271.04	205626.23	.19	.19
44.2500	38.0550								
		45.94	42	16.09	18.39	96933.13	4071191.57	3.73	3.92
62.5790	53.8179								
		64.96	129	49.43	67.82	274168.30	35367710.88	32.44	36.36
88.5000	76.1100								
		91.87	81	31.03	98.85	775465.06	62812669.89	57.61	93.97
125.1579	107.6358								
		129.93	3	1.15	100.00	2193346.41	6580039.23	6.03	100.00
177.0000	152.2200								

(VII)

Appendix

EXAMPLES OF COMPUTER PRINTOUT OF PROBIT ANALYSIS.

(a) PROBIT ANALYSIS FOR PARALLEL LINES PROGRAM NO. S103.

HIGHLIGHTS OF THE PROGRAM.

THIS PROGRAM WILL PERFORM INDEPENDENT SINGLE LINE ANALYSIS FOR EACH OF THE SERIES IN THEEXPERIMENT. THE LINES ARE NOT RESTRICTED TO BE PARALLEL (MODEL 1).

CARRY OUT A JOINT ANALYSIS FOR ANY SPECIFIED SUBSET OR SUBSETS OF SERIES. HERE THE LINES ARE RESTRICTED TO BE PARALLEL WITHIN A SUBSET (MODEL 2).

TEST FOR PARALLELISM U.ING THE LIKELIHOOD RATIO STATISTIC.

COMPUTE A CHI-SQUARE TEST FOR HEYEROGENEITY. THE CHI-SQUARE VALUE IS COMPUTED DIRECTLY FROM THE OBSERVED AND EXPECTED FREQUENCIES AFTER COMBINING EXTREME DOSE GROUPS SO THAT NO EXPECTED FREQUENCY, UNDER MODEL 1, IS LESS THAN 5. IF DESIRED A CRITERION OTHER THAN 5 MAY BE SPECIFIED IN THE INPUT.

IF THE REGRESSION COEFFICIENT FROM JOINT ANALYSIS (MODEL 2) IS SIGNIFICANT, ESTIMATES OF EFFECTIVE DOSE (ED) IN TRANSFORMED AND ORIGINAL SCALES AND CORRESPONDING CONFIDENCE LIMITS. ARE COMPUTED. IF THE REGRESSION COEFFICIENT IS NOT SIGNIFICANT, NO CONFIDENCE STATEMENTS ARE MADE.

IF A REFERENCE SERIES HAS BEEN SPECIFIED AND THE DATA DO NOT CONTRADICT THE HYPOTHESIS OF PARALLELISM THE PROGRAM WILL PERFORM A COMPARISON OF EFFECTIVENESS IN TERMS OF RELATIVE POTENCIES

THIS PROGRAM WILL NOT ESTIMATE THE NATURAL RESPONSE RATE. THAT IS THE RESPONSE IN THE ABSENCE OF THE STIMULUS, BY MEANS OF MAXIMUM LIKELIHOOD.

EXPERIMENT EXP 1 S139

VARIABLE	CONC
RESPONSE	DEATH

SERIES NUMBER	IDENTIFICATION
1	12
2	20
3	30
4	42

(b) P R O B I T A N A L Y S I S F O R S I N G L E L I N E PROGRAM NO. S103

EXPLANATION NOTES

M O O E L

THIS PROGRAM FITS THE REGRESSION LINE Y = A +B(X) TO THE PROBIT OF PROPORTIONAL RESPONSE CORRECTED FOR NATURAL RATE (NRR). NOTE X = TRANSFORMED DOSE. ALSO NOTE THAT THIS PROGRAM DOES NOT DEAL WITH MAXIMUM LIKELIHOOD (ML) ESTIMATION OF THE NRR.

METHOD OF FITTING

MAXIMUM LIKELIHOOD ITERATIVE PROCEDURE AS DESCRIBED IN PROBIT ANALYSIS (1962) BY D.J.FINNEY. THE PROGRAM GOES THROUGH 10 ITERATIONS AND COMPUTES INTERNALLY THE LOG.LIKELIHOOD CORRESPONDING TO THE PARAMETER ESTIMATES YIELDED BY EACH ITERATION. THE PROGRAM THEN SELECTS AS ML ESTIMATES THOSE ASSOCIATED WITH THE ITERATION FOR WHICH THE LOG LIKELIHOOD WAS LARGEST.

METHOD OF TESTING GOODNESS OF FIT

THE CHI-SQUARE VALUE FOR HETEROGENEITY IS COMPUTED DIRECTLY FROM THE OBSERVED AND EXPECTED FREQUENCIES. AFTER COMBINING EXTREME DOSE GROUPS SO THAT NO EXPECTED FREQUENCY IS LESS THAN 2.

STATISTICAL INFERENCE

DEPENDING ON H - HETEROGENEITY FACTOR
T - 95PER CENT T - VALUE WITH NO. OF D.F. ASSOCIATED WITH H
G=HXT*T*(1/(B*B*SNWXX)).

(1) SIGNIFICANCE OF B. IF G IS GREATER TH OR EQUAL TO I B IS NOT SIGNIFICANT.
(2) EXACT 95 PER CENT CONFIDENCE LIMITS FOR ED IN TRANSFORMED SCALE. FORMULA
(M-GXXBAR+-TXSQRT(U-VXG))/(1-G).
(3) EXACT 95 PER.C. CONFIDENCE LIMITS FOR ED. OBTAINED FROM (2) BY TAKING THE INVERSE TRANSFORM USING H.T.G AS RESULTING FROM INTERNAL PROCESSING. THE PROGRAM WILL DECIDE ON (1) AND

IF B IS SIGNIFICANT, IT WILL

1) COMPUTE (2) AND (3) USING H.T.G AS RESULTING FROM INTERNAL PROCESSING.
2) GIVE THE VALUES OF U AND V SO THAT (2) AND (3) CAN BE EASILY RECOMPUTED USING VALUES FOR H,T,G OTHER THAN THOSE PROVIDED AUTOMATICALLY BY THE PROGRAM.

SITUATIONS WHERE 2) MAY BE USEFUL
- DECISIONS THAT THE PROGRAM MAKES CONCERNING GROUPING ARENOT SATISFACTORY FOR PARTICULAR PROBLEM
- IF VERY FEW D.F. ASSOCIATED WITH H, T MAY BE QUITE LARGE. A REMEDY (SEE FINNEY, SECTION18) IS TO POOL CHI-SQUARE VALUES FROM COMPARABLE TESTS.

IF B IS NOT SIGNIFICANT

EXACT 95 P.C. CONF.LIMITS ARE NOT COMPUTED, BUT U AND V ARE STILL GIVEN. NOTE THAT A DIFFERENT VALUE OF H MAY RESULT IN A DIFFERENT DECISION ON THE SIGNIFICANCE OF B.

(c) PROBIT ANALYSIS FOR SINGLE LINE

EXPERIMENT EXP 1 S139
SERIES 1
IDENTIFICATION 12

NATURAL RESPONSE RATE =0.0000, OBTAINED FROM CO TROL GROUP N = 10 , R=, 0
(NRR)

ESTIMATES FOR Y=A+B*X
FROM ITERATIONS 7 AND 8

A	B	LOG-E LIKLIHOOD,
1.0037	4.9193	-4.7121
1.0037	4.9193	-4.7121

WEIGHTED MEANS, SUM OF SQUARES AND PRODUCTS FROM ITERATION 8

		SNWXX	SNWXY	SNWYY	D.F.
SUM W.N. =	18.1615				
XBAR =	.7759	11.4628	70.5317	435.9791	
YBAR =	4.8204	-10.9324	-67.9225	-421.9993	
		.5304	2.6093	13.9798	3
				12.8358	1 REGN.
				1.1440	2 RESID.

TABLE OF OBSERVED AND EXPECTED FREQUENCIES

DOSE NUMBER	TRANSFORMED SAMPLE	DOSE **	SIZE	FREQUENCY OBSERVED		FREQUENCY EXPECTED		PROPORTION RESPONDING (ADJUSTED FOR NRR) OBSERVED	EXPECTED	(OBS. -EXP.)
	Z	X	N	R	N-R	R	N-R			
1	10.0000	1.0000	10	8	2	8.22	1.78	.8000	.8220	-.0220
2	6.6000	.8195	10	5	5	5.14	4.86	.5000	.5141	-.0141
3	4.4000	.6435	10	3	7	2.03	7.97	.3000	.2030	.0970
4	3.0000	.4771	10	0	10	.50	9.50	0.0000	.0496	-.0496

** X = LOG10(Z+PHI); PHI = 0.0000

THE CHI-SQUARE COMPUTED WITHOUT POOLING BECAUSE NOT ENOUGH D.F. LEFT; BEWARE OF THE HETEROGENEITY FACTOR AND ASSOCIATED TESTS.*)
COMPUTED CHI-SQUARE(AFTER POOLING,IF ANY)= 1.144 , WITH 2 D.F., SINCE CRITICAL (5%) CHI-SQUARE IS 5.990
CONCLUDE THAT HETEROGENEITY IS NOT SIGNIFICANT. THE HETEROGENEITY FACTOR IS H = .5720 .
****

FOR INFERENCE PURPOSES USE A T/VALUE OF 1.960. ON THIS BASIS THE VALUE OF G = .2993. HENCE
REGRESSION IS SIGNIFICANT (5% LEVEL). THE VARIANCE OF B = 1.8853 AND THE STANDARD ERROR OF B = 1.3731
****

IN TRANSFORMED SCALE

TAKING H = 1.000 T = 1.960 G = .2993

RESPONSE LEVEL %	GENERAL FORMULAE (SEE FIRST PAGE) APPROXIMATE VARIANCE OF ED (IGNORING G)	VALUES REQUIRED TO CALCULATE EXACT 95% CONFIDENCE LIMITS U	V	EFFECTIVE DOSE (ED)	IN TRANSFORMED SCALE APPROXIMATE VARIANCE OF ED	EXACT 95% C.L. FOR ED LOWER	UPPER	IN ORIGINAL SCALE ED	EXACT 95% C.L. FOR ED LOWER	UPPER
50	H* .2379E-02	.2379E-02	.2375E-02	.8124	.2379E-02	.7127	.9432	6.492	5.161	8.775
99	H* .2250E-01	.2250E-01	.2275E-02	1.2854	.2250E-01	1.090	1.916	19.29	12.30	82.44

G= H*T*T* .7791E-01, VAR(B) = H * 1.885

*) NOTE THE EXPERIMENTER MAY CONSIDER REPEATING THIS SERIES WITH A DIFFERENT ARRANGEMENT OF DOSES OR MORE DOSE LEVELS.

(d) PROBIT ANALYSIS FOR SINGLE LINE

EXPERIMENT EXP 1 5139
SERIES 2
IDENTIFICATION 20

NATURAL RESPONSE RATE =0.0000, OBTAINED FROM CONTROL GROUP N = 10 , R=, 0
(NRR)

ESTIMATES FOR Y=A+B*X
FROM ITERATIONS 7 AND 8

A	B	LOG-E LIKLIHOOD,
.7996	5.5647	-4.8026
.7996	5.5647	-4.8026

WEIGHTED MEANS,SUM OF SQUARES AND PRODUCTS FROM ITERATION 8

			SNWXX	SNWXY	SNWYY	D.F.
SUM W.N.	=	17.2871				
XBAR	=	.7456	10.0872	66.4382	439.7505	
YBAR	=	4.9485	-9.6096	-63.7805	-423.3210	
			.4776	2.6578	16.4295	3
					14.7899	1 REGN.
					1.6396	2 RESID.

TABLE OF OBSERVED AND EXPECTED FREQUENCIES

DOSE NUMBER	TRANSFORMED DOSE Z	DOSE ** X	SAMPLE SIZE N	FREQUENCY OBSERVED R	OBSERVED N-R	EXPECTED R	EXPECTED N-R	PROPORTION RESPONDING (ADJUSTED FOR NRR) OBSERVED	EXPECTED	(OBS. -EXP.)
1	10.0000	1.0000	10	9	1	9.14	.86	.9000	.9138	-.0138
2	6.6000	.8195	10	6	4	6.41	3.59	.6000	.6406	-.0406
3	4.4000	.6435	10	4	6	2.68	7.32	.4000	.2677	.1323
4	3.0000	.4771	10	0	10	.61	9.39	0.0000	.0611	-.0611

** X = LOG10(Z+PHI); PHI = 0.0000

THE CHI-SQUARE COMPUTED WITHOUT POOLING BECAUSE NOT ENOUGH D.F. LEFT! BEWARE OF THE HETEROGENEITY FACTOR AND ASSOCIATED TESTS.*)
COMPUTED CHI-SQUARE(AFTER POOLING,IF ANY)= 1.640 , WITH 2 D.F., SINCE CRITICAL (5%) CHI-SQUARE IS 5.990
CONCLUDE THAT HETEROGENEITY IS NOT SIGNIFICANT. THE HETEROGENEITY FACTOR IS H = .8198 .
****

FOR INFERENCE PURPOSES USE A T/VALUE OF 1.960. ON THIS BASIS THE VALUE OF G = .2597. HENCE
REGRESSION IS SIGNIFICANT (5% LEVEL). THE VARIANCE OF B = 2.0937 AND THE STANDARD ERROR OF B = 1.4470
****

IN TRANSFORMED SCALE

TAKING H = 1.000 T = 1.960 G = .2597

RESPONSE LEVEL %	GENERAL FORMULAE (SEE FIRST PAGE) APPROXIMATE VARIANCE OF ED (IGNORING G)	VALUES REQUIRED TO CALCULATE EXACT 95% CONFIDENCE LIMITS U	V	EFFECTIVE DOSE (ED)	IN TRANSFORMED SCALE APPROXIMATE VARIANCE OF ED	EXACT 95% C.L. FOR ED LOWER	UPPER	IN ORIGINAL SCALE ED	EXACT 95% C.L.FOR ED LOWER	UPPER
50	H* .1874E-02	.1874E-02	.1858E-02	.7548	.1874E-02	.6594	.8567	5.686	4.565	7.190
99	H* .1422E-01	.1422E-01	.1868E-02	1.1730	.1422E-01	1.013	1.633	14.89	10.30	42.97

G= H*T*T* .6761E-01. VAR(B) = H * 2.094

*) NOTE THE EXPERIMENTER MAY CONSIDER REPEATING THIS SERIES WITH A DIFFERENT ARRANGEMENT OF DOSES OR MORE DOSE LEVELS.

(VII)

(c) PROBIT ANALYSIS FOR SINGLE LINE

EXPERIMENT EXP 1 S139
SERIES 3
IDENTIFICATION 30

NATURAL RESPONSE RATE =0.0000, OBTAINED FROM CONTROL GROUP N = 10 , R=, 0
(NRR)

ESTIMATES FOR Y=A+B*X
FROM ITERATIONS 7 AND 8

A	B	LOG-E LIKLIHOOD,
.5443	6.5770	-3.8245
.5443	6.5770	-3.8245

WEIGHTED MEANS, SUM OF SQUARES AND PRODUCTS FROM ITERATION 8

		SNWXX	SNWXY	SNWYY	D.F.
SUM W.N. =	15.1249				
XBAR =	.5739	7.1999	53.9216	404.5558	
YBAR =	5.0766	-6.8687	-51.7431	-389.7909	
		.3312	2.1785	14.7648	3
				14.3278	1 REGN.
				.4370	2 RESID.

TABLE OF OBSERVED AND EXPECTED FREQUENCIES

DOSE NUMBER	TRANSFORMED	SAMPLE DOSE **	SIZE	FREQUENCY OBSERVED		FREQUENCY EXPECTED		PROPORTION RESPONDING (ADJUSTED FOR NRR) OBSERVED	EXPECTED	(OBS. -EXP.)
	Z	X	N	R	N-R	R	N-R			
1	10.0000	1.0000	10	10	0	9.87	.13	1.0000	.9868	.0132
2	6.6000	.8195	10	8	2	8.50	1.50	.8000	.8496	-.0496
3	4.4000	.6435	10	5	5	4.51	5.49	.5000	.4508	.0492
4	3.0000	.4771	10	1	9	1.12	8.88	.1000	.1117	-.0117

** X = LOG10(Z+PHI); PHI = 0.0000

THE CHI-SQUARE COMPUTED WITHOUT POOLING BECAUSE NOT ENOUGH D.F. LEFT; BEWARE OF THE HETEROGENEITY FACTOR AND ASSOCIATED TESTS.*)
COMPUTED CHI-SQUARE(AFTER POOLING,IF ANY)= .4370 , WITH 2 D.F., SINCE CRITICAL (5%) CHI-SQUARE IS 5.990
CONCLUDE THAT HETEROGENEITY IS NOT SIGNIFICANT. THE HETEROGENEITY FACTOR IS H = .2185 .
****

FOR INFERENCE PURPOSES USE A T/VALUE OF 1.960. ON THIS BASIS THE VALUE OF G = .2681. HENCE
REGRESSION IS SIGNIFICANT (5% LEVEL). THE VARIANCE OF B = 3.0191 AND THE STANDARD ERROR OF B = 1.7376
****

IN TRANSFORMED SCALE — TAKING H = 1.000 T = 1.960 G = .2681

RESPONSE LEVEL %	APPROXIMATE VARIANCE OF ED (IGNORING G)	VALUES REQUIRED TO CALCULATE EXACT 95% CONFIDENCE LIMITS U	V	EFFECTIVE DOSE (ED)	IN TRANSFORMED SCALE: APPROXIMATE VARIANCE OF ED	EXACT 95% C.L. FOR ED LOWER	UPPER	IN ORIGINAL SCALE: ED	EXACT 95% C.L. FOR ED LOWER	UPPER
50	H* .1538E-02	.1538E-02	.1528E-02	.6623	.1538E-02	.5680	.7479	4.595	3.699	5.597
99	H* .9698E-02	.9698E-02	.1528E-02	1.0160	.9698E-02	.8833	1.399	10.38	7.643	25.09

G= H*T*T* .6979E-01, VAR(B) = H * 3.019

*) NOTE THE EXPERIMENTER MAY CONSIDER REPEATING THIS SERIES WITH A DIFFERENT ARRANGEMENT OF DOSES OR MORE DOSE LEVELS.

(f) PROBIT ANALYSIS FOR SINGLE LINE

EXPERIMENT EXP 1 S139
SERIES 4
IDENTIFICATION 42

NATURAL RESPONSE RATE =0.0000, OBTAINED FROM CO TROL GROUP N = 10 , R=, 0
(NRR)

ESTIMATES FOR Y=A+B*X
FROM ITERATIONS 8 AND 9

A	B	LOG-E LIKLIHOOD,
.1948	7.6365	-3.4420
.1948	7.6365	-3.4420

WEIGHTED MEANS, SUM OF SQUARES AND PRODUCTS FROM ITERATION 9

			SNWXX	SNWXY	SNWYY	D.F.
SUM W.N.	=	13.2446				
XBAR	=	.6392	5.6343	44.6757	354.5734	
YBAR	=	5.0761	-5.4114	-42.9735	-341.2665	
			--------	--------	--------	
			.2229	1.7022	13.3069	3
					12.9989	1 REGN.
					.3080	2 RESID.

TABLE OF OBSERVED AND EXPECTED FREQUENCIES

DOSE NUMBER	TRANSFORMED DOSE **	SAMPLE	SIZE	FREQUENCY OBSERVED		FREQUENCY EXPECTED		PROPORTION RESPONDING (ADJUSTED FOR NRR) OBSERVED	EXPECTED	(OBS. -EXP.)
	Z	X	N	R	N-R	R	N-R			
1	10.0000	1.0000	10	10	0	9.98	.02	1.0000	.9977	.0023
2	6.6000	.8195	10	9	1	9.27	.73	.9000	.9269	-.0269
3	4.4000	.6435	10	6	4	5.43	4.57	.6000	.5432	.0568
4	3.0000	.4771	10	1	9	1.23	8.77	.1000	.1227	-.0227

** X = LOG10(Z+PHI); PHI = 0.0000

THE CHI-SQUARE COMPUTED WITHOUT POOLING BECAUSE NOT ENOUGH D.F. LEFT; BEWARE OF THE HETEROGENEITY FACTOR AND ASSOCIATED TESTS.*)
COMPUTED CHI-SQUARE(AFTER POOLING, IF ANY)= .3080 , WITH 2 D.F., SINCE CRITICAL (5%) CHI-SQUARE IS 5.990
CONCLUDE THAT HETEROGENEITY IS NOT SIGNIFICANT. THE HETEROGENEITY FACTOR IS H = .1540 .
****

FOR INFERENCE PURPOSES USE A T/VALUE OF 1.960. ON THIS BASIS THE VALUE OF G = .2955. HENCE
REGRESSION IS SIGNIFICANT (5% LEVEL). THE VARIANCE OF B = 4.4863 AND THE STANDARD ERROR OF B = 2.1181
****

IN TRANSFORMED SCALE

TAKING H = 1.000 T = 1.960 G = .2955

RESPONSE LEVEL %	GENERAL FORMULAE (SEE FIRST PAGE): APPROXIMATE VARIANCE OF ED (IGNORING G)	VALUES REQUIRED TO CALCULATE EXACT 95% CONFIDENCE LIMITS U	V	EFFECTIVE DOSE (ED)	IN TRANSFORMED SCALE: APPROXIMATE VARIANCE OF ED	EXACT 95% C.L. FOR ED LOWER	UPPER	IN ORIGINAL SCALE: ED	EXACT 95% C.L. FOR ED LOWER	UPPER
50	H* .1302E-02	.1302E-02	.1295E-02	.6292	.1302E-02	.5407	.7094	4.258	3.473	5.122
99	H* .7977E-02	.7977E-02	.1295E-02	.9339	.7977E-02	.8151	1.300	8.589	6.533	19.95

G= H*T*T* .7693E-01, VAR(B) = H * 4.486

*) NOTE THE EXPERIMENTER MAY CONSIDER REPEATING THIS SERIES WITH A DIFFERENT ARRANGEMENT OF DOSES OR MORE DOSE LEVELS.

(VII)

(g) P R O B I T   A N A L Y S I S   F O R   P A R A L L E L   L I N E S

COMBINING THE FOLLOWING SERIES

SERIES NUMBER	IDENTIFICATION
1	12
2	20
3	30
4	42

SERIES 1 WAS USED AS REFERENCE SERIES

(h) JOINT PROBIT LINE ANALYSIS FOR SERIES NUMBERS 1 2 3 4 EXPERIMENT EXP 1 S139

REFERENCE SERIES I

MAXIMUM LIKELIHOOD ESTIMATES

SERIES NUMBER	ESTIMATES OF REGRESSION PAREMETERS FROM JOINT ANALYSIS ITERATION 8 * (LINES CONSTRAINED TO BE PARALLEL) A	B	LOG-E LIKELIHOOD	SUMMARY OF ESTIMATES OF REGRESSION PARAMETERS FORM INDIVIDUAL ANALYSIS (LINES NOT CONSTRAINED TO BE PARALLEL) A	B	LOG-E LIKELIHOOD
1	.1809	5.9686	-4.9756	1.0037	4.9193	-4.7121
2	.4960	5.9686	-4.8390	.7996	5.5647	-4.8026
3	1.0560	5.9686	-3.8871	.6443	6.5770	-3.8245
4	1.2757	5.9686	-3.7946	.1948	7.6365	-3.4420
	TOTAL LOG-E LIKELIHOOD	LL1 =	-17.4963	TOTAL LOG-E LIKELIHOOD	LL2 =	-16.7812

* NOTE AT ITERATION 7 THE ESTIMATE OF B FROM THE JOINT ANALYSIS IS 5.9686

LIKELIHOOD RATIO TEST FOR PARALLELISM

THE VALUE OF THE LOG-E LIKLIHOOD RATIO STATISTIC -2(LL1 - LL2) = 1.4301 WITH 3 D.F.
SINCE THE CRITICAL (5%) CHI-SQUARE VALUE IS 7.8100 CONCLUDE THAT

THE DATA DO NOT CONTRADICT THE HYPOTHESIS OF PARALLELISM
****

THERE ARE NO DEGREES OF FREEDOM LEFT (AFTER GROUPING) TO PERFORM A TEST FOR HETEROGENEITY
IN THE ANALYSIS THAT FOLLOWS THE HETEROGENEITY FACTOR, H, IS TAKEN TO EQUAL 1.0

(i) JOINT PROBIT LINE ANALYSIS FOR SERIES NUMBERS 1 2 3 4 EXPERIMENT EXP 1 S139

REFERENCE SERIES 1

TABLE OF OBSERVED AND EXPECTED FREQUENCIES

MODEL 1 LINES NOT RESTRICTED TO BE PARALL EL
MODEL 2 LINES RESTRICTED TO BE PARALLEL

SERIES NO.	DOSE NO.	DOSE	TRANSFORMED DOSE**	SAMPLE SIZE	OBSERVED FREQUENCY		EXPECTED FREQUENCY MODEL 1		EXPECTED FREQUENCY MODEL 2		PROPORTION RESPONDING ADJUSTED FOR NRR OBSERVED	MODEL 1	MODEL 2
		Z	X	N	R	N-R	R	N-R	R.	N-R			
1	1	10.0000	1.0000	10	8	2	8.22	1.78	8.77	1.23	.8000	.8220	.8766
	2	6.6000	.8195	10	5	5	5.14	4.86	5.32	4.68	.5000	.5141	.5323
	3	4.4000	.6435	10	3	7	2.03	7.97	1.66	8.34	.3000	.2030	.1660
	4	3.0000	.4771	10	0	10	.50	9.50	.25	9.75	.0001	.0496	.0248
2	1	10.0000	1.0000	10	9	1	9.14	.86	9.29	.71	.9000	.9138	.9288
	2	6.6000	.8195	10	6	4	6.41	3.59	6.52	3.48	.6000	.6406	.6517
	3	4.4000	.6435	10	4	6	2.68	7.32	2.54	7.46	.4000	.2677	.2543
	4	3.0000	.4771	10	0	10	.61	9.39	.49	9.51	.0001	.0611	.0491
3	1	10.0000	1.0000	10	10	0	9.87	.13	9.78	.22	.9999	.9868	.9785
	2	6.6000	.8195	10	8	2	8.50	1.50	8.28	1.72	.8000	.8496	.8279
	3	4.4000	.6435	10	5	5	4.51	5.49	4.58	5.42	.5000	.4508	.4581
	4	3.0000	.4771	10	1	9	1.12	8.88	1.36	8.64	.1000	.1117	.1361
4	1	10.0000	1.0000	10	10	0	9.98	.02	9.87	.13	.9999	.9977	.9871
	2	6.6000	.8195	10	9	1	9.27	.73	8.75	1.25	.9000	.9269	.8754
	3	4.4000	.6435	10	6	4	5.43	4.57	5.40	4.60	.6000	.5432	.5404
	4	3.0000	.4771	10	1	9	1.23	8.77	1.86	8.14	.1000	.1227	.1864

** X = LOG10(Z+PHI); PHI = 0.0000

GOODNESS OF FIT OF PARALLEL LINE MODEL 2

COMPUTED CHI-SQUARE 5.2915 WITH 11 D.F.

POOLING OF DOSE GROUPS. CRITERION FOR SMALL EXPECTED FREQUENCIES, LESS THAN 2

SERIES	POOLING OF DOSE GROUPS.
1	NO POOLING PERFORMED (NOT ENOUGH DEGREES OF FREEDOM LEFT)
2	NO POOLING PERFORMED (NOT ENOUGH DEGREES OF FREEDOM LEFT)
3	NO POOLING PERFORMED (NOT ENOUGH DEGREES OF FREEDOM LEFT)
4	NO POOLING PERFORMED (NOT ENOUGH DEGREES OF FREEDOM LEFT)

(j) JOINT PROBIT LINE ANALYSIS FOR SERIES NUMBERS 1 2 3 4 EXPERIMENT EXP 1 S139

REFERENCE SERIES 1

THE ESTIMATES GIVEN BELOW ARE OBTAINED UNDER THE HYPOTHESIS OF PARALLELISM, WHICH IS SUSTAINED BY THE DATA

USING H = 1.000 AND G = .6800E-01 COMPUTED WITH T = 1.960 NO D.F. LEFT AFTER POOLING

SERIES NUMBER	RESPONSE LEVEL %	IN TRANSFORMED SCALE: EFFECTIVE DOSE (ED)	APPROXIMATE VARIANCE OF ED (IGNORING G)	EXACT 95% CONFIDENCE LIMITS FOR ED: LOWER	UPPER	IN ORIGINAL SCALE: ED	EXACT 95% CONFIDENCE LIMITS FOR ED: LOWER	UPPER
1	50	.80595	.15617E-02	.72789	.88841	6.39666	5.34427	7.73411
	99	1.1958	.46573E-02	1.0844	1.3685	15.6961	12.1447	23.3603
2	50	.75420	.16251E-02	.67299	.83668	5.67811	4.70962	6.86563
	99	1.1440	.44344E-02	1.0348	1.3114	13.9329	10.8350	20.4835
3	50	.66107	.18598E-02	.57259	.74767	4.58211	3.73759	5.59329
	99	1.0509	.43720E-02	.94138	1.2154	11.2435	8.73734	16.4227
4	50	.62645	.21223E-02	.53199	.71906	4.23109	3.40398	5.23669
	99	1.0163	.46356E-02	.90285	1.1848	10.3822	7.99555	15.3025

NOTE AFTER POOLING OF DOSE GROUPS THERE WERE NOT ENOUGH D.F. LEFT TO OBTAIN AN ESTIMATE OF HETEROGENEITY.
THE HETEROGENEITY FACTOR WAS SET EQUAL TO 1.

ESTIMATED POTENCIES RELATIVE TO SERIES 1

SERIES NUMBER	IN TRANSFORMED SCALE: ESTIMATE OF RELATIVE POTENCY (RP)	APPROXIMATE VARIANCE OF RP (IGNORING G)	EXACT 95% CONFIDENCE LIMITS FOR RP: LOWER	UPPER	IN ORIGINAL SCALE: ESTIMATE OF RELATIVE POTENCY	EXACT 95% CONFIDENCE LIMITS FOR RP: LOWER	UPPER
2	.5175E-01	.3178E-02	-.6113E-01	.1678	1.127	.8687	1.472
3	.1449	.3434E-02	.2904E-01	.2670	1.396	1.069	1.849
4	.1795	.3698E-02	.5917E-01	.3061	1.512	1.146	2.023

(VII)

(k) Output of results of probit analysis under column headings.

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 MFB    LONDON UNIV. NOSBE  L454-A     MAR  78    CDC6600.
14.42.36.  1IB 22  UM3ZS6H      25/04/78  CDC6600 FROM     /SV
14.42.36.  1IB 22  IP  00000192 WORDS - FILE INPUT  , DC 04
14.42.36.  1AJ 22 -JOB(UMBZS13,J3)
14.42.41.  ACT 22 -ATTACH(LIB,PROBIT,ID=LIBULRC)
14.42.41.  PFM 22  PF ATTACHED,PROBIT*,PROBIT EDITLIB
14.42.41.  PFM 22   CY=0003 ID=LIBULRC   CREATED 02/02/78
14.42.41.  1AJ 22 -LIBRARY(LIB)
14.42.42.  1AJ 22 -LDSET(PRESET=ZERO)
14.42.42.  MSG 22  MAIN.
14.42.57.  MSG 22     CM LWA+1 = 56150B, LOADER USED  72100B
14.43.02.  MSG 22        STOP
14.43.03.  1EJ 22  OP  00005375 WORDS - FILE OUTPUT , DC 40
14.43.03.  1EJ 22  MS    7168  WORDS  (    7168 MAX USED)
14.43.03.  1EJ 22  CP        2.336 SEC.          .029 ADJ.
14.43.03.  1EJ 22  IO        1.111 SEC.          .004 ADJ.
14.43.03.  1EJ 22  CM       55.532 KWS.          .043 ADJ.
14.43.03.  1EJ 22  PP        9.139 SEC.
14.43.03.  1EJ 22  6000 UNITS USED               .077
14.43.03.  1EJ 22  6000 UNITS CHARGED            .077
14.43.03.  1EJ 22  EJ  END OF JOB, SV   25/04/78
**ULCC END   OF INFORMATION** UM3ZS6H **0000000000000000000000
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