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Spraying of apple trees with air mist blower and Ultra Low Volume sprayer with normal and reduced amounts of pesticides

Undersøgelser over forhold vedrørende frugttræsprøjtning med særlig henblik på reduktion af pesticidforbrug

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CONTENTS

1. Summary

The investigations into sprayings with ULV sprayer and air mist sprayer were carried out in 1975–79. The effects of concentration and amount of liquid were investigated, and an empirical standard of deposits and distribution was established. Deposits were found to be directly proportional to the concentration used and, consequently, to the amount of pesticide per hectare. By reductions of the amount of liquid, the retention per litre of spraying liquid was increased so the amount of the pesticide could be reduced by 22–36%. The deposit showed a fairly close correlation to the temperatures at the time of spraying, a monitoring of the liquid amount deposited showing almost a halving of the deposited liquid following a change in the temperature from 13°C to 23.6°C. The loss of spray material to the orchard floor could not be measured but computations based on the results show that, in the case of normal spraying, the loss amounts to 60–70% of the spraying liquid.

Key words: Fruit tree spraying, ULV, deposits, number of spots, temperature, reduced amounts of pesticides.

2. Resumé

Rapporten indeholder resultatet af undersøgelser over ULV- og tågesprøjtning udført 1975–78. Ændringer i opfanget sprøjtevæske og fordeling heraf er undersøgt i forhold til ændringer i sprøjtevæskens mængde og koncentration af pesticid. I tilknytning hertil er undersøgt den pesticidmængde, der opfanges ved sprøjtning som det udføres i praksis. For Captan 83 midler er denne mængde 2,30 $\mu g/cm^2$ fordelt på 40 pletter/cm^2.

Den anvendte ULV-sprøjte var ikke i stand til at give en tilfredsstillende dækning af træerne især forårsaget af en uhensigtsmæssig konstruktion.

Et sprøjteprogram, hvor der blev anvendt 40% af normeret dosering gav utilfredsstillende effekt både med ULV- og tågesprøjte.

Resultater primært for tågesprøjten viste, at opfanget pesticid var proportionalt med koncentration af pesticid i sprøjtevæsken og dermed også med præparatmængde pr. ha. Nedsættelse af væskemængden reducerede opfanget pesticid og pletantal. Opfanget væske pr. liter blev imidlertid øget. I det afprøvede område, 511–80 l/ha, kunne 22–36% af pesticidmængden derfor være sparet, uden at det ville reducere opfanget pesticid. Antallet af sammenfaldende pletter blev reduceret, hvorfor det totale pletantal blev reduceret mindre end forventet. Opfanget pesticid var nært korreleret til luftens temperatur på sprøjtetidspunktet. Ved 23,6°C opfangedes halvt så meget som ved 13°C. Forøget koncentration af pesticid ændrede mængde af opfanget pesticid og fordeling heraf på en måde, der synes at hænge sammen med ændrede fysiske forhold i sprøjtevæsken. Tilsætning af fordampningshæmmende middel til sprøjtevæsken havde nogen positiv effekt ved tågesprøjtning.

Nøgleord: Frugttræsprøjtning, ULV, dosis, pletantal, temperatur, reduceret pesticidmængde.

3. Introduction

The cultivation of top fruit requires a systematic control of diseases and pests, which may destroy either the trees or the fruits.

As the fruits are mainly used for direct consumption, their appearance and lesions, if any, are decisive for their utility value and, consequently, of very great economic importance.

In 1977, pesticides totally amounting to abt. 56 mill. kroner were sold in Denmark (*Laug,* 1978), out of which amount abt. 20 mill. kroner was spent on the spraying of fruit trees.

The spraying equipment used has been subjected to some testing and development (*Jepsen & Hansen,* 1956; *Zumbach & Stadtler,* 1973) but not to the same systematic extent as the pesticides.

In response to wishes expressed from commercial quarters for investigations of a recently marketed technical system, such systematic investigations have been carried out. As part of the project, the sprayers used have been subjected to technical tests at The National Institute for Agricultural Engineering at Bygholm. The results of such tests are to be published in a special report.

3.1 General observations on spraying for fruit trees

Spraying of fruit trees is arranged with many pathological and economic aspects in view, which, under Danish conditions, results in a spray programme comprising 12–18 sprayings per year with a great variety of pesticides. The control of scab (*Venturia inaequalis*) and Gloeosporium (*Gloeosporium album, G. perennans,* and *G. fructigenum*) requires 10 or more sprayings (*Weber et al.,* 1961), which together with the control of powdery mildew (*Podosphaera leucotricha*) with 5–7 sprayings (*Mygind,* 1964), constitute the main part of the spray programme, which after the fruit-gathering is extended to sprayings against fruit tree canker (*Nectria galligena*) with 1–2 sprayings. To this fungicide spray programme is coupled sprayings against pests, in particular apple aphids (*Aphis pomi*), apple sawflies (*Hoplocampa testudinea*), codling moths (*Laspeyresia pomonella*), dock sawflies (*Ametategia glabrata),* red spider mites (*Panonychus ulmi*) and several, rarely occurring pests. Normally, the aim of fungicide sprayings is prophylactic whereas insecticide sprayings are of a curative character.

The *doses* applied (kg/ha or concentration) have been fixed on the basis of tests made at the Institute of Plant Pathology at Lyngby (*Anon.,* 1978a), where the application is made with equipment fairly similar to that used by the commercial fruit growers (*Anon.,* 1978).

3.2 Spraying equipment

The function of the spraying equipment is to deposit as much pesticide as possible on the surface of the plants with a completely uniform distribution on all parts of the plant. The technical development of sprayers is shown in the below survey. Up to about 1950, the sprayer types used mostly were gun launchers and mast sprayers. During the decade of 1950–60, these were completely replaced by air mist sprayers. This development was furthered in those years by the fact that, beside foreign sprayers, 3 Danish spraying units were available, and that tests (among others *Jepsen & Hansen,* 1956) established their adequacy. By the use of air as the carrying agent for the drops of liquid, the amount of liquid could be reduced from 2,000 l/ha to 200 l/ha whereas the pesticide concentration must then be increased proportionately so as to have the same amount applied per area unit.

With the starting point in sprayings by aeroplane, sprayers (ULV) have, as a natural development, been constructed for liquid amounts of up to 45–50 l/ha. For sprayings from the air, small amounts of liquid are evidently advantageous. On the other hand, the economy is very modest in case of mobile sprayers in orchards (*Vang-Petersen,* 1978).

For any given spraying equipment it must be presumed that there is an interaction between its capacity to deposit the spraying liquid uniformly on the plant and the pesticide used, measured by its effect on the pathogen (*Frick,* 1970).

3.3 ULV technique

According to 'Guidelines for Ultra Low Volume Application of Pesticides', ULV refers to amounts less than 5 l/ha (Joint Technical EPPO/FAO/IAAC/GIFAP Committee, 1972). In this investigation, ULV spraying is defined as the application of less than 1/50 of the normal liquid amount in accordance with *Jones et al.,* (1974). This is considered to be more relevant than a definition based on area or litre per hectare in accordance with *Bals* (1976). Thus, in sprayings of fruit trees in Denmark, the ULV span will be liquid amounts up to 40 l/ha. Any sprayer that is able to function with such amounts can be described as a ULV sprayer.

3.4 Atomization and distribution of the liquid

The splitting up of the liquid into drops (atomization) can be achieved by combining, for instance, types of nozzles, the placing of nozzles in relation to the carrying air etc. With a given combination

Survey of the characteristics of fruit tree sprayers

	Liquid amount l/ha	Preparation	Concentration of preparation	Atomizing system	Transportation of liquid
Gun launcher or mast sprayer	2000–3000	As recommended by SpF	1	by liquid pressure	liquid pressure
Air mist or concentration sprayer	200–1000	»	10 –2 ×	by air supported liquid pressure	air pressure
ULV sprayer	5–40	»	400 – 50 ×	rotary atomizer	
ULV–ULD sprayer[1])	5–40	1/3 – 1/2 × recommended amount	1/3 – 1/2 × 400 – 50 ×	»	

[1]) ULV = ultra low volume, ULD = ultra low dosage

in a mist sprayer, the size of the drops (Volume Mean Diameter (VMD)) and the deviation will increase with increasing amounts of liquid through nozzles, and with decreasing velocity of the carriyng air. As regards nozzles atomizing the liquid by pressure, increasing pressure will reduce VMD and the deviation around it (*Conibear & Morgan,* 1963). As regards nozzles atomizing the liquid by centrifugal force (rotary nozzles), VMD depends on the rate of rotation. For the rotary nozzle used on the ULV sprayer in this investigation, VMD is presumed to be computable according to *Bals,* (1970):

$$(1)\ d = \frac{3.8}{A} \times \frac{S}{DC}$$

A being = angular velocity, D = diameter of disc, S = surface tension, and C = specific gravity of spraying liquid.

A rather comprehensive material giving data of distribution patterns at the testing of spraying nozzles and sprayers is available whereas relatively few investigations have been made of the distribution of deposits on the trees (*Stafford et al.,* 1970; *Morgan,* 1972; *Cooke et al.,* 1975; *Cooke et al.,* 1976).

3.5 Climatic effects on spraying

A number of climate parameters are considered to be of great importance to the result of sprayings. Especially the temperature and the air humidity are supposed to play a part, but no investigations proper of this problem under field conditions are available. For sprayings from the air, *Skoog et al.* (1976) have established that the temperature is an essential factor of importance to the amount of the deposit together with other factors of importance in this connection.

4. Material and method

4.1 Sprayers used

In this investigation were used a ULV sprayer and an air mist sprayer of German and Danish make, respectively. The most essential specifications of these sprayers are given below. Both sprayers have been subjected to a technical examination at The National Institute of Agricultural Engineering at Bygholm, and a special report of the results will be available. All sprayings were carried out in orchards with intensively grown apple trees, tree height appr. 3.5–4.0 m.

Before any test spraying was made, the distribution of the liquid on the nozzles of the ULV sprayer was controlled, and the mist sprayer was provided with tested manometers.

	ULV-sprayer	Air mist sprayer
Manufacturer	Mantis GmbH 2100 Hamburg 90 Germany	I/S Schaumann and Sons 5882 Vejstrup Denmark
Designation	Mantis II	DG-1000
Tank capacity, l.	50	1000
Length, cm	100	375
Width, cm	70	120
Height, cm	170	134
Weight, kg	155	690
Blower type	Axial	Axial
Blower performance, m^3/h	25.000	25.000
Nozzles, number	2	2 × 7
Atomizing system		Pneum.[2])
Power consumption h.p.	10	27

[1]) Micron-Sprayers Ldt. [2]) Own make

4.2 Spraying and spraying liquid

Prior to, and during, the spraying, the liquid was stirred vigorously to prevent precipitation of the preparations used. The spraying was carried out against the wind in order to reduce any wind drift between the treatments. Otherwise, the spraying was carried out according to the experimental designs stated.

For sprayings where fluorescent tracers had been added, Captan 83 was, in all cases, used as spraying material too. The relative viscosity of the spraying liquid was measured by means of Oestwald's viscosimeter, and as it is a question of suspensions, it has only been possible to make a relatively rough measurement (Table 1). The surface tension was measured by means of a Traube stalagmoneter.

All *measurings* were made at 20°C, and specific weights were determined by pipetting and weighing.

Table 1. Specific weight and relative viscosity of spraying liquid

	g/cm³		Viscosity (η)		Surface tension dyn/cm
		+ starch		+ starch	
1.48 w/w % captan	1.002	1.008	1.109	1.135	50.8
4.31 w/w % captan	1.015	1.021	1.222	1.277	38.4
12.31 w/w % captan	1.045	1.054	1.556	1.637	33.6
21.26 w/w % captan	1.089	1.097	2.367	2.508	33.6

As regards Captan 83, the viscosity is increased with increasing concentration (%) according to

(2) $y = 1.03124 \times e^{0.0379x}$ ($r = 0.995$)

4.3 Measuring of deposit

During the spraying, part of the liquid will miss the trees and fall on to the ground. The part falling on the trees will, to a certain extent, run off and also end up on the ground. What is then retained on the trees is the actual applied liquid amount, and the pesticide contained therein is the deposit.

In all cases, such deposits were determined by the use of fluroscent tracers. The tracer was Fluoresceine S 7–2214 (*Produits Chemiques Ugine Kuhlman,* Paris) amounting to 0.2 % of the liquid applied. In order to obtain fluorescence in dry state, water-soluble starch (<2%) was further added to the spraying liquid. The extraction of leaf samples was done in a buffer solution (pH 9.0) consisting of 40.7 g H_3BO_3, 49.2 g KCl, and 11.0 g NaOH ad 10 l H_2O. One-sided extraction of leaves was made by careful dabbing of the leaf, placed on an adhesive, waterproof label before the extraction, for which was used 25 ml solution. Analyses of samples were made at the National Weed Research Institute by the use of a Farrand's Ratio Fluorometer–2, (detection limit = 1 drop of a diameter of 102 μm per cm²). The area of the leaf samples taken was measured by means of a Lambda Li Cor areameter, model LI – 3000 + LI 3050 A. The measuring was made after the leaves had been dried and pressed.

4.4 Count of spots

The number of spots was determined by counting from *photos* of the leaves exposed in ultra-violet light. For the exposure were used 2 Philips TL 20 W/08, and the film used was Ilford, HP 4, aperture 5.6, exposure time 5 seconds, with subsequent development for 5.5 minutes in Microphen. For the prints was used Ilfo-Speed, Semi-mat, hardness 4, development for 1 minute in Ilfo-Speed.

4.5 Sampling

Samples were taken by picking of whole, undamaged leaves of a maximum size of 8 × 12 cm with a view to the photographing. The height of the trees is given in zones, zone 1 being the lower third, zone 2 the middle third, and zone 3 the upper third of the trees. Within each zone, endeavours have been made to pick the samples at random. Likewise, it was endeavoured to pick leaves of the same size. All sprayings were made in spraying plots comprising at least 9 trees, and the samples were taken in the middle third of the trees. The number of samples and the methods of extraction (one-sided/two-sided) will be seen from Main Table 1.

4.6 Computation of material

The collected data relative to amounts of deposits and number of spots were neither normally nor logarithmically grouped. By a graphical representation where a sample or a size fraction of samples (x) is expressed as the percentage of the total number (y) (100%), frequency curves will appear, which can best be described as cubic polynominals according to the following formula:

(3) $y = b_0+b_1x+b_2x^2+b_3x^3$ for $0<y<100$

To a considerable extent, the material is therefore described by means of such frequency curves. At the tracing of such curves, the material was, in all cases, classified and, to a minor extent, this may lead to a shifting of the curves in relation to the axes. Where quantile values have been used for the frequency curves, it is a question of the smoothed curves according to (3).

On the bases of deposits measured and the number of spots, the diameter of the drops of liquid has been calculated. This was done according to

$$(4)\ d = 2 \times \sqrt[3]{\frac{\frac{\mu g/cm^2}{spots/cm^2} \times \frac{100}{conc.\ in\ liq.} \times 10^6}{4/3\ \pi}}$$

The measuring and calculating method used give for each sample (= 1 leaf) weight or volume mean diameter, i.e. the diameter of a mean volume drop. The international symbol thereof is MMD or VMD. This has, for instance by *Maas* (1971) been described as the most representative one for the big as well as the small drops on a sample. The method used here gives no possibility of determining the quantitative ratio between the drop sizes on the individual sample.

5. Experimental results

5.1 Pesticide concentration in spraying liquid

Any alteration of the amount of liquid will involve a change of the pesticide concentration when the pesticide rate is to remain unchanged. Conversely, any change of the pesticide concentration with unchanged liquid amount will bring about a change of the pesticide rate.

From the results obtained by *Jones et al.* (1974) and *Frick* (1970), the deposit (d) seems to be deducible from the liquid concentration (c_a) and the liquid amount (l_a) starting from a given basis (n) according to

$$(5)\ d_a = d_n \times \frac{l_{(a)} \times c_{(a)}}{l_{(n)} \times c_{(n)}}$$

showing that the actual deposit is directly proportional to the changes of concentration and liquid amount when the adjustment of the spraying equipment remains unchanged. Thus, for the dependency of the deposit on the liquid concentration, the following equation is set up, derived from (5)

$$(6)\ d_a = d_n \times \frac{C_a}{C_n}$$

according to which the actual deposit (d_a) is changed proportionally to the ratio between the initial concentration (C_n) and the actual concentration (C_a).

5.1.1 Experiments, design and conditions

For the purpose of checking the equation (6), experiments were carried out according to the following design:

a. 1.48 w/w % Captan 83
b. 4.31 w/w % Captan 83
c. 11.89 w/w % Captan 83
d. 21.26 w/w % Captan 83

in which, for each sprayer, it is endeavoured to apply the prescribed liquid amounts etc., as given at the bottom of the page.

The experiments were carried out according to design and under the conditions shown in Main Table 1.

5.1.2 Deposits, air mist sprayer

The results measured were plotted as frequency curves in Main Figs. 1 and 2 from which were calculated the x-values (deposit, $\mu g/cm^2$) for the

	ULV	Air mist sprayer	
Experiment carried out on	17/6, 77	11/10, 76	17/6, 77
Driving pace, km/h	8.2	9.1	10.1
Liquid amount, l/ha	12.5	200	197

quantile values 10, 20 .... 90. On the basis hereof the curves were compared, and according to the formula:

$$x_{2(yi)} = b_o + b_1 x_{1(yi)}$$

the following rectilinear transition from a given quantile value $f(x_1)$ to the corresponding quantile value $f(x_2)$ on another curve was found:

Time of treatment	$x_{2(yi)}$	b_o	b_1	$x_{1(yi)}$	r =
11/10–76	4.3	0.71	3.23	1.5	1.0
	11.9	2.12	8.38	1.5	1.0
	11.9	0.27	2.59	4.3	1.0
17/6–77	4.3	11.38	4.76	1.5	1.0
	11.9	0.25	12.04	1.5	1.0
	21.3	6.72	20.44	1.5	0.99
	11.9	3.97	2.59	4.3	1.0
	21.3	0.85	4.32	4.3	0.99
	21.3	7.23	1.72	11.9	0.98

In all cases, it is a question of the curve forms for the concentrations applied being derivative from each other by factors (b_1), which, with the exception of the ratio 1.5% ~ higher concentrations, 17th June 1977, correspond fairly well to the ratio between the concentrations ($f(x_2) : f(x_1)$). Provided that the drop sizes and the distribution patterns are not affected by alterations of the concentration of the liquid, this must, indeed, be the case as the same amount of liquid has then been retained by the leaves.

5.1.3 Deposits, ULV-sprayer

The results of the measurements have been plotted as frequency curve in Main Fig. 3. A number of samples without deposits, in dependence of the concentrations, were found as shown in Table 1. For 1.5% and 4.3% concentrations, correlation of the quantile values 10–90 was calculated – as was the case with the air mist sprayer – whereas, for the concentrations 11.9% and 21.3%, it has only been possible to calculate the correlation for quantile values above 60–90. Otherwise, the curve pattern differs from that for the mist sprayer by being logarithmic in consequence of the numerous negative samples.

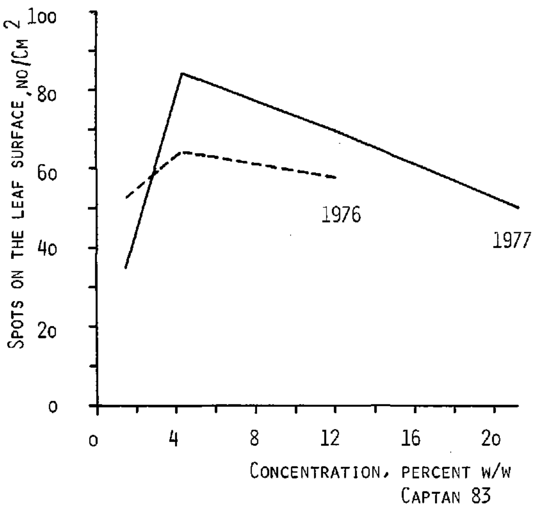

Fig. 1. Air mist blower. Increasing concentration of Captan 83. Effect on number of spots on the leaf surface.

As mentioned in connection with the mist sprayer, there is in the intervals in question, a rectiliniar transition from one curve to another, and slopes corresponding to the theoretical ratio between the concentrations.

Table 2. Per cent of samples without deposit, 17/6, 1977.

	Conc. in liquid			
	1.5	4.3	11.9	21.9
ULV-sprayer	1.9	1.9	29.6	35.2
Mist sprayer	0	0	1.9	0

With the measuring technique used, the detection limit for the drops of 60 μm is abt. 5/cm^2. Therefore, the numerous negative samples after ULV spraying at higher concentrations cannot be ascribed to insufficient registration.

5.1.4 Distribution of spots

The distribution of spots after mist sprayings plotted as frequency curves as shown in Main Figs 4 and 5, and after ULV sprayings as shown in Main Fig. 6. For both kinds of spraying, a pattern appears as shown in Fig. 1 for the mist spraying. If the concentration is increased from 1.48 to 4.31%, the number of spots is considerably increased. In case of any so further increase, a reduction of the number of spots will again be seen.

The size of drops, Table 3, shows a change reversely proportional to the number of drops. If corrections are made for the varying number of drops on the basis of calculations of the correlation between deposits and concentrations, the effect of increased contents of the wetting agent is partly eliminated. On this basis, and by the use of the average figure in cases where, for the same alteration of concentrations, several measurings have been made, the following tabulation can be worked out, namely:

	Factor for change in concentration $(f(x_1) : f(x_2))$					
Actual, rel.	1.79	2.76	2.91	4.93	8.05	14.38
Change in deposit[1])	1.72	2.59	3.09	4.32	8.28	17.75

[1]) Data adjusted for effect of concentration on number of spots.

The factors found correspond fairly well to the theoretic ratio between the concentrations in accordance with the equation set up (7). The correlation between the liquid concentration and deposits after mist spraying is shown in Fig. 2. For the calculation, the primary median values from both experiments have been used, and within the interval tested, it is a question of rectilinear correlation.

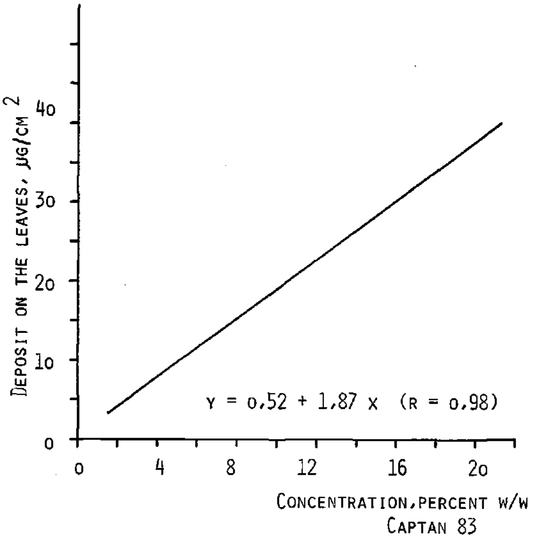

Fig. 2. Air mist blower. Increasing concentration of Captan 83. Effect on deposit on the leaves.

Table 3. Drop sizes (µm, VMD) at different liquid concentrations.

	ULV	Mist sprayer	
Liquid conc.	17/6–77	11/10–76	17/7–77
1.48 per cent	252	189	181
4.32 per cent	232	177	169
11.89 per cent	191	183	186
21.26 per cent	205	–	190

5.1.5 General observations on pesticide concentrations

The replacement of gun launchers and/or mast sprayers by air mist sprayers involved compensation for the lower amount of liquid by a proportional increase of the pesticide concentration. With the low concentrations used so far, even a tenfold increase has hardly brought about any major changes of the physical properties of the spraying liquid. However, an increase of the concentration in connection with still smaller amounts of liquid will, for many pesticides, involve considerable preparation amounts so that the changed physical properties of the spraying liquid may affect the results obtainable by the sprayer.

In the present investigation, an increase of the concentration up to 21.3% Captan 83 has, for both sprayers, resulted in a smaller drop size, the distribution giving a greater number of spots according to a curve pattern showing the maximum af 4–5% concentration. The preparation used contained wetting agents etc. When the concentration is increased, the wetting agents will further the split-up into drops whereas the higher viscosity will have the opposite effect (*Maas,* 1971). This resulted in a curve form as that sketched out in Fig. 3, showing a probable explanation of this phenomenon.

By partly eliminating the said effect on the size of the drops, it has been established that the deposit is changed proportionately to the concentration.

The air mist sprayer gave no difficulties when working with a concentration increased to 21.3% whereas the ULV sprayer proved unable to work satisfactorily with concentrations higher than 6–8%. With a full preparation amount of, for instance, Captan 83, it will, therefore, be unable to work with liquid amounts lower than 35–40 l/ha. A number of pesticides formulated and intended to be used for ULV spraying are available, i.e. almost concentrated pesticides which may be used wholly or partly undiluted (*Maas,* 1971). The mist sprayer has, however, proved able to work with so high concentrations that this should not, for technical reasons, be necessary for ULV sprayings.

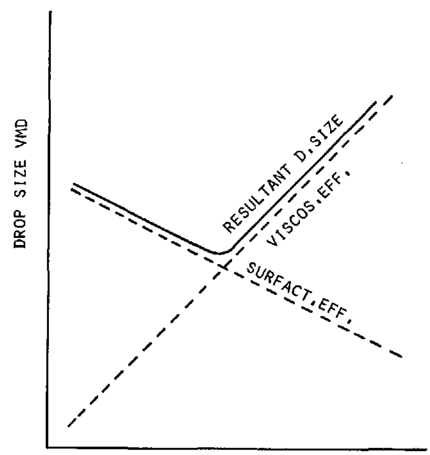

Fig. 3. Expected changes in drop size as a result of changed physical properties in spray liquid caused by changed concentration of pesticide in the spray liquid.

5.2 Significance of liquid amount

During the spraying, a build-up of liquid amounts on the plant surface will take place. During this process, there will be a merging of the drops whereby an increasing number will exceed the weight that can be retained. Therefore, part of the liquid will drip off to an extent which must be expected to increase according to a curve which will asymptotically approach the liquid amount applied. Correspondingly, the deposit is expected to approach asymptotically a maximum value. Therefore, the rectilinear function derived from *Jones et al.* (1974) and *Frick* (1970), shown in (5), seems to apply in case of very small liquid amount intervals only.

Therefore, for the dependence of deposit (d_a) on the amount of liquid (1), the following equation has been set up:

$$(8) \quad d_a = b_0 e^{b_1 l}$$

with b_0 and b_1 = standardization constants attached to the given spraying equipment with a given adjustment. According to equation (8), deposit will be an exponential function of the amount of liquid.

5.2.1 Experiments, design, and conditions

For the purpose of proving the equation (8), experiments have been carried out according to the following design:

	Driving pace, km/h			ULV sprayer
	Mist sprayer			
	4/10–76	29/7–77	21/8–78	29/7–77
a.	2.6	2.9	–	2.3
b.	3.2	3.6	3.6	2.9
c.	5.7	6.3	6.3	5.1
d.	9.1	10.1	10.1	8.2

where, for each sprayer, it has been endeavoured to arrange concentrations and adjustment as shown below:

	ULV	Air mist sprayer		
	29/7–77	4/10–76	29/7–77	21/8–79
Liquid amount at normal driving pace, l/ha	12	173	80	207–85
Conc. of liquid, % w/w	25.0	1.478	5.0	1.478

The experiments were carried out according to design on the dates stated and under conditions as shown in Main Table 1.

5.2.2 Deposits, air mist sprayer

The results of the measurements have been plotted as frequency curves in Main Figs. 7, 8, 9, and 10. In the two experiments in which 4 amounts of liquid were applied, it was not possible to separate the curves for the highest two amounts because the difference between the medium values was too small and the curves were practically coincident.

Correspondingly, it was not possible to separate the median values for the lowest two liquid amounts in the trial made on 21st August 1978, with a basic adjunstment of 85 l/ha. The results obtained, expressed by the liquid amounts retained as an average on the leaves of the trees, are shown in Table 4. The two sprayings carried out on 21st August 1978, are directly comparable as regards the effect of the amounts of liquid changed by the change of the sprayer adjustment (basic adjunstments 207 l/ha and 85 l/ha). Such change brought about a complete, proportional change in the liquid retained, from 203.88 to 89.09 $\mu g/cm^2$. There is a considerable difference between the liquid amounts retained on the 3 dates of spraying, which, in particular, seems ascribable to the temperature variations during the sprayings (vide par. 5.4).

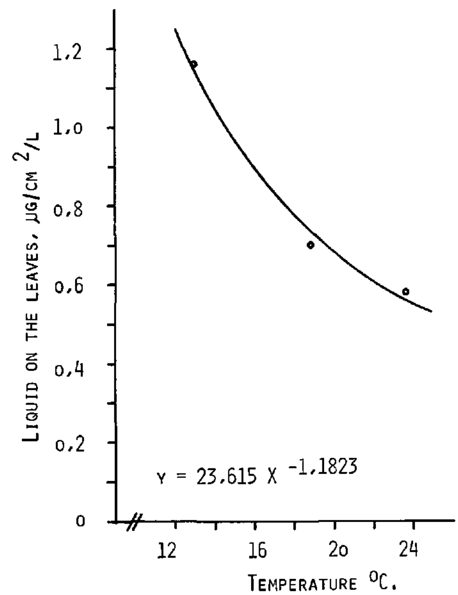

Fig. 4. Air mist blower. Effect of temperature on retained amount of liquid on the leaf surface.

Fig. 4 shows the correlation between temperature and retention of liquid amounts per litre spraying liquid. It will be seen that the retention levels found can be described as a power function of the temperature.

The spraying carried out on 29th August 1977, gave a rather great number of samples without deposit (Table 5) so the results from the said trial must be considered as not quite typical. In the other three sprayings, the liquid amounts retained are evidently decreasing per liter spraying liquid applied with increasing liquid amounts. This was also the case with the highest 3 amounts on 20th July 1977.

Table 4. Liquid amounts retained at different liquid amounts per ha (mean figures)

	l/ha	l/ha average	retained liquid $\mu g/cm^2$	retained liquid $\mu g/cm^2$ average	retained liquid $\mu g/cm^2 \cdot l$
4/10, 76	173	405	246.96	450.61	1.34
	292		345.74		1.18
	511		547.36		1.07
	635		664.41		1.05
29/7, 77	80	178	51.53	120.71	0.64
	128		107.98		0.84
	224		158.28		0.71
	279		165.03		0.59
21/8, 78	85	153	62.25	89.09	0.73
	136		71.72		0.53
	238		112.31		0.47
	207	373	142.08	203.88	0.69
	332		167.79		0.51
	581		301.76		0.52

Within the individual time of spraying and the intervals between the amounts of liquid, the correlation between the amount of liquid deposited and the amount of liquid applied can best be described as an exponential function in accordance with equation (8). For the spraying carried out on 29th July 1977, the curve represents, however, a logarithmic function, due to the great number of negative samples.

5.2.3 Deposits, ULV sprayer

From Table 5 it will be seen that for both sprayers samples without deposit were found. As far as the ULV sprayer is concerned, the number was so great that there would be no sense in making further calculations on the basis of the material. For both sprayers it will be seen that increasing liquid amounts give an essential reduction of the negative samples.

Table 5. Percentage of samples without deposit 29/7, 1977

ULV sprayer		Air mist sprayer	
l/ha	% samples without deposit	l/ha	% samples without deposit
12.0	85.2	90	20.4
19.3	63.0	128	5.6
34.0	50.0	224	5.6
42.8	44.0	279	0

5.2.4 Distribution, air mist sprayer

The distribution of spots (Main Figs. 11 and 12) was assessed on 4th October 1976, and 29th July 1977, and is, in mean figures for the test of 4th October 1976, shown in Fig. 5. Expressed in median figures, the number of spots after each of the two sprayings follows a curve, which can be described by

$$(9)\ y = a\, e^{\frac{b}{x}}$$

the number mounting asymptotically to 77 in both tests. When computed on the basis of mean values, this gives a logarithmic curve as shown in Fig. 5.

As regards the liquid applied/liquid retained ratio, it seems just as relevant to use total retained

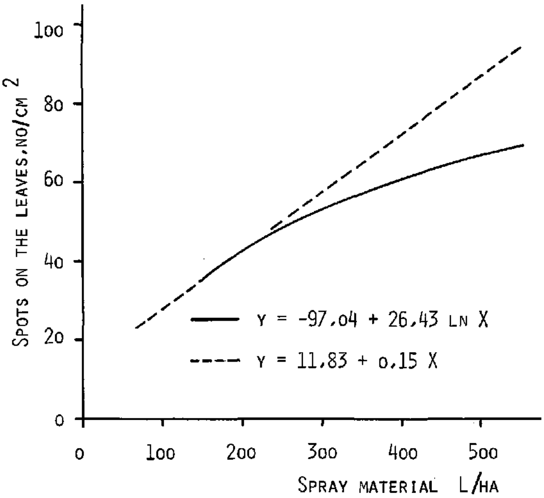

Fig. 5. Air mist blower. Increasing amount of spray liquid per hectare. Effects on number of spots on the leaf surface.

liquid amount as to use median values. Such computation relative to the spraying of 4th October 1976, is shown in Table 6. As there is the same number of samples in the various groupings in the table, mean figures have been used instead of total amounts of liquid retained.

With increasing liquid amounts the drop size increases from 229 μm to 258 μm, and the correlation follows the same exponential curve pattern as that representing the amount of liquid retained in relation to amount of liquid applied, as

$$(10)\ y = 215.59\ x\ e^{0.0028x}\ (r = 0.99)$$

Thus, computations on the basis of the median values as well as of total liquid retained confirm increasing merging of drops at the impact on the plant surface with increasing liquid amounts. The drop size thus enlarged will result in increased reduction by dripping, as presupposed in eqvation (8).

If the number of spots is computed as if being diametrically alike (basic adjustment) according to

$$(11)\ \text{number of spots} = \frac{8 \times \frac{100}{\text{conc.}} \times 10^6 \times \mu g/cm^2}{4/3\ \pi \times d^3}$$

Table 6. Distribution of spots and drop sizes after application of varying liquid amounts. Spraying on 4/10, 1976

	Upper leaf surface (o)				Lower leaf surface (u)				Mean figures		
l/ha	173	292	511	635	173	292	511	635	o.	u.	Mean figures
Zone 1	74	71	86	94	38	34	60	82	81	54	68
Zone 2	43	56	90	75	43	51	58	63	66	54	60
Zone 3	15	36	40	43	28	77	73	83	34	65	50
Mean figures					40	54	68	73	60	58	59
Zone 1	207	215	250	224	247	274	273	287	224	270	247
Zone 2	204	211	229	213	244	252	257	283	214	259	236
Zone 3	220	211	231	277	252	225	251	265	235	248	242
Mean figures					229	231	249	258		224	259

derived from (4), a complete smoothing out of the curve is obtained as shown in Fig. 5.

Vertical distribution of spots in the trees (Table 6) shows the same pattern as that described below for standard sprayings (under 5.3.3), most of the spots being found on the upper surfaces of the leaves from the lowest zone of the trees. On the whole, there is no difference between the number of spots on the upper and the lower surfaces of the leaves.

The spot sizes increase with increasing liquid amounts, such increase being uniform on the upper surfaces of the leaves in the three zones. On the other hand, the spot size on the lower surface of the leaves shows the greatest increase in the base zone of the trees (zone 1). The spot sizes found (207–287 μm) have been calculated on the basis of the average amounts of liquid retained, not on the basis of median values.

Normally, this method of computation gives larger drop diameters than VMD. The computed figures do not, however, exceed the figures given as normal for mist sprayers. Further, it must be taken into consideration that the registered temperature effect will bring about an increase of the drop sizes with the declining air temperature. This is concordant with earlier results from measuring of drop sizes on sprayers (*Reichard et al.*, 1977).

5.2.5 General observations on amounts of liquid

It has been one of the primary objects of this investigation to elucidate the importance of the application of different liquid amounts, in particular small amounts of liquid. A number of reports on such investigations are available (*Morgan*, 1972, 1972c, 1973, 1974; *Byass & Carlton*, 1965; *Stafford et al.*, 1970; *Cooke et al.*, 1976a, and others). These investigations have, however, been carried out in such a way that the amount of liquid was altered simultaneously with exchange of the spraying equipment, change of the sprayer adjustment and/or the liquid concentration, and, consequently, the causal factor cannot be clearly isolated. The methodology used in the present investigation has, as far as possible, only involved alterations of the liquid amounts. As a starting point, sprayer adjustments used in practice were chosen, and then the amount of liquid was being changed by varying the driving pace. Thereby interference in the sprayer adjustment was avoided whereas the air velocity at a given distance from the air nozzles of the sprayer was presumably being changed.

Reichard et al. (1977) found in a trial setup with 3 different sprayers a reduction of abt. 20% when the driving pace was increased from 4 km/h to 8 km/h. The importance thereof and under practical spraying conditions has not been clarified. By reduction of the liquid amount expressed in litre per ha, the utility was increased in accordance with *Yates et al.* (1974) and *Morgan* (1978), so the deposit was not reduced to the same extent. With the same deposit, 22–26% of the pesticide amount could be saved by reduction of the liquid amount with the intervals used in the present investigation.

Likewise, the number of spots per cm^2 was reduced at a lower rate than the reduction of liquid amounts should have brought about. Therefore, to a certain extent this resulted in a smaller size of the spots. Conversely, the results indicate that an increase of the number of spots can only to a certain degree be achieved by increasing the liquid amount when no change is made of the size of the drops produced by the sprayer.

Unfortunately, the ULV sprayer was not suitable for ULV liquid amounts proper. The difficulties were, however, due to faulty construction of the sprayer and had nothing to do with small amounts of liquid. The use of the small liquid amounts and the vigorous atomization in this test absolutely necessitates non-pulsatile liquid inlet to the nozzle, and it was especially on this point that the construction was found inadequate. Considering the results obtained by the mist sprayer, nothing seems to prevent the use of small liquid amounts provided that spraying equipment properly constructed to meet the requirements is used.

Tabulated result of application of different liquid amounts[1])

Factor of change in liquid amount	Retained liquid, $\mu g/cm^2 \cdot 1$ time of spraying and temperature			
	4/10-76	29/7-77	21/8-78	21/8-78
	13°C	18.7°C	23.6°C	23.6°C
× 1	0.99	*)	1.10	1.04
× 1.6	0.87	0.96	0.80	0.77
× 2.8	0.79	0.81	0.71	0.78
× 3.5	0.78	0.67	–	–

[1]) Retained liquid amounts adjusted to the same temperature, 16.8°C, according to
$y = 23.615\ x^{-1.1823}$ (r = 0.99) for x = °C

*) 20% of samples without deposit.

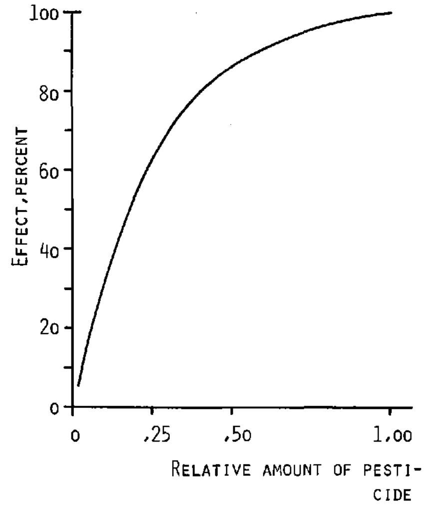

Fig. 6. Effect curvae between amount of pesticide (kg/ha) and spray result. Very often 1/3 of the total pesticide produces 2/3 of the effect.

5.3 Spraying with normal and reduced amounts of pesticide

A comprehensive material is available concerning the effect of applied pesticide amounts (kg/ha or concentration in per cent) from which can be derived a fundamental curve pattern as shown in *Fig. 6* (*Hansen et al.*, 1972; *Nøddegaard & Hansen*, 1974; *Nøddegaard et al.*, 1965; *Hansen & Schadegg*, 1973; *Morgan*, 1974; *Mapother & Morgan*, 1970, and others). The consequence of such curve pattern is that a 100% effect would require disproportionately great amounts of pesticide. In general, a 60–80% effect is achieved with abt. 1/3 of such amounts. All results of the investigations mentioned were based on the amounts of the pesticides applied, not on the deposits actually retained on the trees.

This project gave no possibility of experimental investigations of the dosage/effect correlation; consequently, a necessary reference was established empirically. For mist sprayers in orchards, the following standard are used: Abt. 200 l/ha with a pesticide concentration as that fixed by the Institute of Plant Pathology at Lyngby. The sprayers are calibrated for such outlet with a period of treatment of 12–15 min./ha, corresponding to a driving pace of 8–10 km/h.

By measuring the deposit obtained by this standard spraying technique an expression is found of the amount and distribution of the deposit which, by application and use in practice, have proved to give a satisfactory effect.

In order to test the effect of reduced pesticide amounts, especially in connection with the ULV sprayer, sprayings with reduced pesticide amounts were carried out. It was to be presumed in advance that small reductions would, according to Fig. 6, give small reductions of the effect, difficult to measure, and therefore only 40% of the standard pesticide amount was used. Thereby, other things being equal, a 40–60% effect of the spraying should be secured, thereby rendering it possible to make a biological measuring of the differences between the sprayers used. A further incentive was that the maker of the ULV sprayer used prescribes 50% of the standard pesticide amount as being sufficient for the full effect of the ULV spraying.

5.3.1 Normal pesticide amount, experiments, design, and conditions

The air mist sprayer to be used with 165–200 l/ha at a driving pace of 9–10 km/h. Adjusted with 15 nozzles (7 on either side) with disc/insertion at 1.5/0.9, fluid pressure 4.2 kg/vm^2, air pressure 5.0 kg/cm^2 and 540/600 revs. of the power transmission shaft. Otherwise, sprayings are carried out under the conditions given in Main Table 1. Experiments carried out on 27th September and 11th October 1976, and 17th June 1977, were used for assessment.

5.3.2 Deposits

The distribution of deposits is shown in Fig. 7, in number as well as frequency. The most frequently appearing value is 1.84 μg/cm^2, and the median value is 2.30 μg/cm^2. The distribution of the 520 samples over the three individual experiments and on the upper and lower surfaces of the leaves are shown in Main Figs. 13 and 14. In spite of the different spraying dates and the ensuing differences in the conditions (Main Table 1), the data prove to be fairly uniform, both from time to

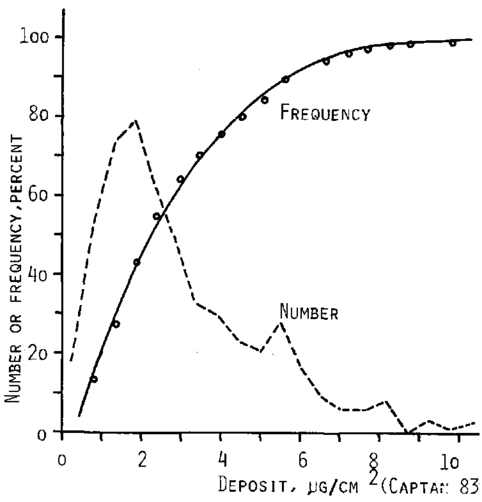

Fig. 7. Standard spraying with air mist blower. Deposit on the leaves based on 3 spraytimes. Total of 520 samples. Median deposit is 2.3 µg/cm.

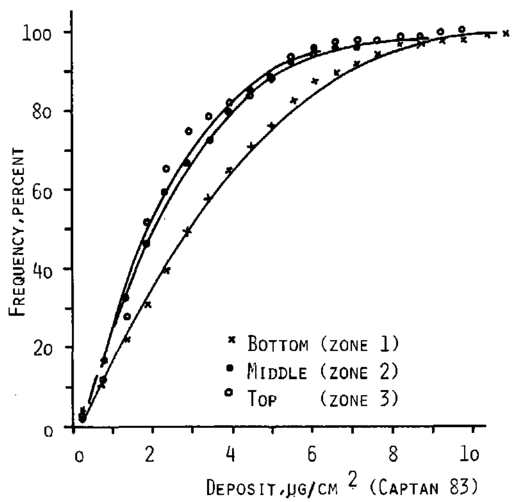

Fig. 8. Standard spraying with air mist blower. Deposit on the leaves in the 3 zones vertically in the trees.

time and between the upper and lower leaf surfaces. As mentioned under Material and method, the frequency curve can most appropriately be described as a cubic polynomial, and the smoothed-out curve in Fig. 7 is bases on

$$(12)\ y = 7.05 + 31.86x - 3.34x^2 + 0.11x^3 \quad \text{for } o < y < 100$$

The vertical distribution in the trees is shown in Fig. 8. In the upper two thirds of the trees, deposits are almost uniform whereas they are abt. 50% higher in the lowest third. The reason therefor must be the shorter distance from the spraying aggregate, the direction of the nozzles, and the dripping-off from the upper parts of the trees. Some variation in the deposits after the three sprayings was observed, the greatest variation being seen in the base zone (Main Fig. 15).

The deposits on the upper and lower leaf surfaces were found to be almost identical (Main Fig. 14). A vertical examination of the trees (Fig. 9, Main Fig. 16) shows, however, that it is a question of interaction. The lowest deposit was found on the upper leaf surfaces in the top of the trees whereas the highest deposit was found on the upper surfaces in the basic zone.

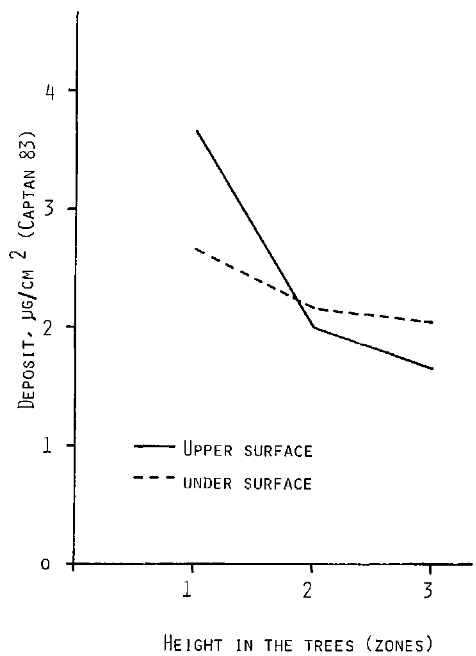

Fig. 9. Standard spraying with air mist blower. Deposit on the leaf surfaces vertically in the trees.

In the 3 sprayings, the greatest deviation in deposits on the upper leaf surfaces was found in the lower third of the trees (Main Fig. 15), which indicates that, as mentioned above, there has been some dripping off from the upper parts of the trees, giving an accumulation varying with the amount of the dripping-off liquid.

5.3.3 Distribution

The distribution of the 520 data used in the underlying 3 experiments is shown in Main Fig. 17, and for the upper and lower surfaces of the leaves, in Main Fig. 18. The total distribution of spots (Fig. 10) gives the same curve pattern as the deposits, the most frequent value being 25 spots/cm^2 and a median value of abt. 40 spots/cm^2. The curve pattern shown can, as was the case with deposits, be described as a cubic polynomial in the interval $8.12 \lesssim y \lesssim 98$ according to

$$(3)\ y = 0.36 + 1.53x - 0.01x^2 + 0.000014x^3$$

As regards the number of spots, there is a clear and parallel interval between the curves for the upper and lower leaf surfaces (Main Fig. 19), the greater number being found on the upper surfaces. The horizontal distribution in the trees is shown in Fig. 11. As was the case with deposits, it is also here a question of the lower third of the trees clearly deviating with abt. 50% more spots than the upper two thirds, no difference between the upper zones having been found.

The uniformity of the distribution from one spraying to another was highest in the middle third of the trees and lowest in the upper and, in particular, the lowest third, as was the case with deposits (Main Fig. 15). Also as regards number of spots it is a question of interaction vertically in the trees when leaf surfaces are taken into consideration as shown in Fig. 12 and Main Fig. 20.

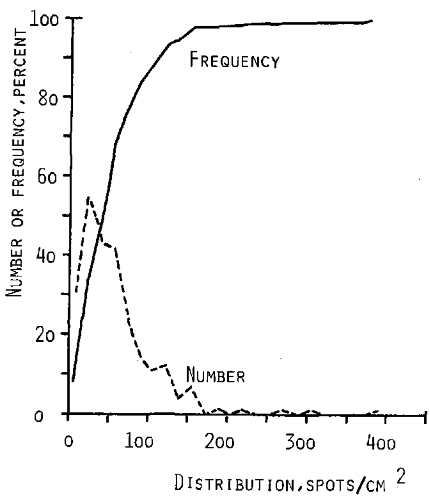

Fig. 10. Standard spraying with air mist blower. Number of spots on the leaves based on 3 spray times.

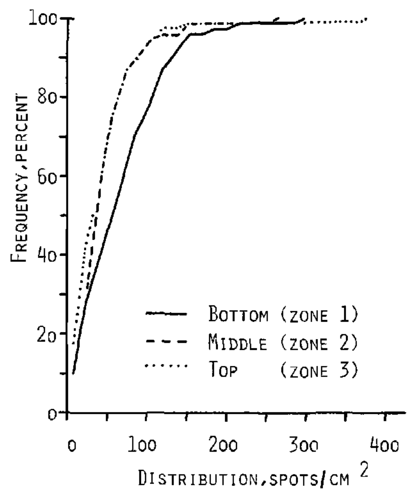

Fig. 11. Standard spraying with air mist blower. Number of spots on the leaf surface in 3 zones vertically in the trees.

The greatest number of spots was found on the upper surfaces in the lowest third, and the smallest number on the lower surfaces in the middle third of the trees.

The correlation between deposit and number of spots was calculated by reading the quantile values 0, 10, 20 . . . 90 on the respective smoothed-out frequency curves and collocating these values as shown in Fig. 13. Thereby deposit (y) appears as a rectilinear function of the number of spots (x) according to

(14) $y = 0.333 + 0.0504x \quad (r = 1)$

as a given part of the spots corresponds to the same part of deposit. The reason why the curve does not pass through 0.0 is explicable by the fact that when the number of spots approaches zero, the spot size is increasing, the samples in question having, for instance, been badly placed in relation to the spray and having only been reached by either a few big drops or by drops dripping off from other leaves. On the basis of the values found for deposit and number of spots a drop size can be calculated as described under Material and method (equation 5).

Table 7. Calculation of drop size after normal spraying

	Drop size µm VMD			
	Zone 1	Zone 2	Zone 3	Av.
Upper leaf surface	184	179	186	183
Under leaf surface	211	207	188	202
Av.	198	193	187	193

Table 7 shows values for drop diameters calculated on the basis of median values from Main Figs. 16 and 20. The biggest drops were found on the lower leaf surfaces in zone 1, the smallest on the upper surfaces in zone 2. VMD is decreasing with increasing height in the trees and, on the whole, biggest on the lower surfaces of the leaves. The methods of spraying and calculation used make it then possible to lay down an empirical standard for sprayings as shown in Table 8. Due to the variations given, for instance in the temperature at the time of spraying, it will, in particular, be applicable to a series of sprayings. For a pesticide like Captan 83, the liquid amount retained will correspond to 2.3 µg captan/cm^2.

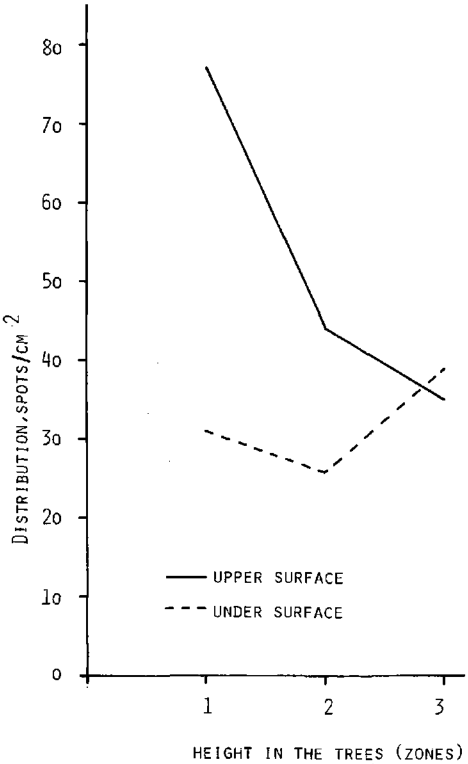

Fig. 12. Standard spraying with air mist blower. Number of spots on the leaf surfaces vertically in the trees.

Table 8. Emperical standard for spraying with air mist sprayer at normal conditions

Retained	Median values
Deposit of liquid, $\mu g/cm^2$	156
Destribution of spots pr. cm^2	40
Drop size, μm VMD	193

5.3.4 Normal pesticide amount in general

As an average of several sprayings at different times within the period of growth, the deposit after sprayings with normal amount of pesticide, Captan 83, is found to be 2.3 $\mu g/cm^2$. From investigations made by *Frick* (1970), *Jones et al.* (1974), *Cooke et al.* (1975), and *Cooke et al.* (1976 a and b) can be calculated that, in the investigations mentioned, deposits of the same magnitude had been found, in the last-mentioned two investigations, these had been 2.6 $\mu g/cm^2$. Some variations in the amounts of deposits between the different dates of spraying had been found in these investigations too.

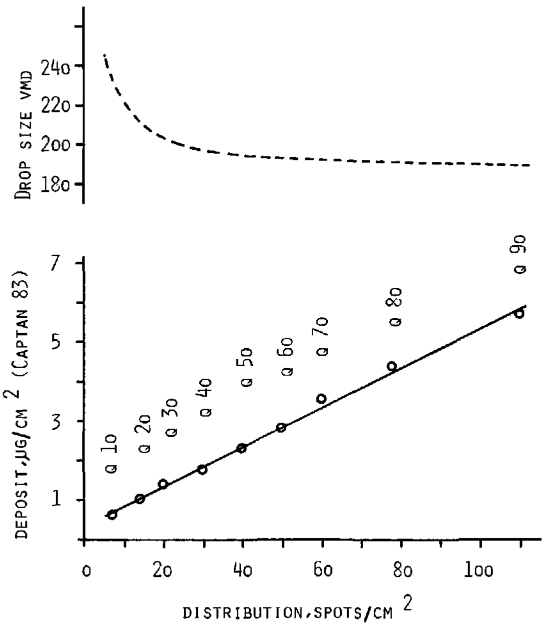

Fig. 13. Standard spraying with air mist blower. Regression line between frequency curvaes for deposit and number of spots. Each point indicated by the quantile. Resulting drop size given in the upper curvae.

The pattern found for the distribution vertically in the trees and between the upper and lower surfaces of the leaves is in conformity with the results recorded by *Byass* and *Carlton* (1965) and *Jones* and *Morgan* (1974). With the rather great variations found, there will be areas with over- and under-depositings (*Byass & Carlton,* 1963), which presumably will be compensated for where repeated sprayings are carried out. The number of spots, 40/cm^2, found is surprisingly low but in conformity with the results from aeroplane-sprayings of cotton (*Maas,* 1970). Provided that the drop size of the sprayer used here is fairly similar to that of the sprayers used in the investigations of the amounts of deposit referred to above, the number of spots must have been the same

Table 9. Review on results of sprayings with normal amounts of pesticide at standard spraying technique[1])

Dato	27/9–76	4/10–76	11/10–76	17/6–77	21/8–78
Temp. °C	16	13	14	19.5	23.6
l/ha	165	173	200	197	207
Conc.[2])	1.48	1.48	1.48	1.48	1.48
Retained liquid $\mu g/cm^2 \cdot l$	0.78	1.09	0.95	0.69	0.53
Spots/cm^2	38	28	43	40	–

[1]) Median-values [2]) Concentration of Captan 83.

as in the investigations mentioned as, on the whole, deposits were the same. The drop size found is perfectly in conformity with the drop sizes usually given for mist sprayers and with measurements made by *Richard et al.* (1977).

Table 9 shows a review of all sprayings carried out as standard sprayings. The retained liquid amounts per litre liquid applied can, as mentioned before be expressed as a power function of the temperature at the time of spraying, according to

$$(15) \qquad y = 17.07856\ t^{-1.095}\ (r = 0.99)$$
with t = temperature.

When the temperature effect is taken into consideration, the deposit at 16.8°C, 200 l/ha, and standard adjustment can be calculated as 156 μg liquid per cm^2, corresponding to the ascertained 2.3 μg Captan 83 applied in a 1.48% concentration.

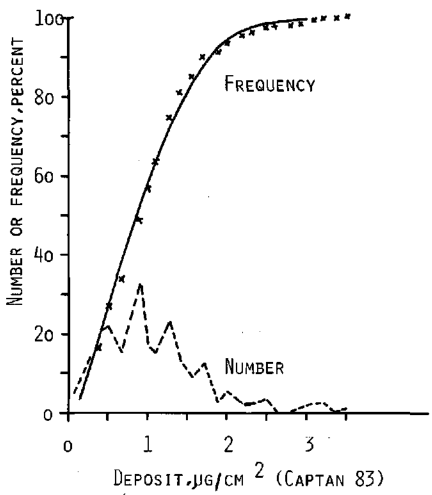

Fig. 14. Deposit after spraying with 40% of recommended amount of pesticide (Captan 83). Air mist blower.

5.3.5 Reduced pesticide amount, experiments, design, and conditions

In 1975, 1976, and 1977, an orchard of 1.4 ha comprising different apple varieties was sprayed according to a quite normal spraying programme at intervals of two weeks during the period of growth. The pesticides and fungicides applied will be seen in Main Table 2. The orchard was divided into 2 sub-plots of equal size (no replicates) and was sprayed in the following manner:

Sub-plot A: ULV sprayer, 12 l/ha, 40% of normal concentration.

Sub-plot B: Air mist sprayer, 80 l/ha, normal concentration.

The liquid amounts and the pesticide concentrations used resulted in the application of 40% of the standard amount of pesticide. In connection with the experiment, the effect of an evaporation-inhibiting additive (Ulvapron (*Anon.*, 1977)) was tested. The other conditions will be seen in Main Table 1.

5.3.6 Deposit

Determinations of deposits were made three times in 1977 and once in 1979. After ULV sprayings, there was a very great number of samples without discernible deposit (Table 10), and the addition of an evaporation-inhibiting agent (*Anon.*, 1977) showed no effect thereon, whereas it was effective in connection with the mist sprayer. Out of 216 samples taken after 3 sprayings there was in no case more than 50% with deposits after the ULV sprayer whereas the mist sprayer gave samples without deposit in one case only. By comparison with the results of the evaluation

Table 10. Percentage of samples without discernible deposits

Sprayer	9/6–77 ULV	9/6–77 air mist	23/8–77 ULV	23/8–77 air mist	30/8–77 ULV	30/8–77 air mist	30/8–77 ULV	30/8–77 air mist	13/6–79 air mist
Liquid am. l/ha	12	80	24	80	24	80	24	80	80
Conc., %	9.1	1.5	4.8	1.5	4.8	1.5	4.8	1.5	1.5
Evaporation inhibitor	no	no	no	no	no	no	yes	yes	no
Samples without dep. %	50	0	72	0	58	4	69	0	0

of the spraying effect mentioned below, further computations in respect of the ULV sprayer were deemed to be without interest in this experiment.

The distribution of deposits (Fig. 14) after mist sprayings shows the same curve pattern as after normal sprayings. The most frequently occurring value in 1977 was 0.91 $\mu g/cm^2$, and the median value was 0.84 $\mu g/cm^2$, both calculated as Captan 83. The distribution of the underlying 214 data from the three separate experiments in 1977 is shown in Main Fig. 21. In relation to sprayings with normal amounts of pesticide, the median value was reduced to abt. 37% against the theoretical expectation of 40%.

The curve patterns for normal amount of pesticide (x) and for 40% of normal amount of pesticide can be deduced from each other by a rectilinear function, which, for the reduced amount of pesticide (y), is as follows:

(16) $y = 0.1 + 0.32x$ $(r = 0.998)$

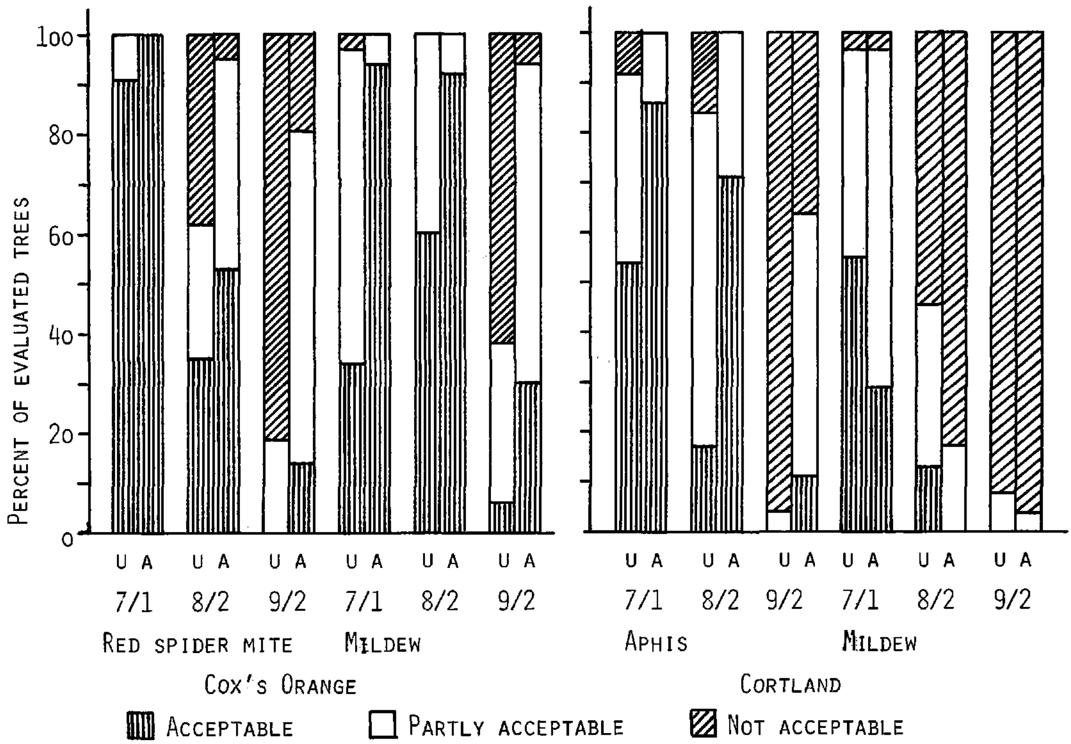

Fig. 15. Spraying with 40% of recommended amount of pesticides. Effect on red spider mite, mildew and aphids in 1976 at the given times.

Thus, it is a question of the readjustment of the sprayer from abt. 200 l/ha to 80 l/ha having reduced the liquid retained (and thereby the deposit) proportionally, so it is not only a question of a parallel displacement of the curve.

The equation giving the curve pattern for the 40% amount of pesticide is, analogous with the curve for normal amounts, as follows:

$$(17)\quad y = 16.28 + 97.01x - 30.00x^2 + 3.11x^3$$

The number of spots (Main Fig. 22) was counted in 1979, showing that no changes had occurred therein due to the readjustment of the sprayer from 200 to 80 l/ha.

5.3.7 Spraying effect

For fear of winddrift in particular, it was necesarry to use large plots and, consequently, it was not possible to establish replicates. This was a motivation for a more practical measurement of the spraying effect. The assessment was made by a visual grouping of the trees according to acceptable, partly acceptable, and unacceptable effect. All attacks of diseases found were estimated.

Generally speaking, none of the sprayers gave sufficient effect with the amount of pesticide applied, Figs. 15 and 16. The ULV sprayer was definitely less effective against aphids (*Aphis pomi*), fruit tree red spider mites (*Panonychus ulmi*), and against powdery mildew (*Podosphaera leucotricha*) in 1976. For both sprayers, the attacks of red spider mites became so severe that it was finally necessary to carry out control with mist sprayer and normal amount of pesticide. In 1977, only attacks of powdery mildew occurred. In Cox's Orange, which is moderately susceptible to this disease, the mist sprayer was having an almost sufficient effect, but not so with the ULV sprayer. In Cortland, which is highly susceptible to powdery mildew, none of the sprayers had an acceptable effect.

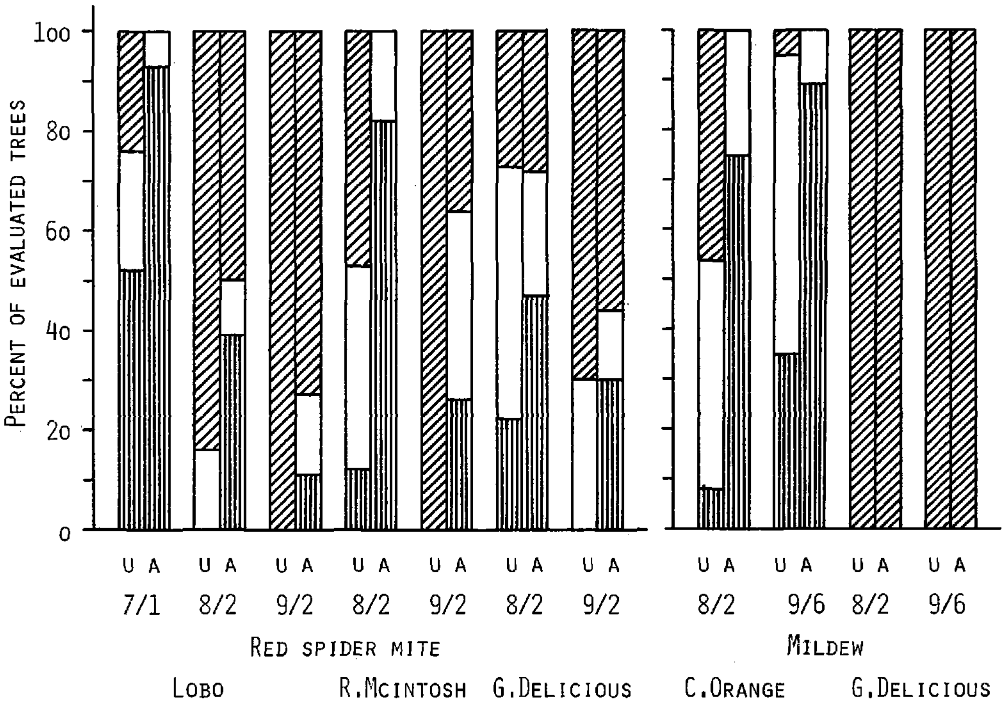

Fig. 16. Spraying with 40% of prescribed amount of pesticides. Effect on red spider mite in 1976 and mildew in 1977 at the given times.

Table 11. Fruit quality 1975, 1976 and 1977. 40% pesticide

Cultivar	stored until		% with russeting	% with rot and Gloeosporium	storage
Golden Delicious	23/3–76	air mist sp.	32.9	3.0	cold st.
		ULV-sp.	21.5	5.7	
Cortland	23/3–76	air mist sp.	5.9	1.9	cold st.
		ULV-sp.	7.5	1.3	
Cox's Orange	30/11–76	air mist sp.	20.1	3.1	cold st. +
		ULV-sp.	26.6	3.1	cold air
Cox's Orange	6/2–78	air mist sp.	47.8	1.0	cold st. +
		ULV-sp.	42.9	1.3	cold air

Fruit from the experiment was, after storage, sorted for russeting and rot (Table 11). There was no measurable difference between the effect of the sprayers.

The sprayings were carried out according to the same design in 1978 and 1979. Observations from these years were in complete conformity with the results obtained in the experimental period.

5.3.8 General observations on reduced amounts of pesticide

Today, several spraying preparations especially formulated for use in ULV sprayers are available, i.e. highly concentrated pesticides with very low steam pressure (*Maas,* 1971) to be used in an undiluted state. Such preparations have, however, not yet been introduced in orchards in this country, and therefore it has not been found of immediate importance to test them, normally used pesticides having been exclusively used instead. As it was expected that modest reductions of the amount of pesticide would only give small reductions in the effect, which would be difficult to measure, a reduction down to 40% of the prescribed amount was chosen.

The sprayings over three years as mentioned above have given unsatisfactory biological effects, and the extent thereof seems to be in conformity with the reduction of the pesticide amount.

The number of spots was found to be the same as that recorded for the normal pesticide amount, so the effect measured was alone a result of the lower amount of pesticide. It has been established above that there is good correlation between the concentration of the pesticide and the deposit and, consequently between the liquid amount per ha and the deposits. Thereby, there should also be a good correlation between effect and deposit so this ratio can be represented by the same curve pattern (Fig. 6). The results found seem to be well correlated therewith.

Table 12. Rewiev on results of sprayings with 40% of pesticide with air mist sprayer[1])

Dato	9/6–77	23/8–77	30/7–77	21/8–78	13/6–79
Temp. °C	16.5	18.5	21.5	23.6	12.8
Liquid amount, l/ha	80	80	80	85	80
Conc. per cent[2])	1.478	1.478	1.478	1.478	1.478
Retained liquid, $\mu g/cm^2 \cdot l$	0.73	0.83	0.60[3])	0.67	1.23

[1]) Median values
[2]) Concentration of Captan 83
[3]) Non evaporative agent added

The liquid amounts retained as shown in Table 12 correspond, on an average and at a temperature of 16.8°C, to a deposit of Captan 83 of 1.0 $\mu g/cm^2$ at 80 l/ha with a concentration of 1.48%. This corresponds to abt. 44% of 'standard' in accordance with the reduction aimed at.

This part of the completed investigations had, as one of its objects, to find out whether the ULV sprayer and the technique used were viable and, in particular, whether the preconceived improvement of the distribution of the deposits justified a reduction of the pesticide amount. For the ULV sprayer used, already the numerous samples without deposit and the aggravation shown at increased concentration, proved that the technical performances of the sprayer do not come up to expectations.

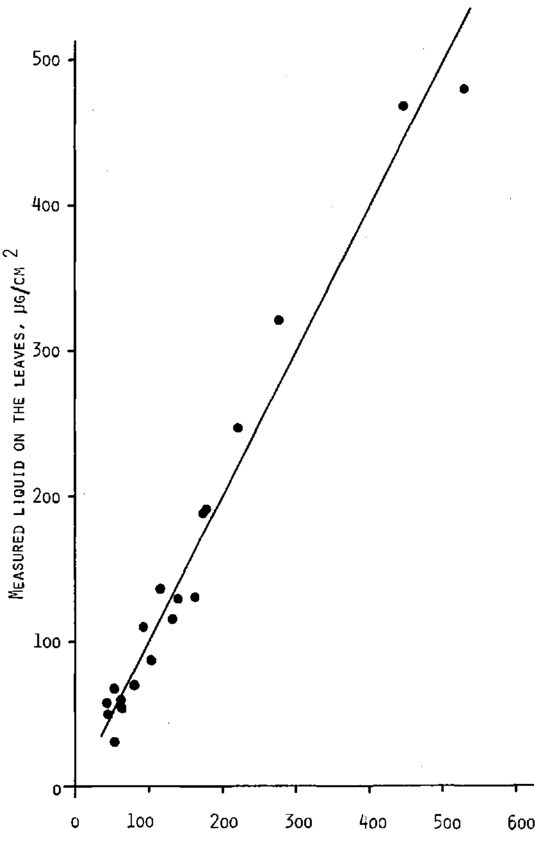

Fig. 17. Relation between calculated and measured amount of liquid on the leaf surface according to liquid per hectare (l/ha) and temperature (°C).

During the experiments it was found that the sprayer has a tendency towards 'blobbing', a phenomenon which must be ascribed to pulsating influx of liquid into the rotating nozzles. This phenomenon seems to be universal as others (*Faust,* 1977) have found the same tendency. As regards the mist sprayer, there has been no question of a better distribution (greater number of spots) and therefore, an increased effect from smaller liquid amounts was not to be expected.

As to the choice of methodology to be applied for a reduction of the pesticide amount for the mist sprayer, several possibilities presented themselves, such as, in this case, to use normal pesticide concentrations with reduced liquid amounts. Another possibility was to use normal liquid amounts and reduced pesticide concentrations, or, as the third possibility, a combination of reduced liquid amounts and higher concentrations. It cannot be excluded that another effect might be obtained by making use of the lastmentioned possibility, especially when the effect of the higher pesticide concentration on the drop size and number of spots is taken into account.

5.4 Effects of temperature and liquid amount

In the preceding paragraphs (4.2.2 and 4.3.4) was mentioned the effect on deposits of the temperature at the time of spraying. It seems possible to forecast on the basis of equations (8) and (15) how great an amount of liquid will be retained at a given temperature at the spraying and with a given liquid amount. The following equation can be set up, namely:

$$(18) \quad y = ax^{b_1} \times e^{b_{2x}} \times t^{b_3}$$

By calculations on the basis of 20 tests for which the necessary data were available, the following equation could be set up, namely:

$$(19) \quad y = 42.51x^{0.95326} \times e^{-0.00024x} \times t^{-1.35496} \quad (r = 0.96)$$

The agreement between the prognosis and the actual data found is shown in Fig. 17, in which the curve superimposed on the graph represents the 1/1 ratio.

Table 13. Retained liquid on fruits and leaves after immersion

	Fruit size		Retained liquid, $\mu g/cm^2$	
	g/fruit	cm^2/fruit	fruits	leaves
Rød Ananas	88.1	106.3	2845[a]	4960[b]
Cox's Orange	90.3	103.8	3223[a]	4244[c]
Spartan	90.5	103.8	4256[b]	5653[a]
Golden Delicious	96.4	111.4	4617[b]	3535[d]
Av.			3735	4598
Sign.			***	***

5.5 Deposit at full liquid amount (laboratory experiments)

Prior to the construction of the air mist sprayer, the so-called full liquid amount was used. For sprayings by gun launcher until dripping set in was required 2.000–3.000 l/ha for intensely grown apple trees. For the purpose of determining how much liquid can be retained on the plant surface, a minor laboratory experiment was made.

Fruits and leaves were immersed into a 1.5% Captan 83 solution. After careful lifting and the dripping ended, the retained liquid amount was measured. The area of fruit rinds and leaves was measured by areameter (par. 3.3).

Within the individual varieties there were no differences between fruits or leaves on different trees. On the other hand, the fruits can be divided into 2 groups of different varieties. As regards the leaves, there is a significant difference between all 4 varieties (Table 13). In support of the varietal difference established, measurements were made on the 'Smoothe' variety. This differs from the mother variety 'Golden Delicious', by being more smooth-skinned and less disposed to russeting. As was to be expected, 'Smoothe' retained less liquid (Table 14) than 'Golden Delicious'.

Converted into deposit, the liquid amount retained on the leaves corresponds to 6.90 $\mu g/cm^2$. This is of the same magnitude as the largest deposits found in the field experiments carried out.

6. Discussion

For the planned test it was necessary to use the spraying equipment available instead of equipment developed for experimental use as, for instance, *Hale* and *Sharp* (1973, 1974). The air mist sprayer used was, however, extremely usable, giving uniform results from different sprayings. On the other hand, the technical construction of the ULV sprayer has proved unsatisfactory, resulting in nonuniform spraying results. Therefore, the results of this investigation have almost exclusively been based on the use of the mist sprayer. Hereby it is attempted to elucidate problems of fundamental importance which may set guidelines for the development of methods for the reduction of the pesticide amount.

The measuring of deposits by means of fluores-

Table 14. Retained liquid by fruits of 'Golden Delicious' and 'Smoothe'

	Fruit size		Retained liquid
	g/fruit	cm^2/fruit	$\mu g/cm^2$
Golden Delicious	142.8	148.4	4067
Smoothe	148.4	155.9	3200
Sign.			***
LSD			387

cent, watersoluble tracers has, to some extent, been used before and has been recognized as a usable method (*Staniland,* 1960; *Byass,* 1969; *Stafford et al.,* 1970; *Sharp,* 1974). The watersolubility secures correlation between the amount of tracers and the amount of pesticide whereas the lower solubility of starch might make it problematic whether the number of spots found corresponds to the real number. The deposit amount, which is measured with great accuracy, is, however, so closely correlated with the number of spots that, with a view to the fact that the deposit is zero when the number of spots is zero, a reasonable certainty is reckoned with in the counting of spots.

When samples were taken, leaves with a surface of more than 12 cm² were picked. Tests of the areameter unit used have shown that the error of measurement is less than 1% when such surface areas are used. Thus, together with the manual counting of spots, it is a question of the three paramenters by which the drop size is measured having been determined with great accuracy.

The drop sizes found for the mist sprayer actually correspond very well with the drops measured from the liquid spray, which are generally reckoned to be 200–250 μm as measured by, for instance, *Reichard et al.* (1977).

By spraying in the same manner as in practice, an empirical standard for the size of an adequate deposit has been established. For Captan 83, this has been found to be 2.30 μg/cm², which is of the same magnitude as that found in other experiments and in accordance with *Morgan* (1972) and *Warmann et al.* (1975) for adequate effect against scab and *Gloeosporium*. The number of spots per cm² found is surprisingly low but of the same magnitude as that found after sprayings of cotton (*Maas,* 1970). Thus, the mean distance between drops will be rather great compared with the diameter on, for instance, many hyphae. Therefore, a consequent effect must, to a certain degree, be ascribed to indirect contact between the primary spots and the pathogen. Actually, it has been established that there is an effect outside the area covered by a pesticide spot (*Bent,* 1967; *Hislop,* 1967). The pesticide spots only need to be quite small to contain a toxic amount of pesticide; for insecticides, only a drop if 20 μm is needed (*Agger,* 1977), many insecticides being lethal to insects in amounts as small as 100 ng (*Bals,* 1976). Greater importance must therefore be assigned to the mean distance between the spots than to the size of the spots so that many small spots must presumably be of greater effect with the same deposit than a few big spots in accordance with *Frick* (1970). The size of the standard deposit must therefore be seen in connection with the number of spots, which, slightly depending on the flattening out at the impact, only secure abt. 2.0% of the plant surface to be covered by the pesticide.

A reduction of the drop size from 200 μm to 70–80 μm does not seen in itself to bring about any major biological effect. *Frick* (1970) found increasing effect of Dinocap against powdery mildew when the drop size was altered from 400 μm to 175 μm, but no effect by a further reduction to 100 μm. *Fisher* and *Morgan* (1968) found increased effect against red spider mites by a drop size reduction from 1.560 μm to 575 μm. By extrapolation of the curve it can be rendered probable that, also in that case, the maximum effect is found at a drop size of abt. 200 μm. In experiments with reduced pesticide amounts and the same number of spots as in this experiment, the spraying effect has been reduced to an extent corresponding to the reduction of the pesticide amount. The drop size was reduced from 193 μm to 140 μm, apparently without any effect.

An increased effect of standard dosage seems attainable, not in consequence of smaller drops but through a better distribution with a smaller mean distance between the spots. An increase of the liquid amount increases the number of spots but gives, with a modest increase thereof, a considerably higher waste of the spraying liquid by its dripping to the ground. Instead, it would therefore be an obvious idea to reduce the waste by reducing the liquid amount as much as possible. To the extent the number of spots on the plant surface depends on the density of the liquid drops in the spray, it is, at the same time, necessary to reduce the drop size in order to retain and, if possible, to increase the number of spots. At 25 l/ha there will, with a drop size of, for instance 100 μm, be produced the same number of drops as at 200 l/ha with a drop size of 200 μm.

Deposits have been found to be somewhat greater in the lower parts of the trees than at the top in agreement with other investigations (*Byass & Carlton,* 1976; *Jones & Morgan,* 1974). This seems to depend on physical matters, such as the dripping off from the tree top and an inappropriate vertical orientation of the spraying nozzles in relation to the trees. In accordance with *Byass* and *Carlton* (1965) this seems to indicate that a better distribution vertically in the tree crown might lead to a reduction of the pesticide amount. Here an essential factor is a reduction of the dripping-off, which is obtained by reducing the liquid amount and the size of the drops. Merging drops will only with greater difficulty be able to grow to a size that cannot be retained on the leaves. In the present investigation it has been estableshed, in accordance with *Yates et al.* (1974) and *Morgan* (1978), that the utilization of spraying liquid is increased when the liquid amount is reduced, presumably a result of reduced dripping.

It has not been possible to register the amount of spraying liquid that is wasted on the ground in connection with the spraying. On the basis of the data found, it is, however, possible to calculate how large a plant surface could have been covered by the given dosage? With a 'standard' deposit, such surface is 12.88 ha. With a total plant surface of 4–5 ha (*Vittrup,* 1965), the waste must have been 60–70% of the spraying liquid in accordance with the percentages of waste stated by *Morgan* (1972, 1973 and 1978).

In case of reduction of the liquid amount, an increased pesticide concentration is required to secure the same pesticide amount/ha. The expectation of hereby retaining the same deposit has, in principle, proved to be fulfilled. Provided that the altered physical qualities of the spraying liquid do not modify the output of the sprayer, deposits will alter proportionately with the alteration of the pesticide concentration. This means that it will be possible to adjust different sprayers to give the same deposits by using different concentrations. Correspondingly, it will be possible to adjust for the same deposit for a given sprayer by varying the liquid amounts.

The mist sprayer has proved to work without difficulty with concentrations up to 20%. With full amount of pesticide Captan 83 and, for instance 25 l/ha, a concentration of 12% is required. Consequently, there should be no special problems with the concentration in ULV sprayings.

The tests made so far of fruit tree sprayers (*Jepsen & Hansen,* 1956; *Zumbach & Stadtler,* 1973; *Reichard et al.,* 1977) have been carried out by measurings of the drop spectrum of the spraying liquid. In reality, it is not possible to evaluate the importance thereof, which would be the case by a combination of measurings of deposit and number of spots by a technique like that used in this experiment or a technique of a similar nature.

On the basis of the experiments made it has been possible to establish a great effect of the air temperature during the spraying on deposits. According to *Reichard et al.* (1977), the greatest number of drops occur in the liquid spray in the fraction under 37 μm. The ratio between surface and liquid content in a drop is $\frac{3}{r}$, and for drops under 30 μm the surface/content ratio will be 6.7 times higher than for drops of 200 μm. The numerous small drops will be exposed to evaporation, and this will increase with increasing temperature. A correlation as convincing as that found here may be ascribed to a further effect of the strong air flow from the blower. This ratio problem has not been investigated, but, other things being equal, the great amount of air (25.000 m^3/h) and its initial velocity (45 m/sec.) seem to be essential factors influencing such ratio.

The results from sprayings with the ULV sprayer confirm, in accordance with *McMehan* and *Halvorsen* (1977) and *Bera* (1979), that, at the moment, no suitable ULV sprayers for spraying of fruit trees are in existence. From investigations of pesticide concentrations will be seen that the sprayer proves to work with difficulty with concentrations higher than abt. 4.5%. This indicates a faulty construction of, in particular, the pump and the pressure equalization design, causing a pulsating liquid inlet into the 2 rotating nozzles.

Faust (1977) countered similar problems by replacing the pumping system be compressed air via a reduction valve to the liquid tank.

In laboratory experiments it has been attempted to determine the nominally attainable deposit. Though it is not possible to paralellize totally to field conditions, the investigation must, however, be regarded as representative. The measured deposit on the leaves was found to be 3 times the standard deposit and of the same amount as the maximum deposits found in individual samples from field experiments. In the greatest number of cases by far of sprayings under standard conditions, the median deposits have been found to be abt. 1/3 of the maximum deposit. Converted into 4 ha plant surface per ha (*Vittrup,* 1965), the found liquid amount retained is equal to 1.839 l/ha, corresponding to the full liquid amount being given as 2.000–3.000 l/ha.

7. Conclusion

The ULV sprayer used did not prove suitable for the purpose, mainly on account of faulty construction. However, the tests made with the air mist sprayer may give some information about ULV spraying although the lowest liquid amounts applied with the sprayer mentioned are abt. twice the highest amount used for ULV spraying proper.

The change-over to ULV spraying will, even with reduction of the pesticide amount, require a higher concentration of the pesticide in the spraying liquid than that used now. The investigations made show that generally a change of the deposit proportionate to the concentration is to be expected. An increase of the number of spots on the plant surface has been found, depending on the concentration, which may indicate that this, too, is a factor to be considered in connection with a better distribution of the spraying liquid. A reduction of the liquid amount per ha results in a reduction of the deposit and the number of spots, but not to the same extent. The run-off is reduced whereby the retained liquid amount per litre spraying liquid is increased. The number of spots does not decrease as much as is to be expected as the frequency of the mergence of spots is reduced. In the intervals of the liquid amounts tested here, the amount of pesticide per ha necessary to obtain the same deposit could show a reduction of 22–36% from the highest to the lowest liquid amounts, due to the reduced run-off.

In sprayings with normal pesticide amount and standard adjustment of the sprayer, a 'standard' deposit of abt. 2.3 $\mu m/cm^2$ was found, distributed in abt. 40 spots. The distribution vertically in the trees shows a great predominance in the lower parts of the trees compared with the upper parts. A more uniform distribution, for instance by a change in the placing of the spraying aggregate in relation to the trees, may possibly lead to a reduction of the pesticide consumption, depending on the necessary size of uniform deposits.

Sprayings with 40% standard pesticide amounts have not shown a satisfactory effect against aphids, red spider mites, and powdery mildew. The pesticide amount used gave a deposit of abt. 40% of the 'standard' deposit with the same distribution as that obtaibed by normal amounts of pesticide, and with a corresponding reduced effect of the sprayings.

Neither in the literature nor in the present investigation are found results indicating that a greater effect of pesticides is attainable just by having small drops of liquid. These are, however, a prerequisite of a reasonably adequate surface cover where small amounts of liquid are used.

A fairly good correlation has been proved between air temperature and deposited liquid amount. In sprayings at 13°C, almost double the amount was retained per litre spraying liquid compared with that obtained in sprayings at 23.6°C.

Calculations of the loss of spraying liquid during the spraying have confirmed that 60–70% of the liquid must be expected to end on the ground in connection with the spraying.

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Main Table 1. Conditio

	Driving Speed km/hour		Amount of liquid l/ha		
	ULV	Air mist blower	ULV	Air mist blower	
Concentration of liquid	–	9,1	–	200	–
Concentration of liquid	8,2	10,1	12,5	197	5(
Amounts of liquid	–	2,6–9,1	–	173–635	–
Amounts of liquid	2,3–8,2	2,9–10,1	12,0–42,8	80–279	5(
Amounts of liquid	–	3,6–10,1	–	85–238	–
Amounts of liquid	–	23,6–10,1	–	207–581	–
Standard spraying	–	10,1	–	164	–
Reduced amounts of pesticide ...	7,0	8,4	12	80	5(
Reduced amounts of pesticede ..	7,0	8,4	24	80	5(
	7,0	8,4	24	80	5(

[1]) Samples measured one-sided
[2]) Samples measured two-sided

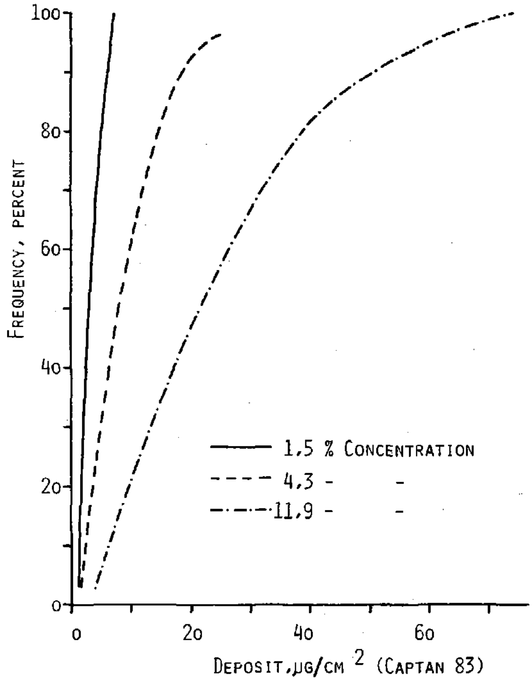
Main Table 2. Schedule and pesticides in exp. with reduced amounts of pesticides

Date	Pesticides	kg/ha
26/4 1976	Captafol	0,64
4/5 –	Mancozeb	1,6
	Dinocap	0,8
	Paration	0,5
13/5 –	Captan 83	1,2
	Dinocap	0,8
24/5 –	Benomyl	0,5
4/6 –	Captan 83	1,2
	Morestan	0,24
9/6 –	Gusathion 50	0,6
11/6 –	Morestan	0,24
18/6 –	Captan 83	1,2
	Dinocap	0,8
24/6 –	Morestan	0,24
1/7 –	Captan 83	1,2
	Dinocap	0,8
	Meta Systox	0,5
8/7 –	Morestan	0,24
9/7 –	Kelthane E 30	0,8
16/7 –	Captan 83	1,2
	Dinocap	0,8
23/7 –	Morestan	0,24
30/7 –	Captan 83	1,2
	Dinocap	0,8
12/8 –	Dicofol	1,5
	Captan 83	1,2
	Dinocap	0,8
26/8 –	Captan 83	1,2
	Dinocap	0,8
9/9 –	Captan 83	1,2
23/9 –	Captan 83	1,2
25/11 –	Copperoxychloride	5,0

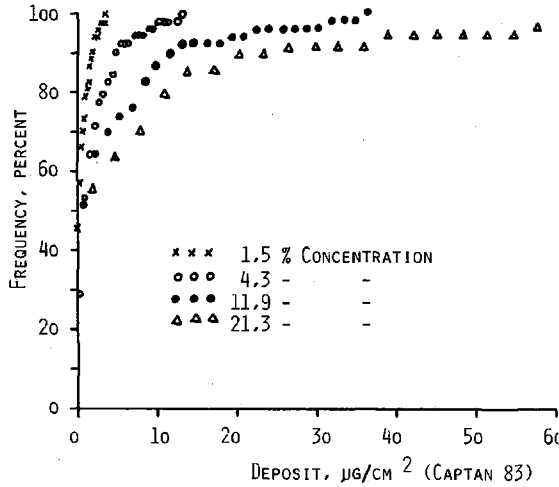
ifferent experiments

Ↄ. . Air mist blower	Concentration of Captan 83 in spray liquid, per cent		Date of experiment		Number of samples		Wind force m/sec	°C at experiment
	ULV	Air mist blower	ULV	Air mist blower	ULV	Air mist blower		
540	–	1,5–11,9	–	11/10–76	–	162[1])	2	14,0
600	1,5–21,3	1,5–21,3	17/6–77	17/6–77	216[1])	216[1])	1	19,5
540	–	1,5	–	4/10–76	–	216[1])	3–4	13,0
600	25,0	5,0	29/7–77	29/7–77	216[1])	216[1])	2–3	18,7
600	–	1,5	–	21/8–78	–	108[2])	2–3	23,6
600	–	1,5	–	21/8–78	–	108[2])	2–3	23,6
600	–	1,5	–	27/9–76	–	144[1])	3	16,0
600	10,0	1,5	9/6–77	9/6–77	60[2])	60[2])	3	16,5
600	4,8	1,5	23/8–77	23/8–77	60[2])	60[2])	2	18,5
600	5,0	1,5	30/8–77	30/8–77	96[2])	96[2])	3	21,0

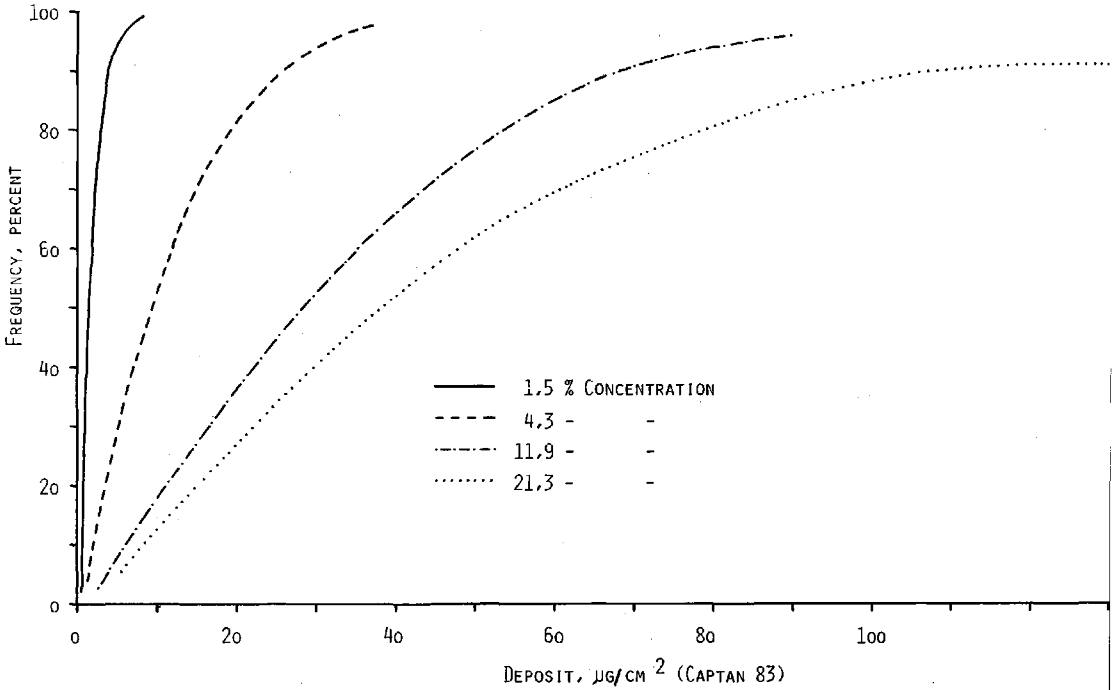
Date	Pesticides	kg/ha
28/4 1977	Captafol	0,64
9/5 –	Mancozeb	1,6
	Dinocap	0,8
	Parathion	0,48
17/5 –	Captan 83	1,2
	Dinocap	0,8
26/5 –	Animert	1,6
27/5 –	Benomyl	0,48
1/6 –	Morestan	0,24
9/6 –	Gusation	0,6
	Dinocap	0,8
	Captan 83	1,2
15/6 –	Morestan	0,24
23/6 –	Captan 83	1,2
	Dinocap	0,8
30/6 –	Morestan	0,24
8/7 –	Captan 83	1,2
	Dinocap	0,8
12/7 –	Morestan	0,24
21/7 –	Captan 83	1,2
	Morestan	0,24
26/7 –	Morestan	0,24
2/8 –	Captan 83	1,2
8/8 –	Morestan	0,24
11/8 –	Captan 83	1,2
	Dinocap	0,8
17/8 –	Morestan	0,24
25/8 –	Captan 83	1,2
	Dinocap	0,8
7/9 –	Captan 83	1,2
20/9 –	Captan 83	1,2
5/10 –	Captan 83	1,2
30/11 –	Copperoxychloride	5,0



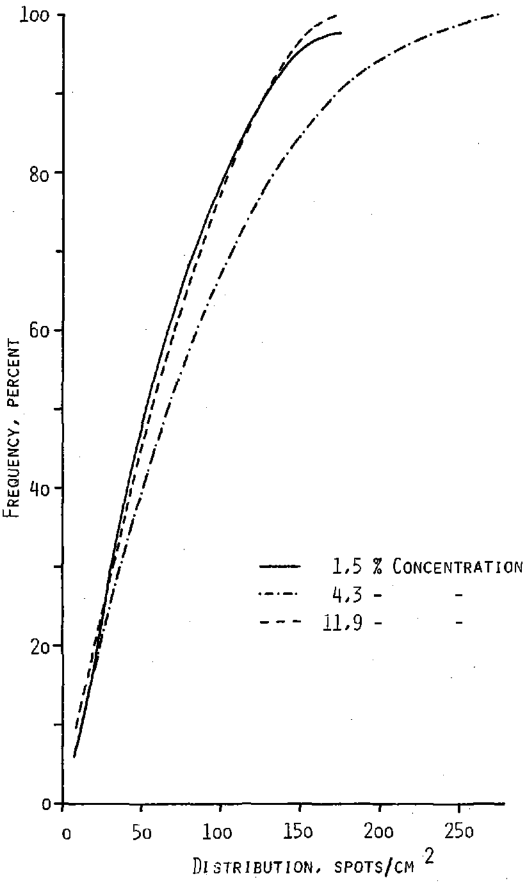
Main Fig. 1. Air mist blower. Increasing concentration of Captan 83. Effect on deposit on the leaves. 11th October 1976.



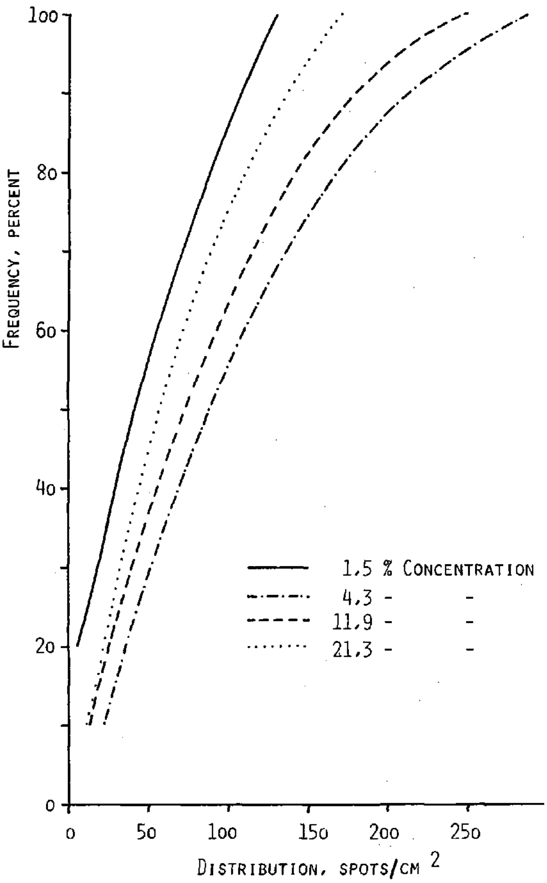
Main Fig. 3. ULV sprayer. Increasing concentration of Captan 83. Effect on deposit on the leaves. 17th June 1977.



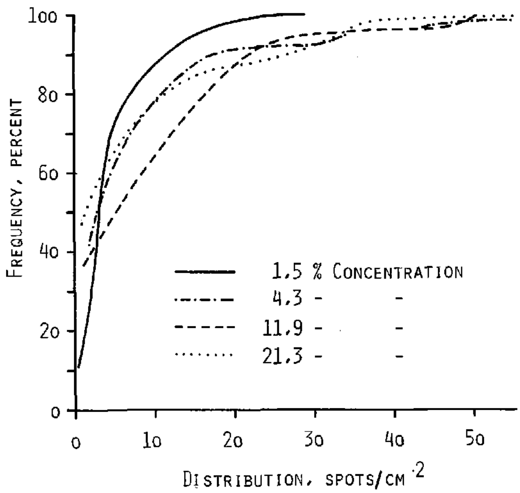
Main Fig. 2. Air mist blower. Increasing concentration of Captan 83. Effect on deposit on the leaves. 17th June 1977.



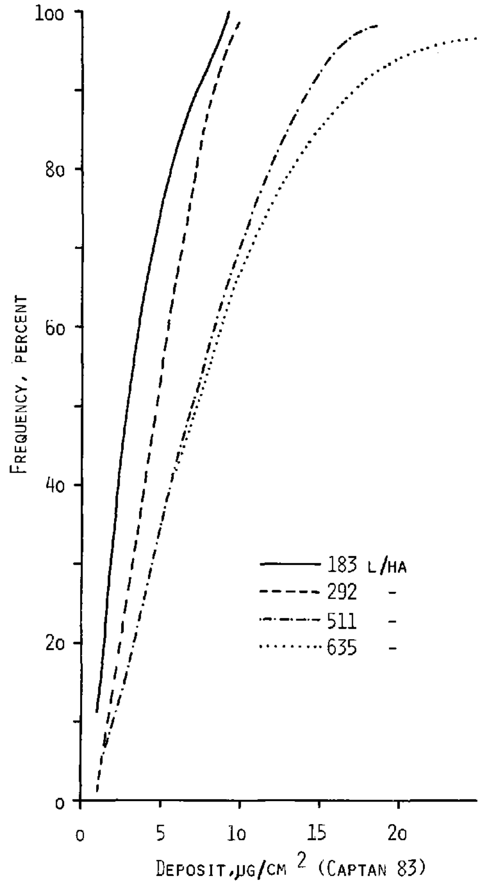
Main Fig. 4. Air mist blower. Increasing concentration of Captan 83. Effect on number of spots on the leaf surface. 11th October 1976.



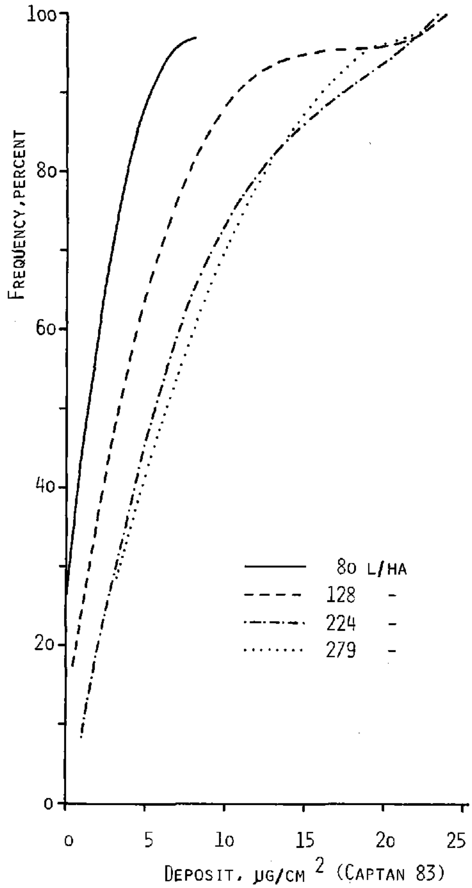
Main Fig. 5. Air mist blower. Increasing concentration of Captan 83. Effect on number of spots on the leaf surface. 17th June 1977.



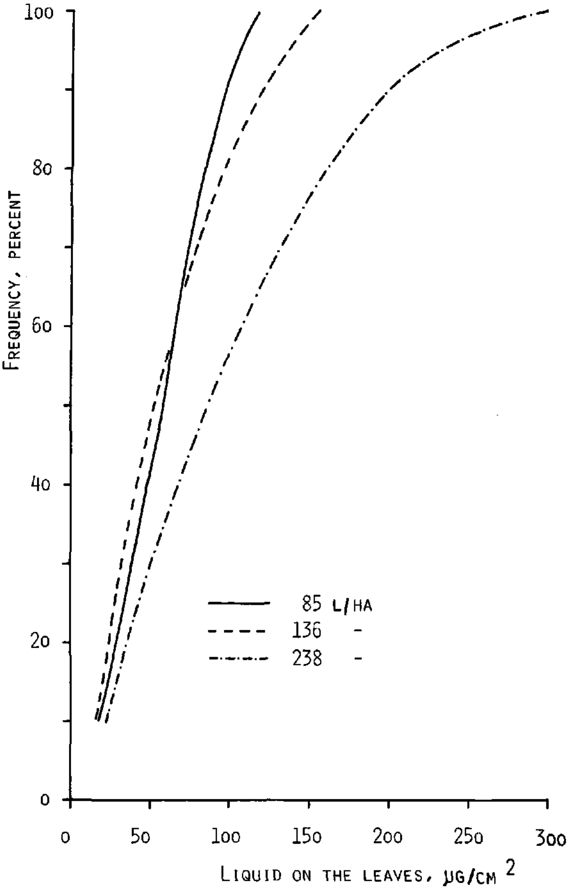
Main Fig. 6. ULV sprayer. Increasing concentration of Captan 83. Effect on number of spots on the leaf surface. 17th June 1977.



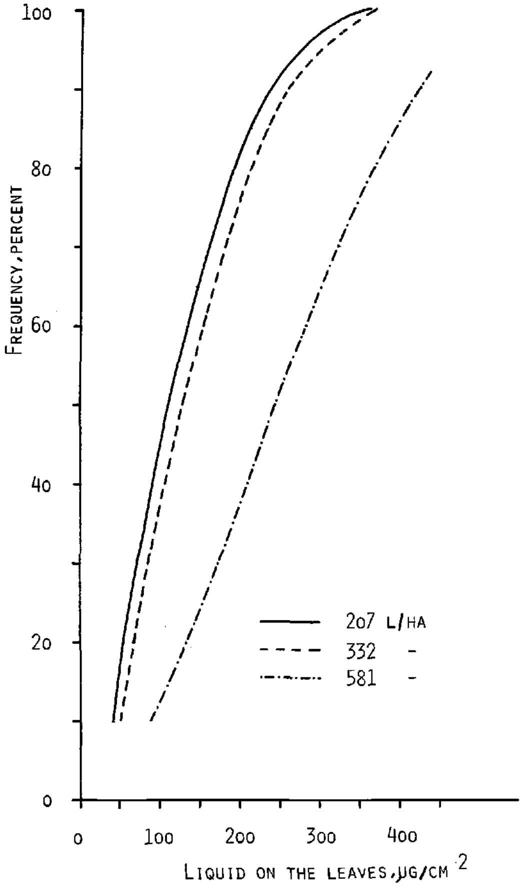
Main Fig. 7. Air mist blower. Increasing amount of spray liquid per hectare. Effect on deposit on the leaves. 4th October 1976.



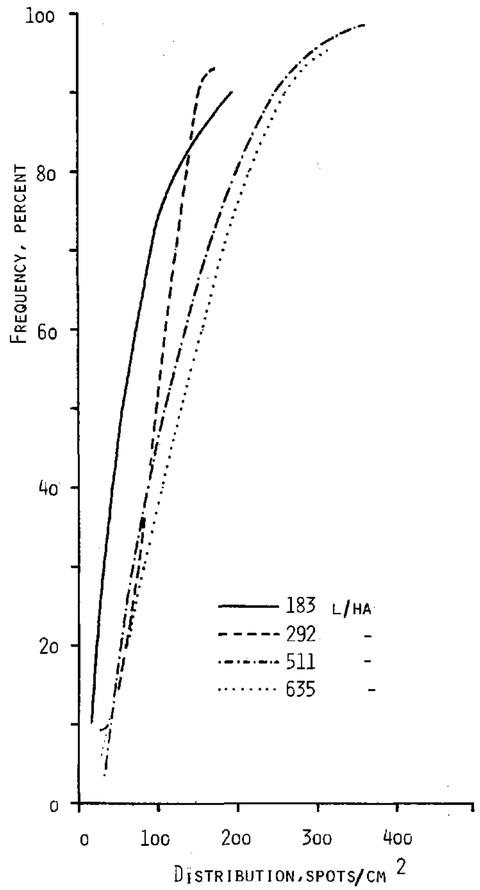
Main Fig. 8. Air mist blower. Increasing amount of spray liquid per hectare. Effect on deposit on the leaves. 29th July 1977.



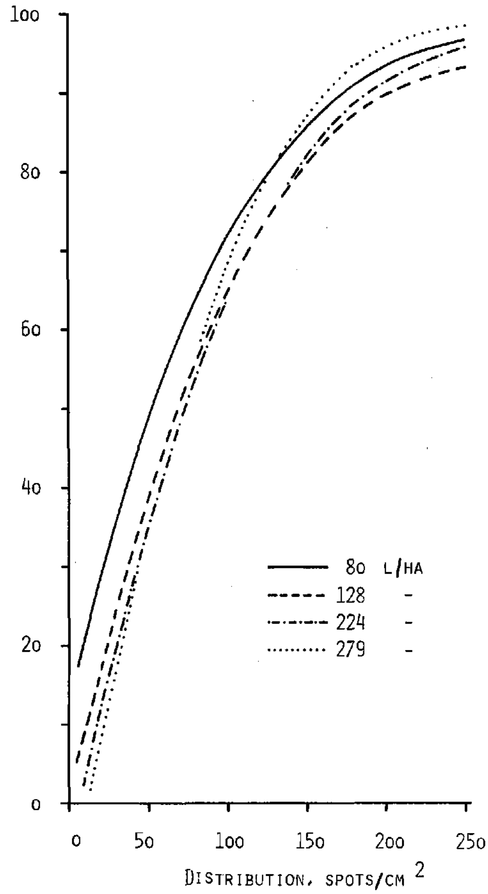
Main Fig. 9. Air mist blower. Increasing amount of spray liquid per hectare. Effect on retained liquid on the leaf surface. 21st August 1978.



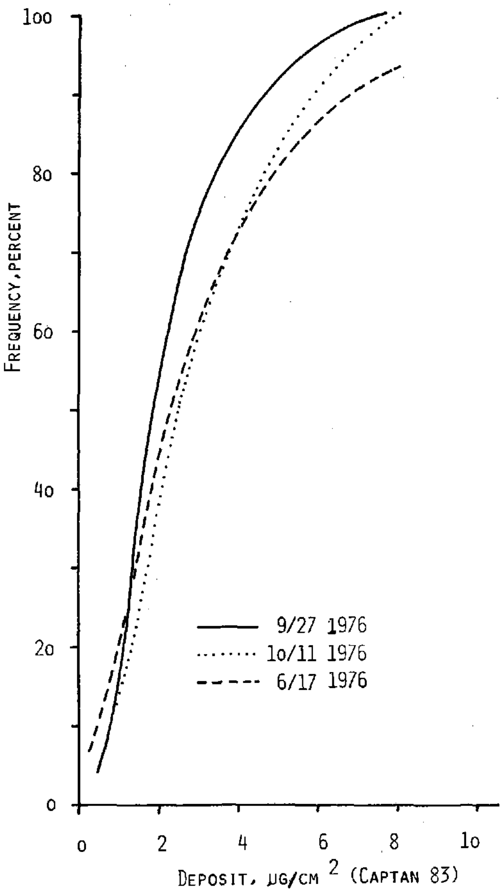
Main Fig. 10. Air mist blower. Increasing amount of spray liquid per hectare. Effect on retained liquid on the leaf surface. 21st August 1978.



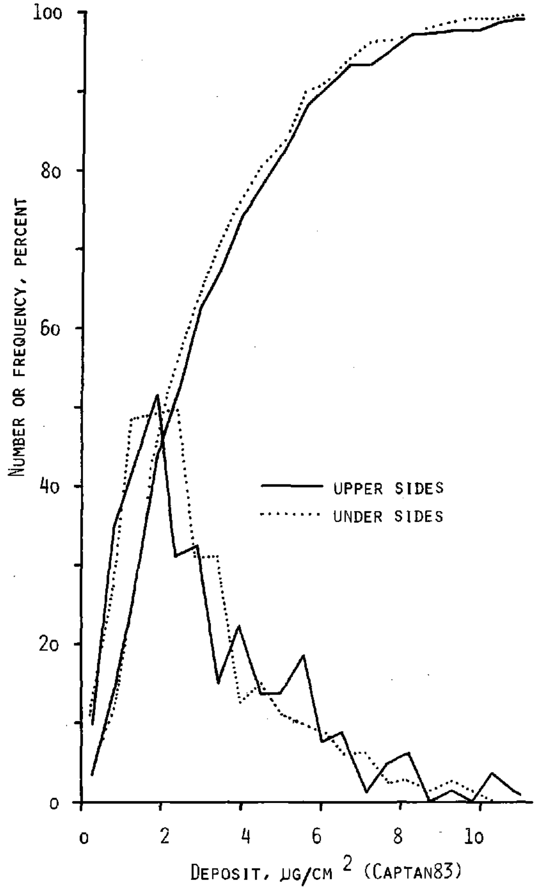
Main Fig. 11. Air mist blower. Increasing amount of spray liquid per hectare. Effect on retained liquid on the leaf surface. 4th October 1976.



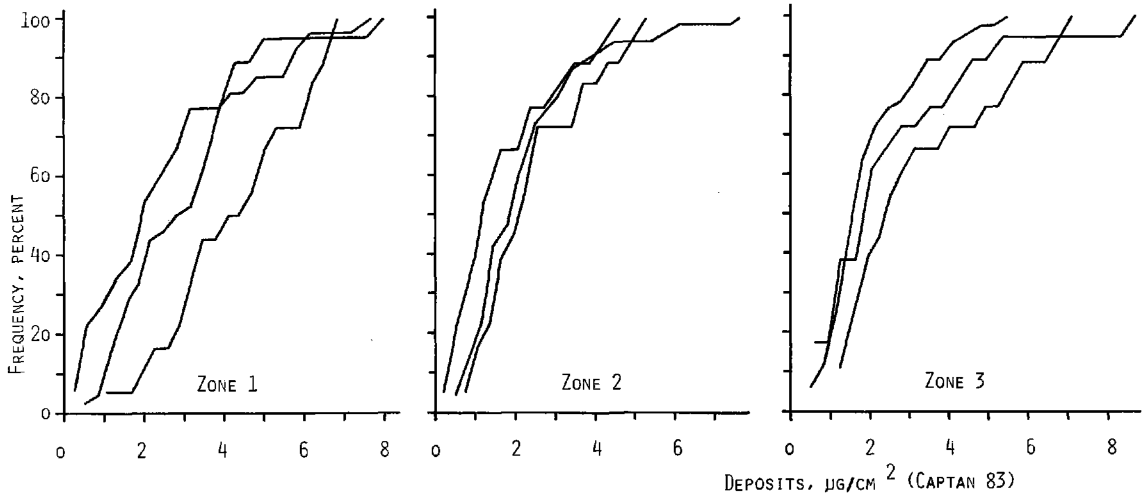
Main Fig. 12. Air mist blower. Increasing amount of spray liquid per hectare. Effect on retained liquid on the leaf surface. 29th July 1977.



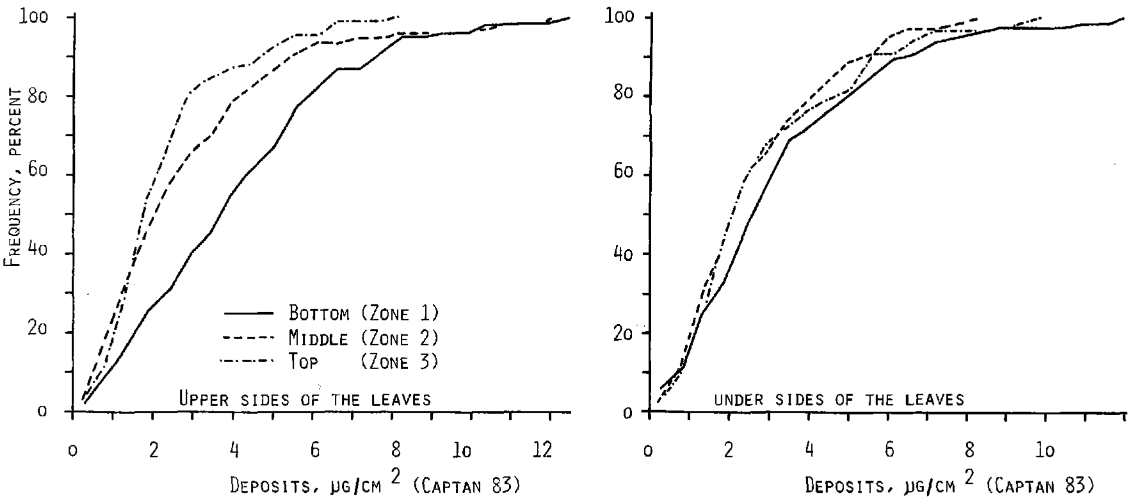
Main Fig. 13. Standard spraying with air mist blower. Deposits on the leaves at different spray times.



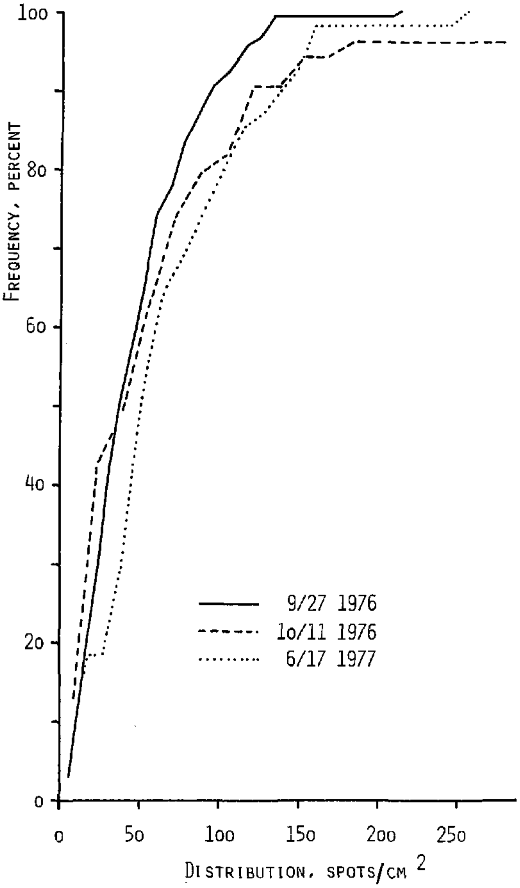
Main Fig. 14. Standard spraying with air mist blower. Deposits on the upper and under surfaces of the leaves. 29th September and 11th October 1976 and 17th June 1977.



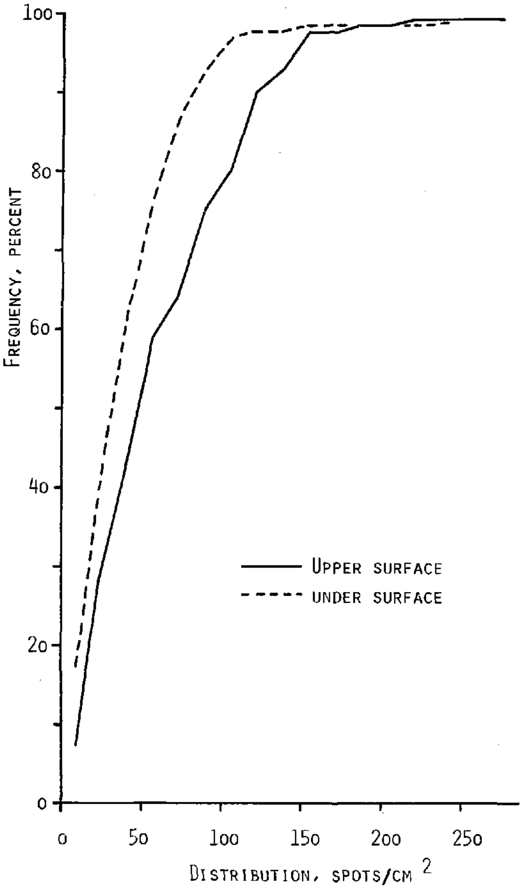
Main Fig. 15. Standard spraying with air mist blower. Deposits in the 3 zones at 3 spraying times. 29th September and 11th October 1976 and 17th June 1977.



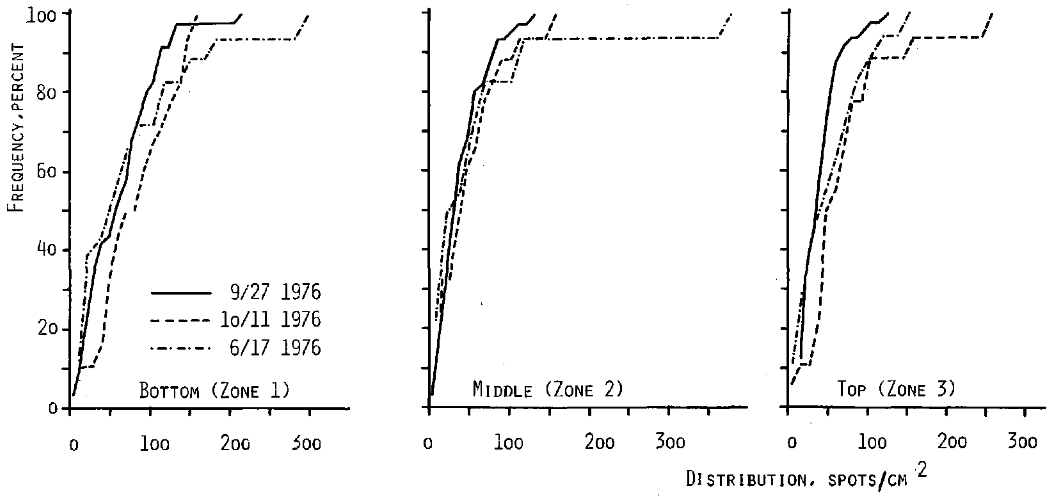
Main Fig. 16. Standard spraying with air mist blower. Deposits on the upper and under surfaces of the leaves into the 3 zones. 29th September and 11th October 1976 and 17th June 1977.



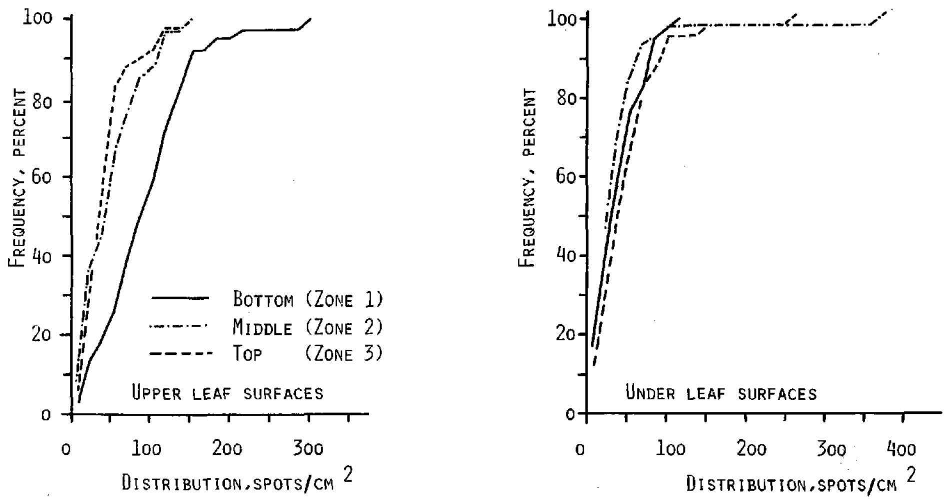
Main Fig. 17. Standard spraying with air mist blower. Number of spots on the leaf surface at 3 spray times.



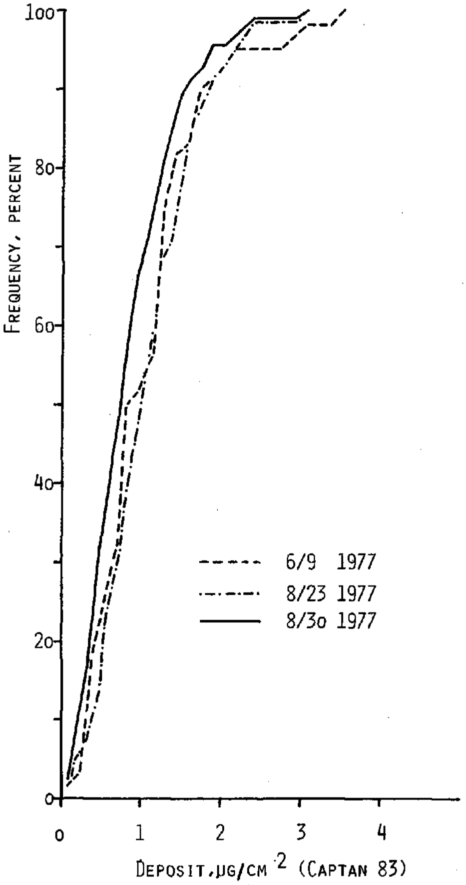
Main Fig. 18. Standard spraying with air mist blower. Number of spots on the upper and lower surface of the leaves. 29th September and 11th October 1976 and 17th June 1977.



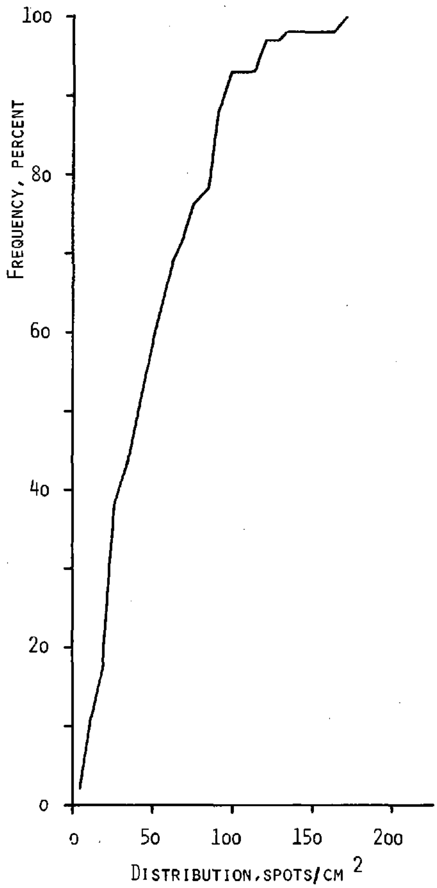
Main Fig. 19. Standard spraying with air mist blower. Number of spots on the leaf surfaces in the 3 zones at 3 spraying times. 29th September and 11th October 1976 and 17th June 1977.



Main Fig. 20. Standard spraying with air mist blower. Number of spots on the upper and under surfaces of the leaves into the 3 zones. 27th September and 11th October 1976 and 17th June 1977.



Main Fig. 21. Air mist blower. Deposits on the surface of the leaves after 40% prescribed amount of pesticides (Captan 83).



Main Fig. 22. Air mist blower. Number of spots on the leaf surface after 40% of prescribed amount of pesticides. 13th June 1979.