COURSE ON SPRAYING TECHNIQUES
for integrated pest management

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Luc M. Lumkes, Consultant[1].

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in ag. mechanization including spraying techniques in developed and developing countries.
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Lembang Horticultural Research
(LEHRI)- Lembang, Indonesia

Project Agricultural Technical
Assistance to the Indonesia
Government (ATA)-395

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SUMMARY

The twin needs to reduce the dosage of plant protection chemicals and to optimize spraying work inspired this contribution. This manual describes ways of improving the use of plant protection products.

The usual spraying technique in developing countries like Indonesia mostly uses too much water with too low a concentration of chemical. Most of the spray is not deposited on the target, thus polluting the environment. This poor technique results in unsatisfactory control of diseases and pests. In an attempt to rectify this, spraying is repeated almost every other day, leading to high residues in some parts of crops. The risk of this is especially high in mixed cropping.

The technique proposed in this publication is to spray a reduced amount of liquid with a very restricted drop spectrum, around 200 microns (no drops sensitive to drift or evaporation, no big drops unable to stay on the target). It should result in about 100 droplets/cm2 everywhere in the crop sprayed. This could be achieved by using special flat spray nozzles and a constant low pressure. It is practised in Europe very successfully and could be transferred to countries like Indonesia too, by means of applied research and extension.

The simple spraying method currently practised in Indonesia involves using a spray lance on the traditional knapsack sprayer. The lance is moved jerkily and uncontrolledly during spraying. Only some of the spray lands on the target, the rest is wasted and polluts the environment. A spectacular improvement could be achieved by switching to the nozzle type and technique advised in this manual. In many cases, using a small boom instead of the lance will contribute to an even distribution of spray.
A specially designed boom should be used to spray beds. The end nozzles of this boom are positioned so that the spray does not land outside the bed.
If these proposals are implemented, the amount of chemicals necessary for spraying in Indonesia could be drastically reduced. Further aid is necessary to refine the improvements.

1. INTRODUCTION TO SPRAYING TECHNIQUES

1.1 General introduction

Integrated Pest Management (IPM) involves applying crop protecting chemicals optimally. By comparison with present-day practice in Indonesia, the technique used to achieve this:

- uses less water and increases the effective dose;
- uses less active ingredient of the chemical;
- lengthens the duration of effective control.

At present, modern crop production is almost impossible without crop protection chemicals. In developing countries, however, the technique of applying these chemicals is deplorable. Not only is much too much water used, but the intervals between spraying are also very short. This can lead to high residues in mixed vegetable cropping, as found near Lembang, Indonesia. It is dangerous to consume crops with such a visible residue.

The current technique of spraying onions at Klampok near Brebes in Java, Indonesia, which uses a standard knapsack sprayer, results in at least 80 per cent of the spray liquid not remaining on the target but falling on the soil in the onion beds and in the adjacent irrigation ditches.

In Klampok it was demonstrated that with improved spraying techniques the onions can be completely covered with small drops. These techniques also enable the amount of active ingredient of the chemical to be reduced.

The easy availability of various pesticides and additives should not result in residues in crops and in contamination of the environment - both of which are a threat to public health. Nor should the health of the operator be at risk: the techniques of spraying practised nowadays in developing countries can expose him to dangerous levels of chemical, especially in the long run.

The objective of this course requested by LEHRI is for more know-how in spraying techniques to become available at the institute and field stations. The training of farmers could be tackled at a later stage. It should be noted that present methods of applying chemicals to crops are changing rapidly in the western world. Therefore, some basic information about improved spraying techniques is included in this course.

1.2 Spraying process

Chemicals to protect crops or to kill weeds are mostly sprayed as a solution in water. In this way water acts as a dilutant and as a carrier. By producing small

droplets an even distribution is possible with small amounts of liquid.
When pesticides were first introduced no technique for accurate spraying was available. So, at first these chemicals were applied by a watering can. This is still sometimes done. Using this method the chemical is applied with a large amount of water, and thus in a very low concentration.
The advent of the sprayer meant that some pressure could be given to the spray liquid to transport it to the target, and the droplet spectrum could be influenced by the type of the nozzle.
If droplets are to be deposited in a target area (normally leaves) of a crop, they have to overcome a critical speed to break through the air resistance around the subject (see figure 1). The critical speed required depends on the dimensions of the crop or its specific parts and the droplet size.

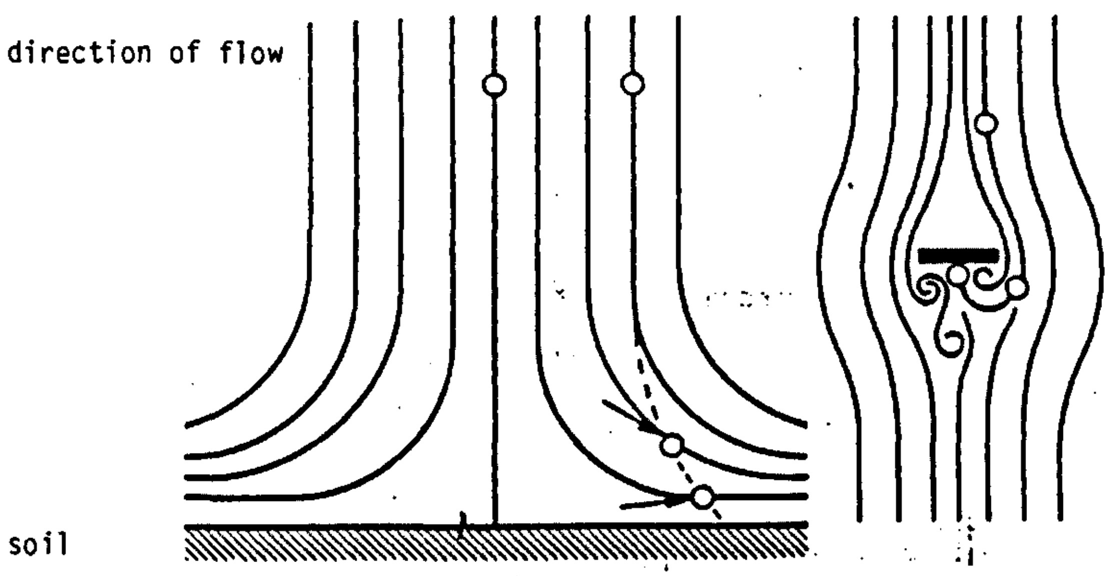


Figure 1. Flowlines of air with droplets in it, around obstacles.

Big droplets go straight to the target, while smaller ones follow the flowlines of the air. They are first deflected around the obstacle and then caught up in the turbulence behind the obstacle, which can push them onto the obstacle.
With standard spraying processes the speed of the droplet is generally higher than 1 m/s, which is often not enough for good direct penetration of the crop canopy. By using recently developed systems of air-assisted spraying, the speed at leaving the nozzle can be up to 25-30 m/s, while by the time droplets reach the target, they may still have a speed of 5-8 m/s.

1.3 Purpose, strategy

The purpose of applying chemicals in crop protection is to deposit an optimal amount of active ingredient on the target. Each situation (pest, disease), requires a different amount of active ingredient, together with an optimal droplet spectrum and an optimal amount of water. This has to be examined experimentally, in relation to the biological and chemical complex formed by the crop and the pest or disease involved. The weather at the time of application will also influence results. In practice, the amount of water used is often far too high. In Indonesia it is often over 1000 l/ha, see also table 1.

Table 1. Categories of amount of water used in spraying (in l/ha).

High volume spraying (HV)	200 - 1500
Low volume spraying (LV)	5 - 200
Ultra low volume spraying (ULV)	1 - 5

The strategy in modern spraying techniques is not to stipulate the amount of water required, but to specify the spraying advice in terms of number of droplets per cm^2 and their desirable size. This strategy not only results in less of water being used, but also in a reduction in the chemicals used (fewer kilograms or liter per ha). In the Netherlands, for instance, it has been found to be possible to decrease the dose of the crop protection chemicals by one-third by using certain new techniques. A preliminary investigation in Indonesia indicated that there are opportunities for reductions of the same magnitude there too.

1.4 Effect of weather on results of spraying

The weather can greatly influence the results of spraying. This has to be examined by spraying experimental plots, see appendix 1. Three main factors are involved: temperature, humidity and wind.

Temperature

The temperature is a critical factor in the spraying process, especially when temperatures are high, as in Indonesia. The evaporation of droplets depends on their size and the temperature:

Table 2. Rate of evaporation of droplets at a temperature of 20°C and a humidity of 80%.

Droplet size in mu	Seconds for evaporation
300	400
200	200
100	50
50	12.5

As can be seen in table 2, the smallest droplets evaporate fastest. At temperatures higher than 20°C the process of evaporation will of course be much faster, in particular for the smaller droplets.
The speed at which a droplet travels from a nozzle to a target is usually at least 1 m/s. Thus in practice only the very small droplets will evaporate rapidly, especially at high temperatures. The droplet spectrum of a nozzle should therefore not include such very small droplets. Nozzles should be checked to ensure they comply.
Evaporation of small droplets can easily contribute to the contamination of the environment and to the poisoning the person operating the sprayer.

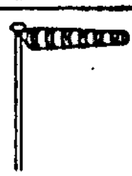
Humidity

At a humidity of less than about 50% the evaporation of droplets can be too rapid, both in the air and after deposition on the target. It is therefore not recommended to spray when the humidity is lower than 50%.
A humidity of over 80% is considered to be too high because at this humidity, dew or mist droplets (50-100 microns ø) can be present on the target. This might prevent pesticides and insecticides from being effective.
Thus, 50% and 80% Relative Humidity (RV) are critical limits. For Indonesia this should be confirmed in experiments in specific climatic zones. A polymeter could be helpful for this research. It shows the saturation pressure and the dew point (see appendix 2).

Wind speed

Wind drift will be discussed in section 3.6. At wind speeds of more than 4 m/s (or comparable values, see table 3) spraying is not advisable because of the drift.

Table 3. Wind strength conversion table: Beaufort scale.

Windforce according to Beaufort	Visual indication	KNMI m/second	KNMI km/hour	Notes
0		0 - 0.2	<1	
1		0.3 - 1.5	1 - 3	
2		1.6 - 3.3	4 - 6	Ideal spraying weather
3		3.4 - 5.4	7 - 10	
4		5.5 - 7.9	11 - 16	Spraying with special equipment only
5		8.0 - 10,7	17 - 21	
6		10.8 - 13.8	22 - 27	
7		13.9 - 17.1	28 - 33	
8		17.2 - 20.7	34 - 40	
9		20.8 - 24.4	41 - 47	
10		24.5 - 28.4	48 - 55	
11		28.5 - 32.6	56 - 63	
12		>32.6	>63	

Source: Royal Dutch Meteorological Institute (KNMI).

The wind speed can be measured with an anemometer (see appendix 3). In research on spraying herbicides, insecticides and pesticides the wind speed has to be checked before and after spraying and recorded on the observation sheet.
A special observation sheet for describing the weather conditions is enclosed as appendix 1.
Another negative effect of wind is its influence on the evaporation of pesticides and insecticides after application. Some of these chemicals are formulated to work in the vapour phase. These chemicals can cause serious contamination of the environment, especially when applied in windy conditions.

2. SAFETY PRECAUTIONS

An instruction programme (illustrated by slides) should be used to inform farmers about the safety precautions needed during the whole process of mixing and spraying pesticides and insecticides. This programme should deal with instructions for the safe transport and storage of these chemicals, as well as with instructions for the safety of the operator.

3. TECHNICAL ASPECTS OF SPRAYING

3.1 Size and quantity of drops needed

Crops cannot hold large amounts of water; furthermore big drops fall off the crop. The strategy is therefore not to give a lot of liquid, but to apply a small amount, in drops of appropriate size and quantity. The aim is an even distribution and droplets as uniform as possible. When too much liquid is used - as is the case in Indonesia - drops overlap on the target, eventually negatively affecting the control of pests and diseases, because the active ingredient is thereby diluted.

Most insecticides and fungicides act on contact, but those that are systemic should be applied in the same way. However, these pesticides that have been available for many years were originally approved for general use on the basis of tests in which they were diluted with large amounts of water. They should therefore be re-evaluated in the light of modern spraying practice.

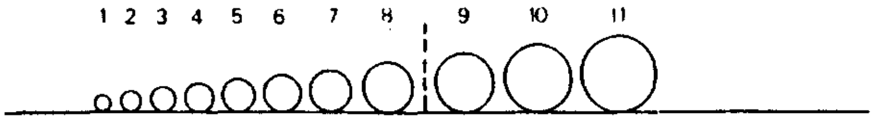
The drops produced by spray nozzles, including Indonesian types of knapsack sprayer, generally vary from about 20 to 600 microns (0.02-0.6 mm): see testing results in section 4.1. A small range of drops is required for spraying outdoors. Drops with a diameter of less than 150 microns are too susceptible to wind drift and evaporation; drops larger than about 400 microns do not remain on the crop. If big drops land on the target, they either roll off directly or split up into smaller drops, most of which then roll off.

Table 4. Classification of drops, based on their diameter in microns.

Image group	Code	VMD of the spectrum in microns
Very fine	VF	80 - 150
Fine	F	150 - 200
Median	M	200 - 300
Rather coarse	RC	300 - 400
Coarse	C	400 - 600

Normally, a few very small drops are present in every drop spectrum; however, they form only a low percentage of the total volume of liquid. Half of the volume are mostly in the middle range of the specific spectrum, and a few are present as bigger drops.

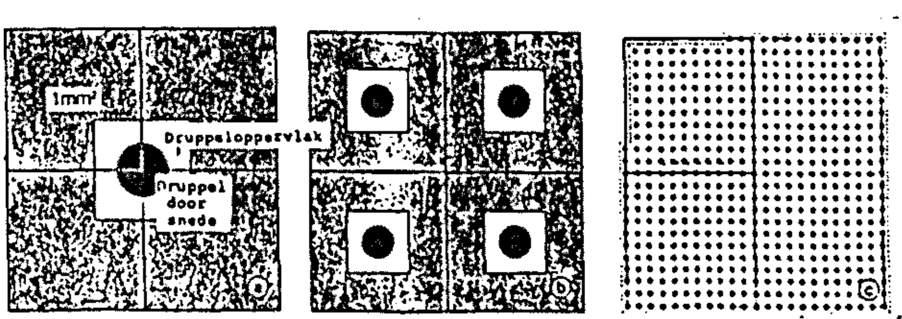
The Volume Median Diameter (VMD) is used to classify drops in the drop spectrum. The VMD or the D 50 of the volume, means that 50 per cent of the volume of the drops have a diameter below that value (see figure 2).



VMD = 250 microns

Figure 2. Drops 1 to 8 together contain as much liquid as drops 9, 10 and 11. The VMD or the D 50 of the volume lies between drops 8 and 9 (for instance, VMD 250 microns).

D 10 is the drop diameter below which 10 per cent of the total volume is.
D 90 is the drop diameter below which 90 per cent of the total volume is. Using these values one can also analyse the width of the drop spectrum.
For good control of pests and diseases the mean drop size should be about, but not more than 200 microns.
Smaller drop sizes are still effective, but a disadvantage is that they are too susceptible to drift and that the spectrum also consists of too many very small drops.
In figure 3 it is demonstrated on 4 mm^2 (enlarged scale in the illustration!) that one drop of 400 microns only covers 1.8 mm^2 of the 4 mm^2, while four drops of 250 microns already cover 75 per cent of the area. When the drops are 50 microns the whole area is almost completely covered.
This coverage is achieved using the same amount of liquid. Thus 1 drop of 400 microns is the same as 4 drops of 250 microns and 490 drops of 50 microns (see also table 6).



a. Drop of 400 microns   b. Four drops of   c. About 400 drops
250 microns   of 50 microns

Figure 3. Coverage by various drop sizes, based on the same amount of liquid, on an area of 4 mm^2.

Researchers (including those at PAGV, Lelystad) have found that about 100 drops/cm^2 is sufficient for optimal control of pests and diseases. For Indonesia this value has to be confirmed in experiments, but 100 drops/cm^2 could safely be advised for the time being. This coverage can be achieved by using only 40 liters of liquid per hectare and a drop diameter of 200 microns (see tables 5 and 6).

With a crop, the surface per hectare can increase about five to eight times, dependent on the type of crop (Leaf Area Index (LAI) 5 to 8). In this case, the total numbers of drops required to control a pest or disease also has to be multiplied accordingly (see table 6). In this context it can be advised to use 200 or 300 l/ha, depending on the crop canopy. If the drops are 200 microns, then 477 drops are available per cm^2 at 200 liters/ha and 716 drops are available per cm^2 at 300 l/ha. At an LAI of 5 or 7 this is enough to achieve the norm of 100 drops.

As an example the LAI of mature rice crop = 2, that of mature tomato crop = 7.

Table 5. Amount of water required per hectare for a specific drop size to produce respectively 100 or 500 drops per cm^2.

Size of the drops	Liters per hectare required	
in microns	100 drops/cm^2	500 drops/cm^2
100	5.23	26.15
200 <-- desirable	41.88	209.40
250	81.81	409.05
300	141.37	706.85
400	335.10	1675.50

When the drop size is halved, about eight times as many drops per cm^2 are produced, as can be seen in table 6.

The following formula can be used to calculate the liters required per hectare:

n = 60/n x (100/d) 3 = Q

(n = number of drops/cm^2 desired; d = drop size in microns; Q = liters per hectare).

Another factor used in this context is the coverage. A coverage of about only three per cent in combination with a drop size of 200 microns has proved sufficient in various experiments and in practice.

In table 6 (next page) the relations are given for various situations. For instance, 40 l/ha liquid with drops of 200 microns produces about 100 drops/cm^2 and gives a coverage of 3% and a mutual distance of only about 1 mm between the coverage and mutual distance of drops. A practical guide, developed by PAGV.

Amount of liquid liters/hectare	Drop size in microns	Number of drops per cm^2	Percentage coverage	Mutual distance in mm
1	2	3	4	5
25	50	3820	7.5	0.11
25	100	477	3.75	0.37
25	200	60	1.875	1.26
25	250	31	1.5	1.90
25	300	18	1.25	2.73
40	50	6112	12.0	0.08
40	100	764	6.0	0.27
40	200	95	3.0	0.92
40	250	49	2.4	1.38
40	300	28	2.0	1.95
40	400	12	1.5	3.51
100	100	1910	15.0	0.13
100	200	239	7.5	0.48
100	250	122	6.0	0.72
100	300	71	5.0	1.01
100	400	30	3.75	1.75
150	100	2865	22.5	0.09
150	200	358	11.25	0.35
150	250	183	9.0	0.53
150	300	106	7.5	0.74
150	400	45	5.625	1.29
200	100	3820	30.0	0.06
200	200	477	15.0	0.27
200	250	244	12.0	0.42
200	300	141	10.0	0.59
200	400	60	7.5	1.03
250	100	4775	37.5	0.05
250	200	597	18.75	0.22
250	250	306	15.0	0.34
250	300	177	12.5	0.49
250	400	75	9.375	0.86
300	100	5730	45.0	0.03
300	200	716	22.5	0.18
300	250	367	18.0	0.29
300	300	212	15.0	0.41
300	400	90	11.25	0.73
400	100	7639	60.0	0.01
400	200	955	30.0	0.13
400	250	489	24.0	0.21
400	300	283	20.0	0.31
400	400	119	15.0	0.57
800	100	15279	120.0*	-0.02*
800	200	1910	60.0	0.03
800	250	978	48.0	0.07
800	300	566	40.0	0.13
1000	100	19099	150.0*	-0.03*
1000	200	2387	75.0	0.00
1000	250	1222	60.0	0.04
1000	300	707	50.0	0.08

* = % coverage >100% means overlap
negative mutual distance means overlap

drops. With 200 l/ha and drops of 200 microns, 477 drops are sprayed per cm^2; in this method a vegetation with an LAI up to 5 can still be covered satisfactorily. Using very big drops of 400 microns and 300 l/ha it gives only 90 drops/cm^2, which can be too low. Because of their larger size, big drops give a better coverage, about 11 per cent on a flat surface, and they are also closer together. Drops of 400 microns, however, are not at all advisable, because of the run-off and subsequent waste of chemicals.

In figure 4 the effect of irregular spraying with different drop sizes (left) is compared with spraying the same amount of liquid in smaller, uniform drops (right).

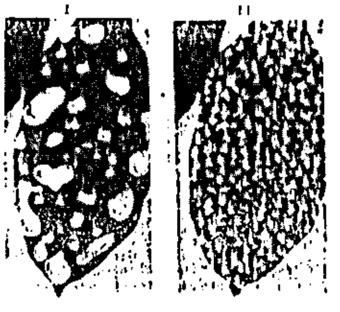


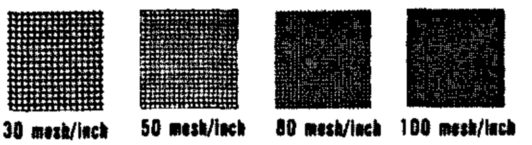
Figure 4. Two leaves sprayed with the same amount of liquid; the one on the left with a small number of big drops and irregular spread, while on the leaf on the right the coverage is almost ideal.
The big drops easily fall off the target directly or split up into smaller ones when they touch the target and by so doing also fall off.

3.2 Different spray nozzles

The liquid is sprayed under pressure through the spray nozzle. A pump builds up the pressure required. Special filters are necessary to prevent the nozzles from clogging. The filter is indispensable if water from irrigation canals or other open water is used. The filter consist of a number of square holes. Dimensions are given in table 7.

Table 7. Filter sizes for sprayers.

Size in Mesh (= number of holes per inch)	Internal dimension in mm
16	1.1 x 1.1
30	0.53 x 0.53
50	0.28 x 0.28
80	0.18 x 0.18
100	0.15 x 0.15
200	0.08 x 0.08



The standard filter built in all sprayers is 50 Mesh. A special fine filter of 100 Mesh is used for nozzles with a small outlet.

3.2.1 Nozzle types

Nozzles can be divided into three groups:
- hollow and full cone nozzle;
- flat spray tips;
- deflector type spray tips.

3.2.1.1 Hollow and full cone nozzle

This type of nozzle is built up of various parts. It has a swirl plate to form a conical spray pattern. If the nozzle has a hole in the middle of its base plate it is called a full cone nozzle, as is illustrated in figure 5 (right).

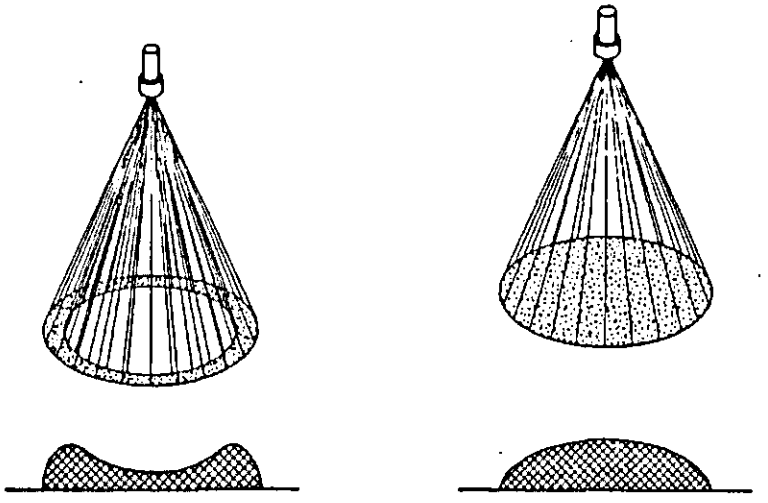
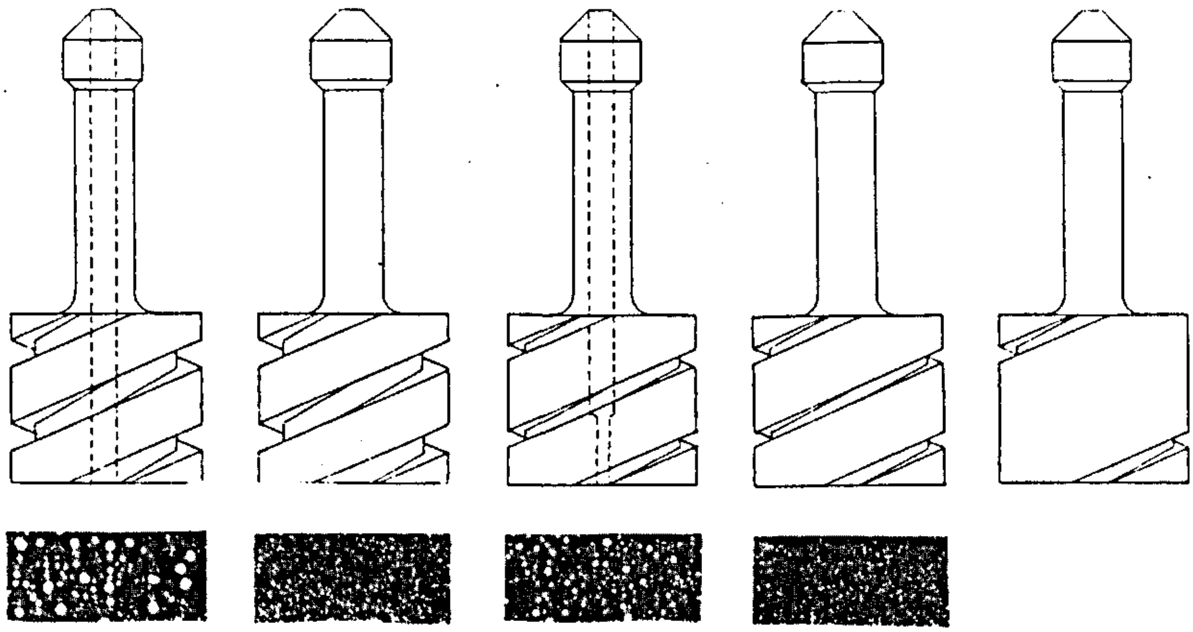


Figure 5. Spray image of a hollow cone and a full cone nozzle.

The hollow and full cone nozzles were - and in many cases still are - the standard nozzles used in portable field plot sprayers. When special field plot sprayers were introduced in Europe about 30 years ago, they were equipped - and in many cases still are equipped - with a small Birchmeier Helico Saphir hollow cone nozzle. These nozzles used large amounts of liquid, generally between 500 and 1000 l/ha. This is the same amount used by the traditional knapsack sprayer (0.3 - 2 l/minute) and, until a few years ago, by motorized sprayers.
A special drop spectrum is created by choosing a nozzle combination in the way illustrated in figure 6.



673 A, 1.3 mm	673 A	2 F - 0.6	2 F	F
nozzle	nozzle	nozzle	nozzle	nozzle
hole, 1.6 mm	hole 1.6	hole 1.2	hole 1.2	hole 1.2
spray pattern				
very coarse	fine	coarse	very fine	very fine

Figure 6. Nozzle combinations of the special Birchmeier Helico Saphir full cone and hollow cone nozzle for hand-operated field plot sprayer.

For herbicides, a very coarse pattern (produced by 1.6 - 673 A - 1,3) or a fine pattern (as produced by the combination 673 A - 1.6) used to be advised. For fungicides and insecticides only the nozzle with a 1.2 mm orifice was advised; this because a very fine spray pattern was thought desirable at that time. The combination of 2 F - 1.2 could be used for this purpose.
The combinations 2 F - 0.6 - 1.2 and F - 1.2 are no longer used.
The drop spectra and output and quality and durability of these nozzles were recently examined at PAGV. Several disadvantages were found:

- huge variations in output between nozzles of the same type;
- pressure reduction in between manometer and nozzle can be unacceptably high (up to 50 per cent).

Some of these disadvantages are caused by chemicals blocking the nozzle. When several nozzles are mounted on a boom, the coefficient of variation in output between nozzles should be less than 10 per cent. When these Birchmeier and other

hollow or full cone nozzles were mounted on a boom it was often between 30 and 40 per cent, which is unacceptably high.
The drop spectrum of a cone nozzle is mostly very wide. It contains too many small drops (contributing to drift) and a large number of big drops (which are not effective). It is also the experience of PAGV and of many other users that the difference in output of the nozzles of one and the same type and series is often too large. This might be an effect of low quality production technique.

The specifications of a cone type nozzle are:

- the spray image is not sharply delineated (i.e. it is diffuse);
- the spray pattern is wide, mostly containing too many small drops. This is especially the case when used with a high pressure. Under these circumstances it also gives too much drift;
- the penetration power is very low;
- a pressure of at least 3 bars is necessary to get an acceptable spray image;
- the VMD of the hollow cone type is 100 to 400 microns, that of the full cone nozzle 300 to 700 microns;
- it is almost impossible to spray very low volumes of liquid, with a full come nozzle. This because of the relatively high output and the relatively high VMD. It is almost impossible to spray the very low volume of liquid that a flat fan nozzle can handle.

3.2.1.2 Flat spray nozzles

This nozzle only consists of a special spray tip, which has a flat opening, see figure 7. It produces a flat spray pattern.
This nozzle has no base plate. The elliptical pattern it produces depends on the size of the tip and the pressure of the spray liquid.

The flat spray nozzle is the most popular nozzle. At low pressure, the flat spray nozzle gives larger drops than the hollow cone nozzle and is thereby less sensitive to wind.

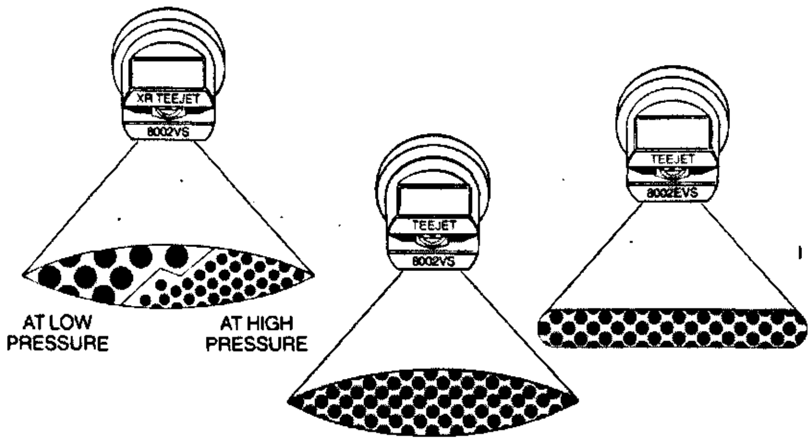


Figure 7. Spray image of a flat spray nozzle tip, in the middle the standard one, in the left the XR nozzle, on the right the band spray nozzle.

The characteristics of a flat spray nozzle are:

- a rather low output;
- sharply delineated elliptical spray pattern;
- when the spray top angle of the nozzle is large (110°) then the necessary distance from the target is only 30 cm;
- good and regular distribution of the spray liquid;
- effective transport to the target (leaf surface) because the spray emerges in straight lines;
- on average the drops are bigger than those produced by a cone type nozzle; the VMD is between 200 and 600 microns;
- the nozzle can be used at low pressure and gives less drift than the cone type nozzle.

In order to get a good and regular spray pattern the nozzles have to be at an angle of at least 5° to the driving direction when mounted on a boom, to prevent them from spraying into each other. An angle of 20° is even more preferable. Both positions are illustrated in figure 8.

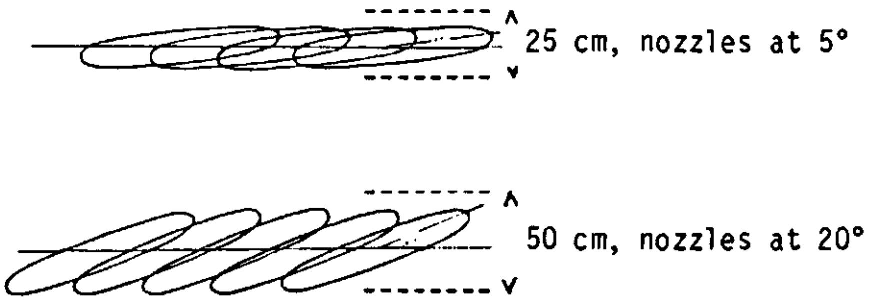


Figure 8. Flat spray nozzles should be mounted at an angle of at least 5° (but preferatly at 20°) to the driving direction on the boom of the sprayer. The spray patterns of the individual nozzles should not touch each other.

The Extended Range (XR) type of Teejet and the Landwirtschaft Universal (LU) type of Lechler are special variants of this nozzle. Both have the same shape, have the same number and colour code and have more or less the same characteristics (quantity and size of drops). These nozzles can be seen as a further refinement of the flat spray nozzle. The special features are that they can be used at very low pressures (from 1 bar upwards) and have a restricted spectrum around their VMD. See also figure 9 and chapter 3.4.

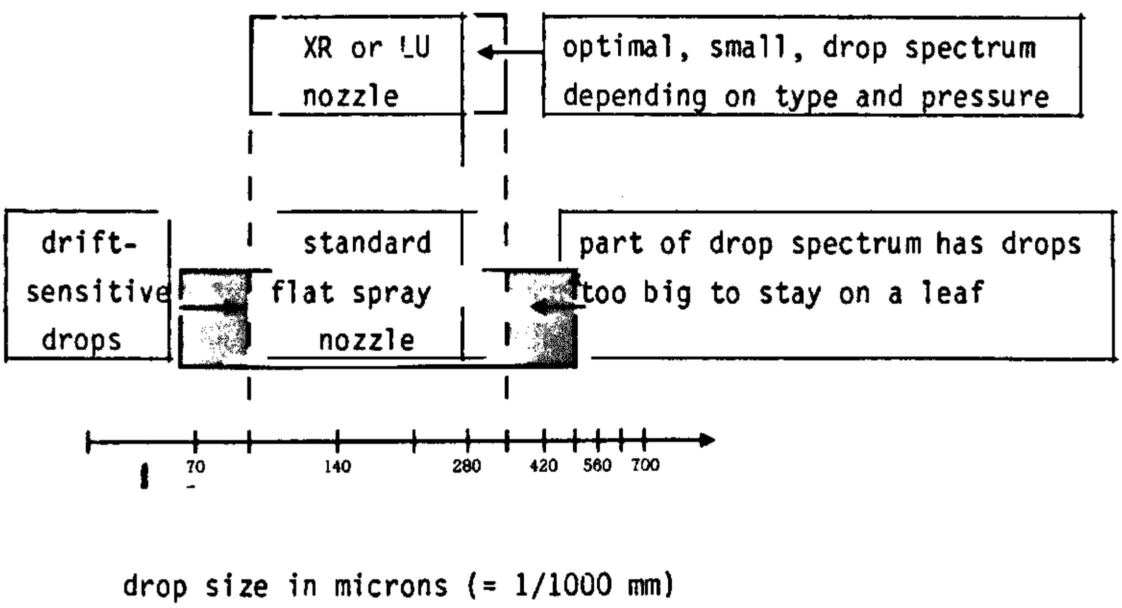


Figure 9. Narrow drop spectra of new flat fan nozzle types such as Teejet XR and Lechler LU.

As mentioned earlier standard flat fan nozzles are better than hollow and full cone nozzles. The Teejet XR and the Lechler LU are, however, a further improvement.

3.2.1.3 Deflector type spray tips

This type of nozzle sprays the liquid indirectly. A flat or slightly rounded surface inside the nozzle, deflects the liquid so that it emerges at an spray angle of 90° (or less).
This nozzle is used for special purposes only, for examide to apply herbicides in Indonesia. It also can be used to spray at on angle of 90° with a lance in tall crops. The nozzle produces a large range of drop sizes, with a VMD of 300 to 600 microns. It is very susceptible to drift. The nozzle is illustrated in figure 10.

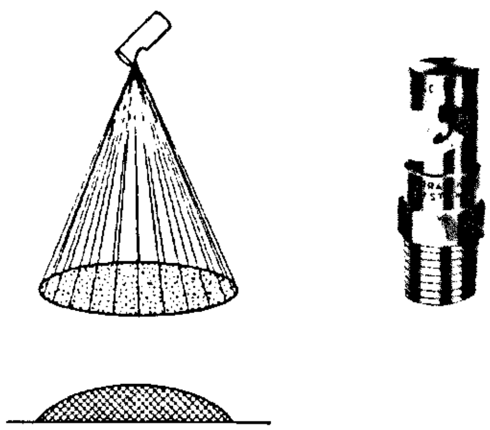


Figure 10. Deflector type spray nozzle.

5.3. Membranes and turret nozzle holders

After the lock of a sprayer is closed the pressure does not always fall immediately throughout the system and therefore some drops can still emerge from the nozzle. This dripping can be avoided by the use of a membrane mounted in a short tube and kept in position by a short piece of string. If the liquid is transported at a certain pressure the membrane will open, allowing the liquid to reach the nozzle. Most membranes open at a pressure between 0.3 and 1 bar.

Figure 11 (next page) shows the position of some parts of the types of nozzles discussed, including the membrane.

In a turret nozzle holder three or more nozzles can be mounted in one unit on one outlet of the conduit pipe. If different types of nozzles are fitted, this makes it easy to change the amount of water or the drop spectrum (e.g. for spraying experiments).

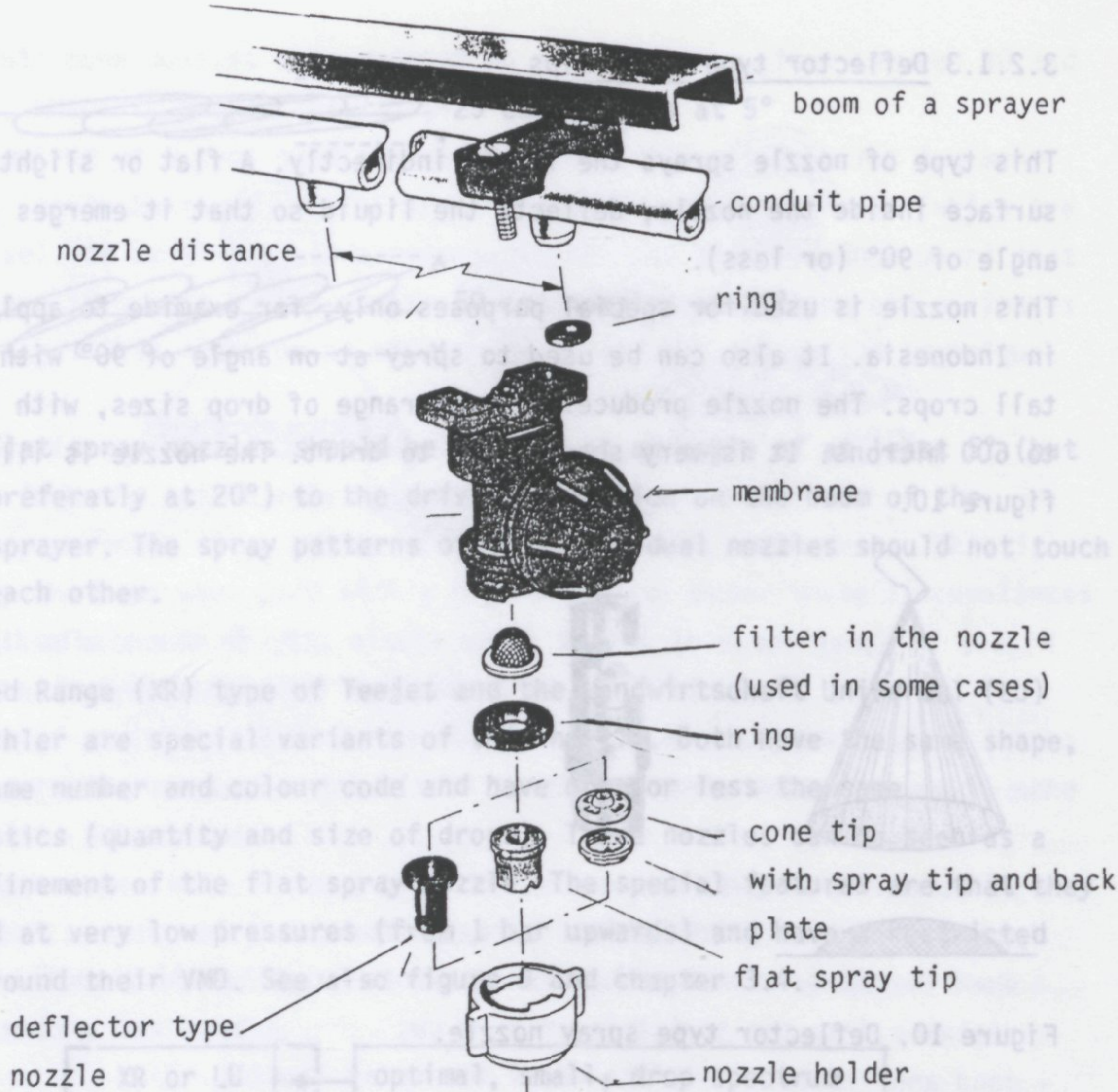


Figure 11. Parts of a sprayer.

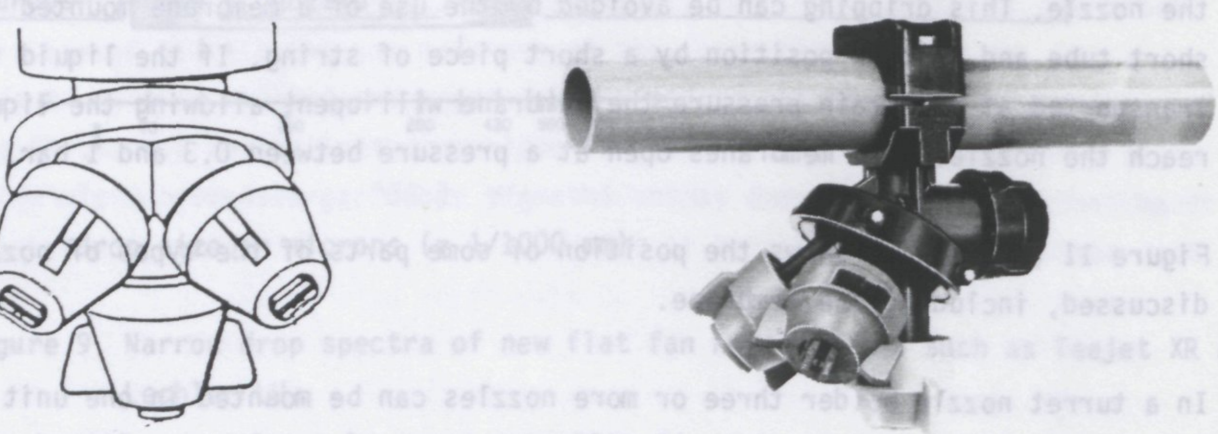


Figure 12. Turret nozzle holder.

3.4 Effect of pressure, top angle and spray height

The effect of spray pressure will be illustrated with table 8, which shows the amount of liquid emitted by standard, flat, Teejet spray nozzles, the Teejet XR and the Teejet Low Pressure (= LP) nozzles and the Lechler LU nozzle, which are all flat spray nozzles.

The capacity in liters per hectare can be calculated by the formula.

L/HA = L/MIN x 600

----

km/ha x nozzle spacing (or, with one nozzle, the required working width of the swath sprayed.

Output of various nozzles in liters/minute

Colour	Code	Pressure (bar)								
nozzle	Nozzle type	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
015	110.015	x	x						x	x
green	standard									
	110.015 XR	0.34	0.42	0.48	0.54	0.59	0.64	0.68	0.72	0.76
	LU-015									
02	110.02	x	x						x	x
	standard									
yellow	110.02 XR	0.45	0.55	0.65	0.72	0.79	0.85	0.91	0.96	1.01
	LU-02									
03	110.03	x	x						x	x
	standard									
blue	110.03 XR	0.67	0.82	0.97	1.08	1.18	1.28	1.37	1.44	1.52
	LU-03									
04	110.04	x	x						x	x
	standard									
red	110.04 XR	0.89	1.09	1.29	1.44	1.58	1.71	1.82	1.91	2.02
	LU-04									
05	110.05	x	x						x	x
	standard									
brown	110.05 XR	1.11	1.36	1.61	1.80	1.97	2.13	2.28	2.39	2.48
	LU-05									
06	110.06	x	x						x	x
	standard									
grey	110.06 XR	1.33	1.63	1.93	2.16	2.37	2.56	2.74	2.86	3.01
	LU-06									
08	110.08	x	x						x	x
	standard									
white	110.08 XR	1.77	2.17	2.58	2.88	3.16	3.41	3.65	3.79	4.00
	LU-08									

8004 LP	110.04 LP	1.49	1.82	2.11	2.35
8005 LP	110.05 LP	1.86	2.28	2.63	2.94
8006 LP	110.06 LP	2.23	2.74	3.16	3.53
8008 LP	110.08 LP	2.98	3.65	4.21	4.71

Table 8. Capacity of one nozzle in liters/minute for standard Teejet flat spray nozzles, for the Teejet XR, the Lechler LU and, at the bottom of the table, for the Teejet LP nozzle.

In table 9, the number of seconds required to walk a distance of 10 m while spraying is converted into speed in terms of km/h.

Table 9. Speed in seconds/10 m ; km/h

Seconds per 10 meters	Kilometers per hour
18 1)	2
17	2.1
16	2.3
15	2.4
14	2.6
13	2.8
12	3
11	3.3
10 2)	3.6
9	4
8	4.5
7.2	5
7	5.1
6	6
5.1	7
5 3)	7.2
4.5	8
4	9
3.6	10
3	12

1) 18 seconds for 10 meters = 55 cm in one second;
2) 10 seconds for 10 meters = 100 cm in one second;
3) 5 seconds for 10 meters = 200 cm in one second.

Table 10. Output in liters/hectare for nozzle spacing of 50 cm at different walking speeds, for different nozzle sizes, pressures and drop spectra.

Nozzle type	Pressure in bars	VMD drops [1)] L	VMD drops [1)] T	Output l/min	Liters per hectare at speed in km/h[2)] 2	3[3)]	4	5	6	8
Colour orange	1.0		140	0.23	138	92	69	55	46	35
Teejet XR	1.5			0.28	168	112	84	67	56	42
110-01[3)]	2.0		102	0.32	192	128	96	77	64	48
No comparable	3.0		92	0.39	234	156	117	94	78	59
Lechler LU	4.0		85	0.46	276	184	138	110	92	69
	5.0		80	0.52						
Colour green	1.0	167		0.34	202	134	101	81	67	51
Teejet XR	1.5	162		0.42	248	164	124	99	82	63
110-015[4)]	2.0	158		0.48	286	190	143	114	95	72
Lechler LU	2.5	153		0.53	320	214	160	128	107	30
347-015[4)]	3.0	148		0.59	352	234	176	141	117	89
	4.0			0.68	408	272	204	163	136	102
	5.0	136		0.79						
Colour yellow	1.0	192	190	0.45	268	180	134	107	90	69
Teejet XR	1.5	189		0.55	328	220	164	132	110	84
110-02	2.0	184	147	0.63	380	254	190	152	127	98
Lechler LU	2.5	178		0.71	428	284	214	171	142	107
367-02	3.0	173	136	0.78	468	312	234	188	156	119
	4.0		124	0.91	546	364	273	218	182	137
	5.0	152	121	1.00						
Colour blue	1.0	243		0.67	402	268	201	161	134	102
Teejet XR	1.5	224		0.82	494	328	247	197	164	126
110-03	2.0	205		0.95	570	380	285	228	190	146
Lechler LU	2.5	195		1.06	638	426	319	255	213	150
407-03	3.0	185		1.17	700	468	350	280	234	177
	4.0			1.37	822	548	411	328	274	206
	5.0			1.58						
Colour red	1.0	298		0.89	536	356	268	214	178	137
Teejet XR	1.5	252		1.09	656	436	328	262	218	168
110-04	2.0	228		1.26	758	504	379	303	252	194
Lechler LU	2.5	235		1.42	850	566	425	340	283	215
447-04	3.0	205		1.55	932	622	466	373	311	237
	4.0			1.82	1092	728	546	436	364	273
	5.0			1.98						
Colour brown										

1) The Volume Median Diameter (VMD) is given, based on information from Lechler (L) and Spraying Systems (T);
2) Nozzle distance 50 cm;
3) 1 m/s walking speed = 3.6 km/hour; see table 9.
4) For this nozzle type, a special fine filter of 100 Mesh is necessary (see table 7). All other nozzles can be used with the standard filter of 50 Mesh.

The nozzle output in liters/minute at a specific pressure (see table 8) gives the amount in liters/hectare for boom-mounted nozzles spaced 50 cm apart when multiplied by 200 for a speed of 6 km/hour. When multiplied by 400 for a walking speed of 3 km/hours. For instance, the 02 (= yellow) nozzle at 2 bars gives 0.63 liters/minute, which is:
126 l/ha at 6 km/ha (= 6 seconds/10 meters);
252 l/ha at 3 km/ha (= 12 seconds/10 meters).

In table 10 the output is given in this way for walking or driving speeds of 2, 3, 4, 5, 6 and 8 km/hours. The output for 2 km and 3 km is calculated by doubling the output at respectively 4 and 6 km.
The Volume Median Diameter (VMD) is also given. This information is based on drop spectrum analyses. Table 10 can be used to choose the appropriate walking speed for spraying with a flat spray nozzle.
Appendix 5 gives more technical information on the nozzle output, VMD, D 10 and D 90 at intervals from 1-6 bars. Table 10 assumes the nozzles on the boom are 50 cm apart. This assumption also holds if only a lance with one nozzle is used. If the nozzle spacing on the boom differs from 50 cm, then multiply the l/ha given in the table by one of the following factors.

Table 11. Conversion table for boom or lance nozzle spacings different from 50 cm.

Other spacings in cm	20	25	30	35	40	45	55	60	75
Conversion factor	2.5	2	1.67	1.43	1.25	1.11	0.91	0.83	0.66

So, at 40 cm nozzle spacing 100 l/ha at 50 cm is 1.25 x 100 = 125 l/ha.

If the liquid sprayed is heavier or lighter than water, a conversion factor also has to be used. In this case one has to look at the tables or measure the nozzle output with water first. Then one has to examine the weight of 1 liter of the solution that is to be sprayed. The conversion factors for some weights are given in table 12.

Table 12. Conversion factor for spraying solutions heavier or lighter than 1 kg/liter.

Kilogram/ liter	0.84	0.96	1.08	1.20	1.28	1.32	1.44	1.68
Conversion factors	0.92	0.98	1.04	1.10	1.13	1.15	1.20	1.30

So, if 1 liter of the liquid weights 1.44 kg, to obtain 100 l/ha one has to set the output at 120 l/ha.

As can be seen in tables 8 and 10, changing the pressure in the XR and the LU nozzles from 1 to 4 bars doubles the output; however, this also alters the VMD of the drops; for instance for the 110.02 XR and the LU 02 from 195 microns to 162 microns at 4 bars. So, with increasing pressure the drop size decreases and the susceptibility to drift increases. It is therefore advisable to use these nozzles at low pressure. Complete lists of the VMD and other properties of various nozzle types are available from their manufacturers.
Figure 13 shows that the smallest nozzles of Lechler, the 347-015 and 367-02, have an almost horizontal relation between pressure and VMD. The same is true of the comparable nozzles Teejet XR 110-015 and 110-02. This makes these nozzles very attractive for use in fields and experimental plots. Between 1 and 3 bars the output of the 02 nozzle at 2 km/ha can be changed from 268 to 468 l/ha, whereas the VMD of the nozzle spectrum only changes from 192 to 173 microns.

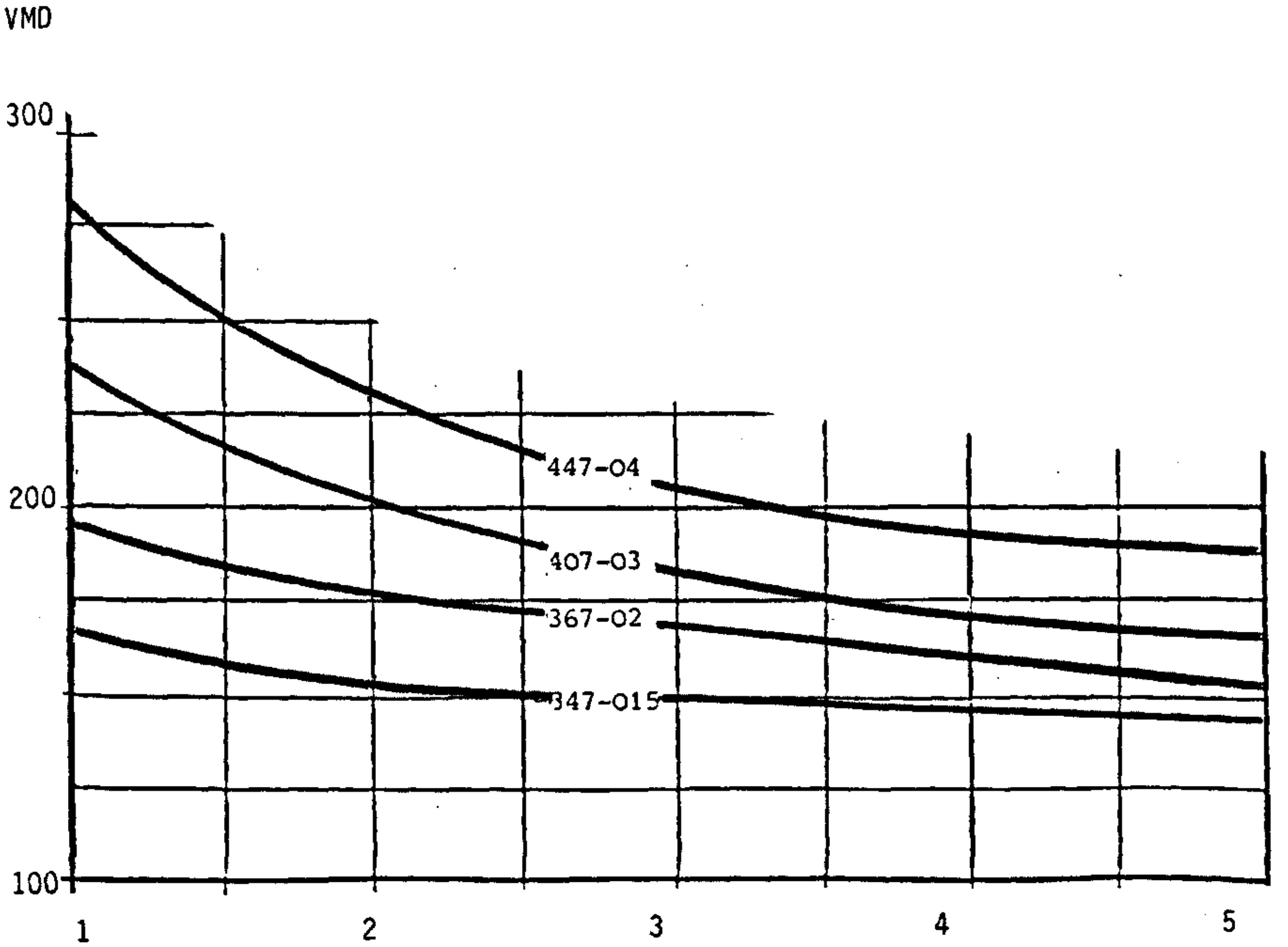
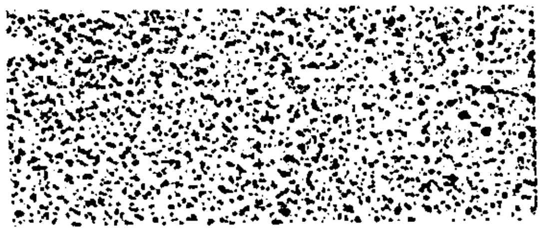


Figure 13. Relation between presure and VMD of the drop spectrum for Lechler LU nozzles.

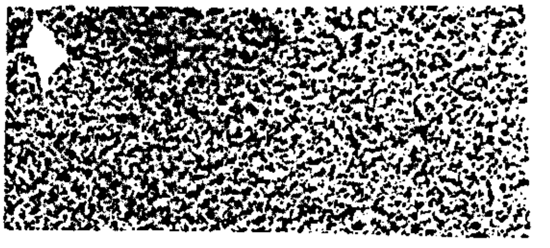
Figure 14 shows the spray patterns obtained on water-sensitive paper by increasing the pressure. The coverage increases from 1-4 bars, but the VMD changes relatively less.



1 bar

4 bar

2 bar



3 bar

Figure 14. Deposition on water-sensitive paper of the drop spectrum of the Teejet XR 015-nozzle at four pressure intervals. Results of experiments done at PAGV.

The top angle of the nozzles, particularly when mounted on a boom, influences the distance that should be kept from the target (see figure 15). It is advisable for the spray pattern of all nozzles to overlap each other at least once.

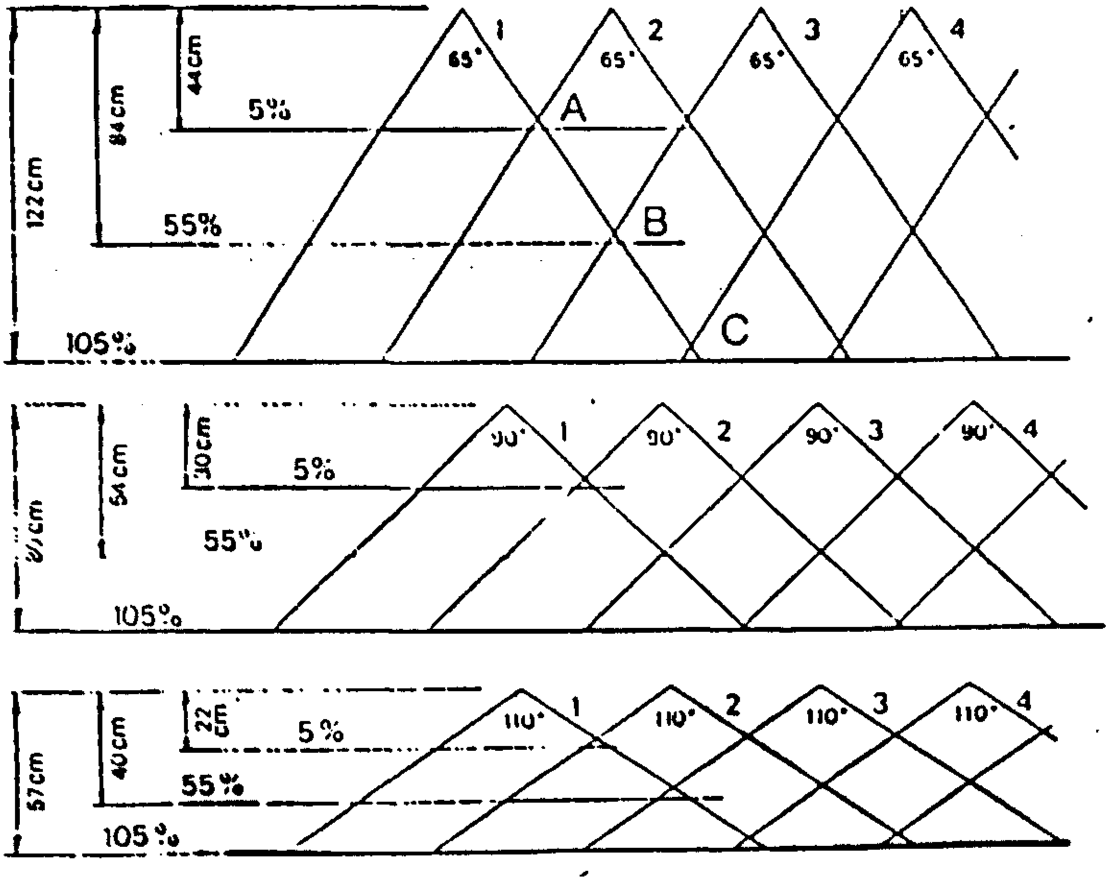


Figure 15. Distance (height) from the target and subsequent overlap of spray pattern of nozzles with various spray angles.

The smaller the spray angle, the fewer drift-susceptible drops are produced. Thus in this respect a top angle of 65° is preferable to one of 110°. However, it is possible to spray at 25-40 cm distance from the target when the spray angle is 110°, while with a spray angle of 65° this distance is 84 cm. Therefore, taking all factors into account, the shorter distance from the target eventually makes the 110° nozzle less susceptible to drift. This means that the 110° nozzle has to be preferred and recommended. It can be used at the lowest spray height possible (25-40 cm) and produces the least amount of drift and pollution of the environment.

With the traditional hollow or full cone nozzle the spray angle is mostly very sharp. This means that the working distance to the target is relatively large and therefore there is a greater risk of spray drift.

3.5 The influence of additives on drop spectrum and deposition

Spray solutions containing wetters and/or stickers can change the drop spectrum and the deposition of the liquid and can also influence retention.
When drops in a spray impact on the leaf surface they will flatten, recoil and subsequently will be retained or deflected. The outcome depends on the physical properties of the drop and on various plant factors. It is necessary to study these processes carefully before using any additives.
In the Netherlands new products are tested in national and international programmes. Table 13 summarizes the effects of certain products on the drop spectrum.

Table 13. Drop spectra of water and water + additives, sprayed by Teejet XR-VS 110.03 nozzle at 2 bars (measured at the Institute of Agricultural Engineering, Wageningen, the Netherlands).

Liquid	% of volume <49 micron	D 10	D40 = VMD	D 90
0	1.2	94	231	466
A	2.5	81	187	423
B	3.5	74	166	390
C	2.9	77	169	411
D	2.5	80	183	416

0 = water only, A = water + wetter Agral LN 1%, B + C are the same additive, no. 1, at 1 and 0.5% respectively, D is another additive, no. 2, at 1%.

All additives tested above resulted in a finer drop spectrum. The D 10, VMD and D 90 became smaller. When the proportion of additive was halved (0.5% compared with 1%, see B to C), the spectrum increased again. Addition of the additives increased the number of drops <49 microns too, which can contribute to more drift.
Research done by Dr. G. Maas and Dr. G. Krasel at the Biologische Bundes Anstalt (BBA) in Braunschweig, Germany and elsewhere suggests, that the additive helps the spray to stick to the target more easily and faster. Experiments at PAGV, Lelystad showed the same mechanism. In spite of a finer drop spectrum the drift did not increase. In the Netherlands, additives are rarely used with agrochemicals because it is felt that the chemical should be sold in a form that is already complete for application. All additives and agrochemicals need approval in the Netherlands.

3.6. How to analyse deposition and drift

The deposition of a spray can be ascertained with the help of the information given in appendix 4. It can be measured on or in the target crop at several depths, on the soil around the crop to ascertain how much spray is wasted, and downwind, to measure drift. Wind drift largely depends on the drop size and the wind speed. At wind speeds higher than about 4 m/s (= 8 km/h or about Beaufort scale 3 (see table 3) spraying should be avoided. Table 14 gives the wind drift at this wind speed for various drop sizes.

Table 14. Spray drift at a wind speed of about 4 m/s for various drop sizes.

Diameter of drops (microns)	Distance reached if not evaporated
1	90 km
10	900 m
20	225 "
50	36 "
100	7.5 "
150	4.7 "
200	3.7 "
250	2.7 "
300	1.8 "
400	1.35 "

As can be concluded from table 14 drops larger than 150 microns are less likely to drift. The advice is to use a drop spectrum around 200 microns.

There are several ways of checking deposition and drift:

a. Water-sensitive paper

The use of water-sensitive paper enables the deposition of drops on the target area and the drift outside to be seen directly. However, drops of 100 microns are difficult to see, while drops less than 100 microns are mostly invisible. Page 8 of the brochure "Water-sensitive paper for monitoring spray distribution" by Ciba-Geigy, shows drops with a VMD of 200 microns. The following illustration is from that leaflet.

Visual assessment of droplet densities

Compare your spray card samples with some known standard. The standard cards below cover the range of acceptable droplet densities for coarse and medium LV sprays. The droplet density in the target area should not be less than:

Number of droplets per cm^2*	Type of spray
20–30	Insecticides
20–30	Herbicides pre-emergence
30–40	Contact herbicides post-emergence
50–70	Fungicides

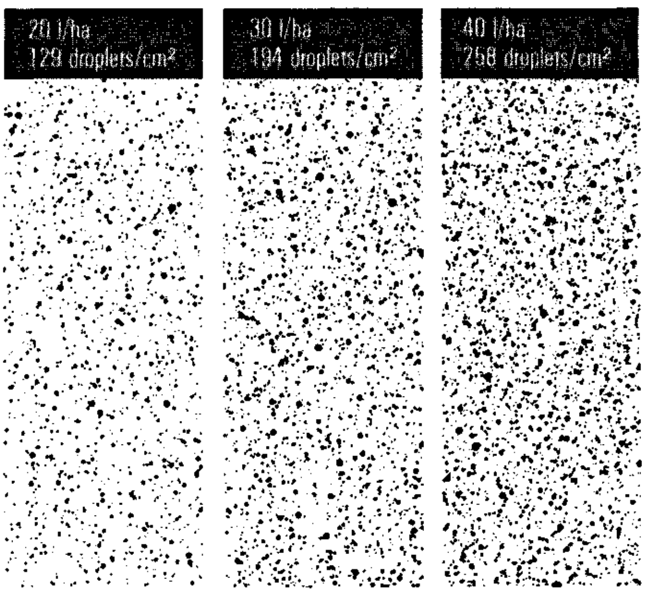
* 1 cm^2 = 0.155 sq inch 1 sq inch = 6.452 cm^2

For routine checking of sprays you might also prepare your own standard cards by selecting spray cards with known droplet densities from previous spray operations.

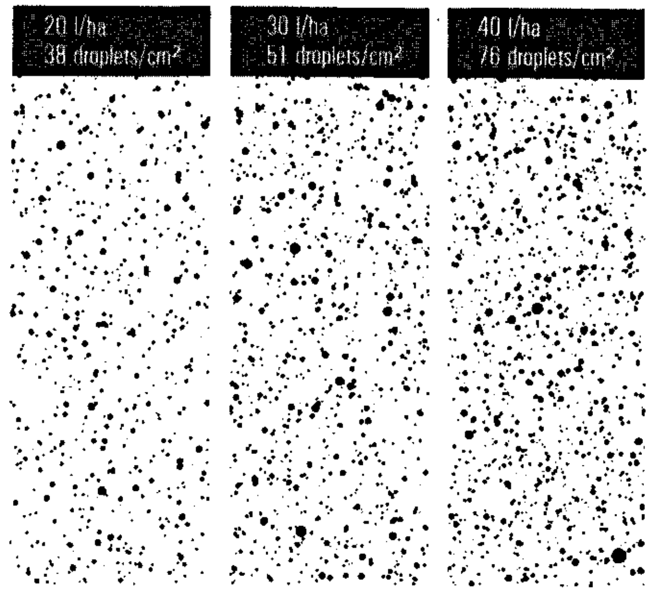
Standard cards with a known droplet density per cm^2

Computer-plotted standard cards displaying the expected number and sizes of stains spraying at 3 different volume rates (20, 30, 40 l/ha) and using 3 different droplet spectra (VMD 200, 300, 400 µm) assuming water is sprayed and the spread factor is two (see page 11).

VMD 200 µm



VMD 300 µm



VMD 400 µm

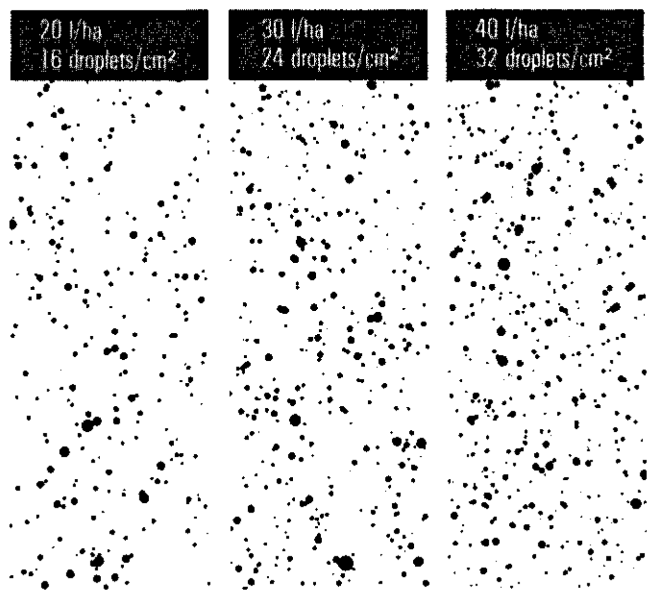


Figure 16. Droplet densities at 20, 30 and 40 l/ha at VMDs of 200, 300 and 400 microns, based on information from Ciba-Geigy on low volume spraying.

The liquid sensitive paper is available in different sizes (26 x 76 mm, 52 x 76 mm and 26 x 500 mm) and as water- or oil-sensitive paper. These papers can be put in all parts of the crop, on the soil and outside the sprayed area. PAGV advises a series of positions: the top of the plant, at 1/3 and at 2/3 height and on the soil. To measure drift the paper must be placed at a height of about 0,50 m, 1, 2, 3, etc. m away from the crops, to measure the total drift distance.
A droplet counting card (as offered by Ciba-Geigy) can be used to count the number of drops. Drop size can be measured with a special magnifying glass, which has drop sizes on a glass plate.
It is also possible to count and measure the drops by means of a computer and an image analyser.
The drops on the water-sensitive paper are about twice their real size, because the paper behaves like as blotting paper. Special oil-sensitive paper is available for oil-based or oil dominating liquids - as are sometimes used for ultra low volume spraying.

Figure 17 shows the results of two series of analyses with water-sensitive paper. A and B (in duplicate) are from the top and underside of the leaves, respectively. C and D are from the top and underside of leaves 1/3 from the top of the plant.

After measuring the results of a spray the water-sensitive paper is still sensitive to water. So, a wet crop, a shower of rain, a high relative humidity or wet hands can change the deposition picture. So far, attempts to seal the pattern with special sprays have failed. The best way to store the results is to photocopy the paper - as done in figure 17. The originals can be kept in good condition if stored in a dry atmosphere.

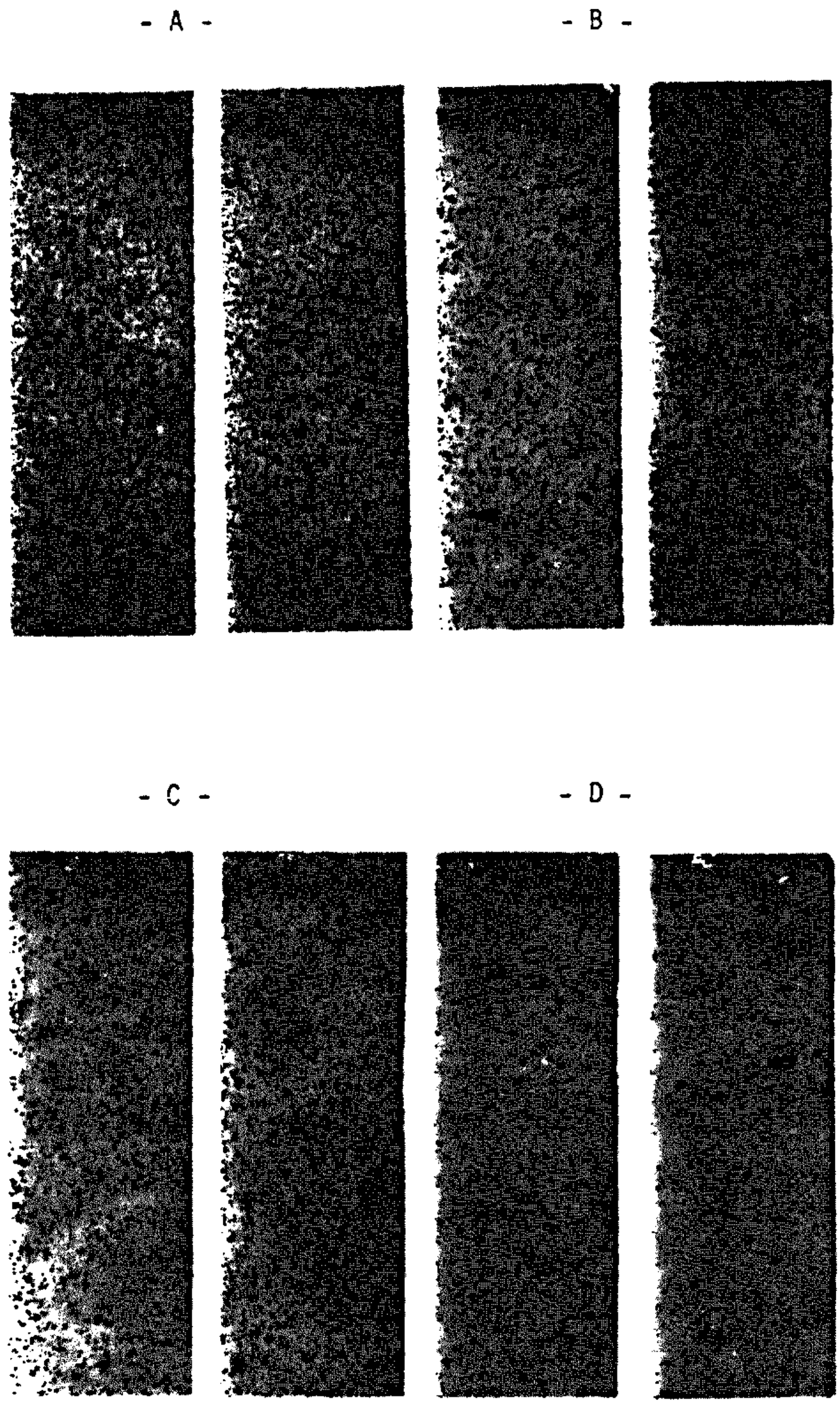


Figure 17. Deposition of droplets on a target, A = upper side of top leaves, B = under side of top leaves, C = upper side of leaves 1/3 from the top, D = under side of leaves 1/3 from the top. Sufficient drops/cm^2 were obtained.

b. Special chemicals

Certain pesticides and insecticides leave a deposit on the plants which is visible when the liquid has evaporated. This allows the result to be examined directly.
The residues of Pyrethroid-type pesticides and insecticides can be analysed in samples by means of the gas chromotograph. Several types of these chemicals can be sprayed in the same strip, so that the results are a very accurate impression of the reality.

c. Fluorescent

Several types of fluorescent are available. They can be mixed in the spray liquid. The results can be analysed later in the darkness of the night using a special fluorescing lamp. Alternatively samples can be taken from leaves at various places and the results can be analysed in a dark room.
A fluorimeter is essential for advanced research, in particular for making a mass balance of the chemical sprayed. The fluorescent tracer method has been adapted for situations where no laboratory is available. This method is also very useful for drift analyses. The spray liquid can be collected and washed off from plants, from filter paper or from pipe cleaners.
A fluorimeter is essential, for developing research on spray techniques. It would be useful in Indonesia, to study the control of pests and diseases that do not appear regularly.
Ciba-Geigy, Switzerland, is very familiar with the fluorimeter method and has documentation in English available.

4. TYPES OF SPRAYERS

4.1 Ordinary knapsack sprayers

In Indonesia the standard sprayer used is a hand-operated knapsack sprayer. This system is used throughout the world as the first step in the mechanization of spraying pesticides and insecticides. It is a relatively cheap appliance, requiring a rather simple technique. In the Netherlands it was very popular until around 1950 and it is still used to treat small plots.

The standard knapsack sprayer is operated by a small pump (see figure 18). It is a robust appliance, made of brass.

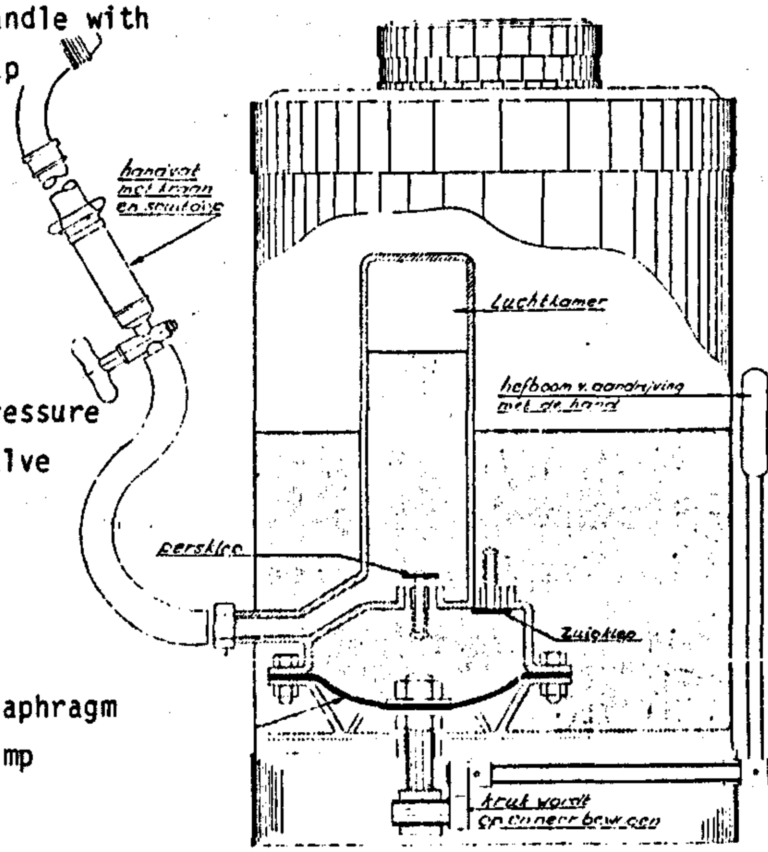


Figure 18. Standard knapsack sprayer.

By moving an over-arm lever or on under-arm handle up and down during spraying the spray liquid is brought under pressure and will leave the nozzle under a certain pressure. A disadvantage of these sprayers if equipped with a conventional nozzle (high output and large droplets) is that the pressure falls rapidly and pumping has to be intensive.

Compared to European prices the knapsack sprayers on the market in Indonesia and other Asian countries are less expensive than in Europe (about D. Fl. 80-110 = Rp. 60.000 - 80.000).
The knapsack sprayers used in Indonesia are equiped with full cone nozzles/spray tips. Samples of these nozzles were bought in shops in Indonesia and analysed for their characteristic spray pattern on a Malvern 2600 E-type particle analyser Va 6 at IMAG, Wageningen. The results are given in appendix 6 and summarized in table 15.

Table 15. Spray pattern of Indonesian full cone nozzles of knapsack sprayers, expressed in D 10, VMD and D 90[1] (in microns) at three pressure levels (3 bar is common).

Name of nozzle/spray tip	Pressure used for test (in bars)	D 10	VMD	D 90
Apolo	1	71.74	244.86	422.38
Apolo	3	47.91	163.52	301.57
Apolo	5	40.89	147.59	286.22
Apolo turned open	1	241.27	566.23	1084.20
Apolo turned open	3	128.31	372.48	644.12
Apolo turned open	5	102.72	326.46	593.56
Jantung	1	289.36	714.74	1299.99
Jantung	3	168.13	513.31	1033.63
Jantung	5	124.16	438.36	933.05
Kepala Dua	1	79.44	266.97	511.39
Kepala Dua	3	51.47	184.92	345.27
Kepala Dua	5	37.97	171.45	320.66
Kepala Satu	1	101.54	331.98	597.51
Kepala Satu	3	60.58	191.09	362.14
Kepala Satu	5	49.13	171.05	336.85
Lampa Duduk	1	94.54	266.09	433.05
Lampa Duduk	3	59.05	156.26	274.62
Lampa Duduk	5	35.87	104.75	193.53
Lampa Duduk turned	1	299.39	706.17	1281.40
Lampa Duduk turned	3	165.28	461.40	795.66
Lampa Duduk turned	5	121.71	388.48	669.36

1) D 10 or D 90 means the drop diameter below which 10 or 90 percent of the total volume is. VMD or D 50 means that 50 percent of the volume has a diameter below that value (see also figure 2 in chapter 3.1).

In Indonesia, the most commonly used pressure is 3-4 bars (1 bar is used at slow pumping, 4-5 bars at heavy pumping). Of the seven types of nozzles tested, four have a reasonable drop spectrum at 3 bars. However, nozzles with a higher output and a very wide spectrum are in general use. The wide spectrum includes a high percentage of drift-sensitive and oversized drops. In Indonesia it is common to spray up to 1500 l/ha liquid with these nozzles.
The pressure applied varies considerably in different standard knapsack sprayers and will cause different spray patterns. This aspect has to be studied in Indonesia and in other countries where these sprayers are used. A special lance with a manometer near the nozzle has been designed, developed and tested by PAGV for this purpose. It could be used for testing in Indonesia and other Asian countries using knapsack sprayers.
In the Netherlands and elsewhere it has been found that the full cone or hollow cone nozzle normally produces a wide drop spectrum and a large proportion of drift-sensitive small droplets. This nozzle type is also sensitive to wear and tear. The spray pattern changes rapidly as nozzles become older. Blocking caused by residues and poor dissolving of chemicals is also a problem. This is rarely noticed, especially when a lance is used, but it can result in large differences in liters/hectare and therefore it is advised to study these aspects carefully. Another problem when using this type of nozzle on a knapsack sprayer with a spray lance, is that of 'brushing'. Each plant is drenched by moving the spray lance in a series of jerks. The result is ineffective, as was illustrated in a tomato crop in Indonesia where spraying occurred every other day and yet Phytophthora infestans was present on the base of the stem.

A special type of the traditional knapsack sprayer has an air chamber. The pressure is created by a plunger pump (like a bycycle pump) before starting spraying. With this pump (see figure 19) the air can be compressed to about 7 bars in a special air chamber. It is then possible to spray for a while, but a disadvantage is that the pressure falls gradually. For this reason, the better sprayers of this type are equipped with a pressure control unit to keep the pressure constant at 2-3 bars only.

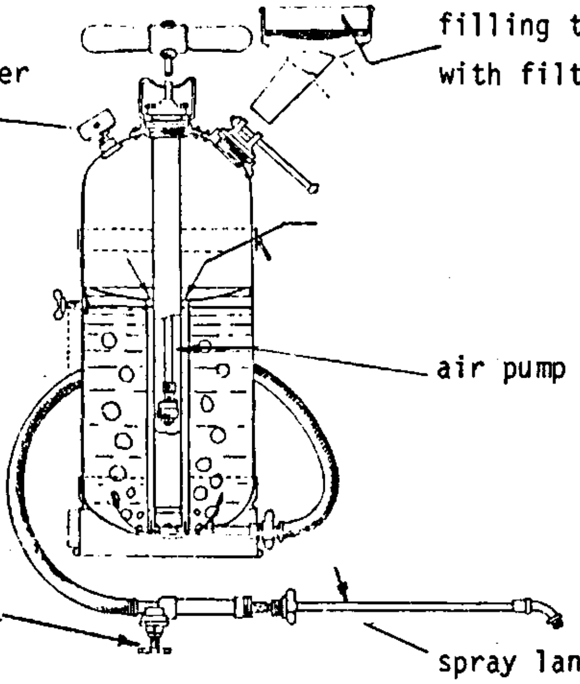


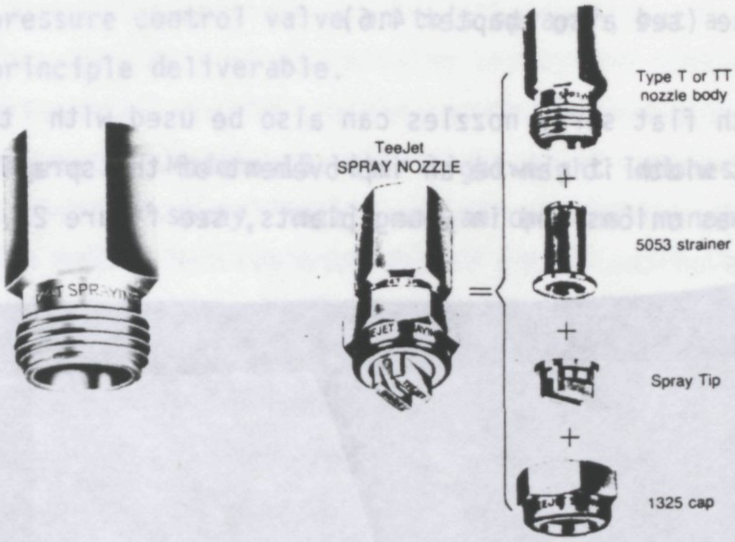
Figure 19. Knapsack sprayer with an air chamber and constant pressure.

In most types of these knapsack sprayers a pressure relief value prevents pressure form becoming too high.

4.2. Improved knapsack sprayers

a. Flat spray nozzle on standard lance

Fitting a flat spray nozzle on the knapsack sprayer will help the operator to work more accurately and systematically. Then he will have to walk slowly and to keep the lance near the target.
An adaptor unit for changing the hollow or full cone nozzle of a traditional knapsack sprayer for the recommended flat spray nozzle is available in Indonesia and elsewhere. It is produced either by Spraying Systems under the trade name Teejet or locally (see figure 20).



A standard Teejet Spray Nozzle of four parts as shown. Parts are interchangeable and available in different designs and materials

Figure 20. Adaptor unit to change the standard hollow cone nozzle in a knapsack sprayer for a flat spray nozzle.

b. Longer lance

The spray lance can be extended up to about 2 m for tall crops, as is illustrated in figure 21. This lance extension unit is also available locally in Indonesia too.

Figure 21. Extended spray lance.

c. Sprayboom instead of a lance (see also chapter 4.6)

A special lightweight boom with flat spray nozzles can also be used with the knapsack sprayer. At the right width it can be an improvement of the spraying technique in low crops, such as onions and in young plants, see figure 22.

Figure 22. A boom with several nozzles 34 cm apart, instead of a lance for surface treatment.

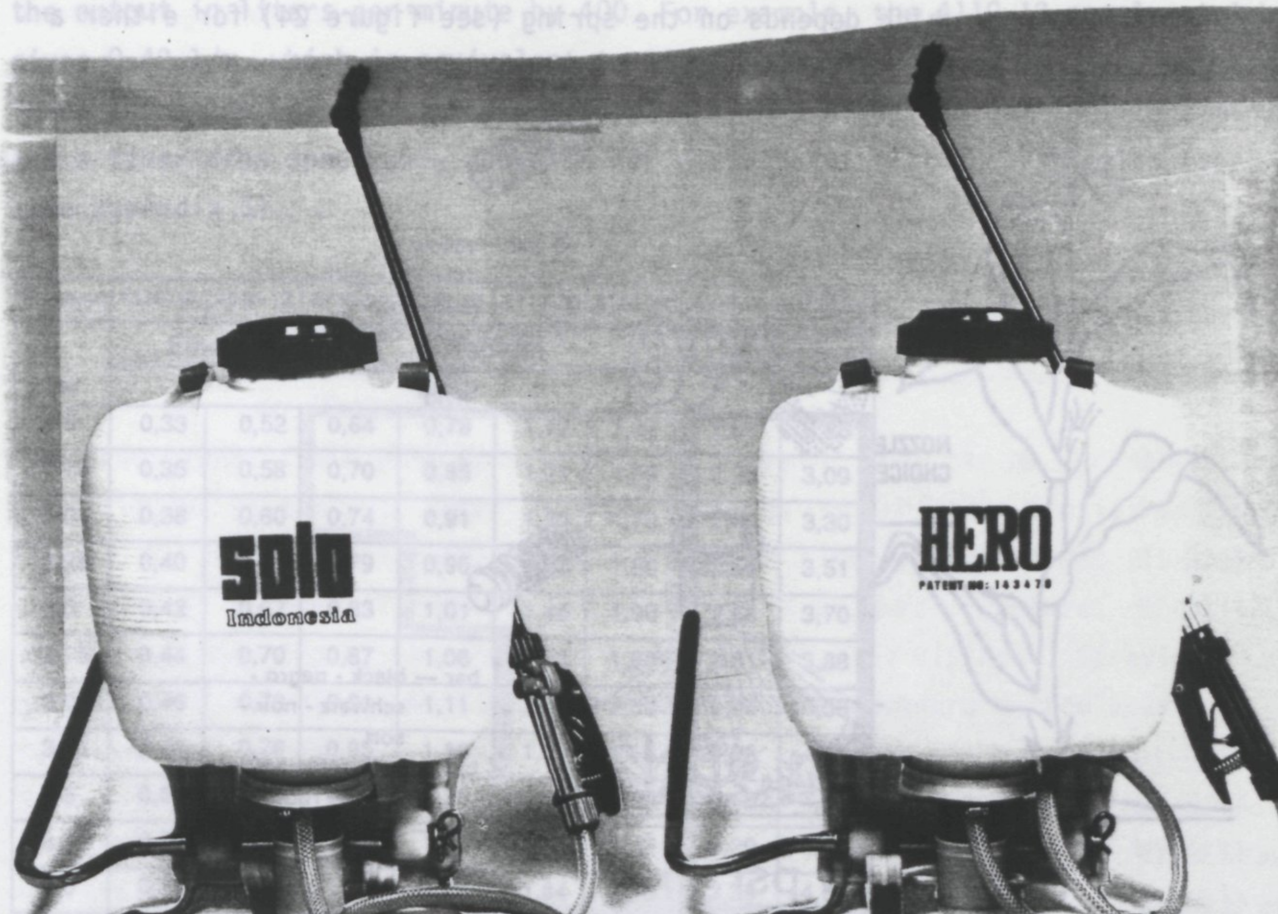
On the boom in figure 22 the nozzle spacing is 34 cm only. The output in liters per hectare can be calculated easily with the help of table 11.
A walking speed of 2-6 km/ha is possible with the boom (see tables 8 and 10 for calibration with Lechler or Teejet flat spray nozzles and table 16 for the output of Hardi flat spray nozzles).

d. Lightweight Indonesian knapsack sprayer with flat spray nozzle

Recently, lightweight knapsack sprayers, made of plastic, have come on the Indonesian market. They are produced in Indonesia under licence from the West Germany company Solo, and marketed under the trade name Hero.
The 15 liter tank machine is priced at the same level as the standard brass sprayer. It can be used either with a hollow cone or with a Lechler flat spray nozzle (as advised!) and others. The flat spray nozzle made by Lechler and sold locally in Indonesia is of a wrong industrial type, produced for washing machines. Other types that fit on the Hero are available, and are also advisable for spraying herbicides, fungicides and insecticides (see chapter 3.2).
The spray lance can be lengthened up to about 2 m for tall crops. There is no

pressure control valve on this sprayer, but a manometer on the lance is in principle deliverable.

Figure 23. Modern 15 liter lightweight Indonesian knapsack sprayer with flat spray nozzle and an optional manometer.



This Hero sprayer, made in Indonesia, has to be field tested in experiments and by farmers.

e. Pressure intervals

A further step is to make pressure limits in the sprayer. In some improved knapsack sprayers the pressure can be fixed, resulting in a more uniform and predictable spray pattern. It is regulated by types of springs, activated by a specific pressure which depends on the spring (see figure 24) for either a hollow cone or a flat spray nozzle.

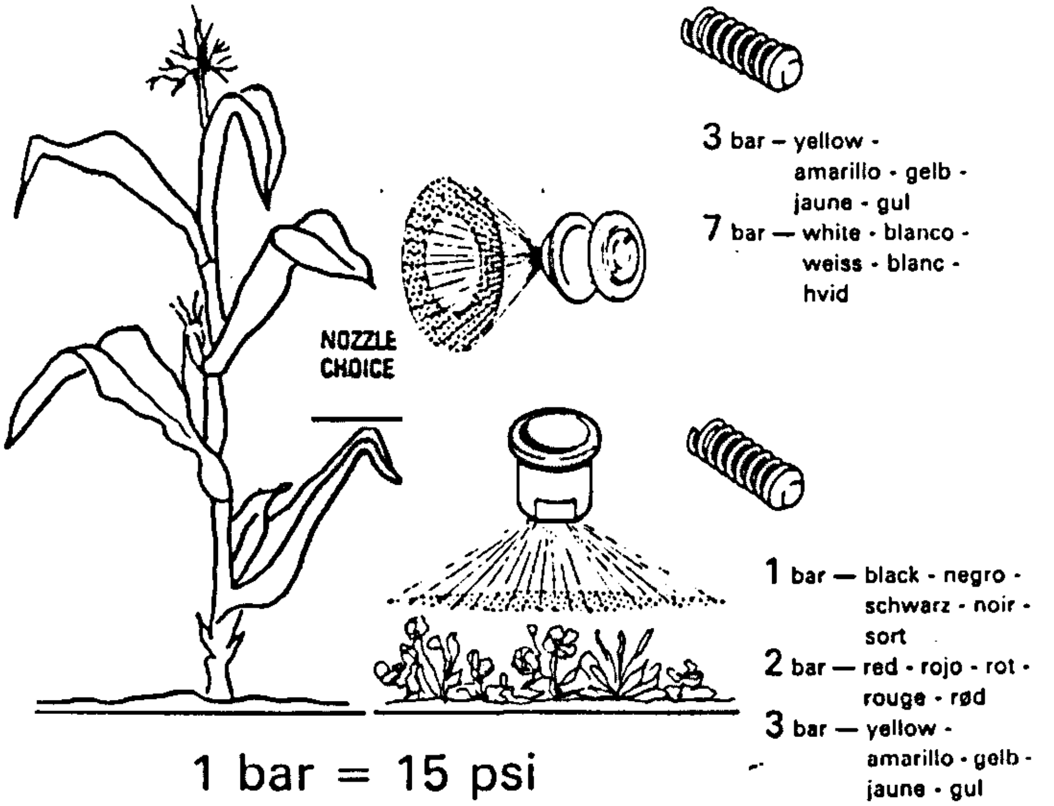


Figure 24. Pressure control springs (pressure regulators) in colour codes for their synthetic tip end. In combination with specific types of nozzles these springs can be used for pressures and spray pattern.

In the Hardi 15 liter plastic model these springs are used in combination with nozzle types according to table 16.

Table 16. Amounts of liquid with various combinations of Hardi nozzles and Hardi pressure regulators.

Regulating pressure spring Colour code	Pressure in bars (1 bar=15 PSI)	Nozzle type and number		Output liters/ minute
Black	1	Flat spray	4110-12	0.42
Red	2	" "	4110-12	0.60
Yellow	3	" "	4110-12	0.73
Yellow	3	Hollow cone	1553-12	0.82
White	7	" "	1553-18	1.43

Because the pressure can be kept constant, the amount of liquid can be changed according to need by choosing any of the combinations in table 16.
Both the flat spray nozzle and the hollow cone nozzle can spray a swath about 50 cm wide. With a walking speed of 83 centimeters/second (equivalent to 3 km/hour), the output in liters per hectare can be calculated by multiplying the output in liters per minute by 400. For example, the 4110-12 nozzle at 1 bar gives 0.42 l/m, which is equivalent to 168 l/ha.
Tabel 17 can be used for other pressures - with a higher output in liters/minute and a finer drop spectrum - and also for other Hardi flat spray nozzles (see also appendix 5).

Nozzle no.	4110-10	4110-12	4110-14	4110-16	4110-20	4110-24	4110-30	4110-36
	Fine		Medium				Coarse	
bar	l/min							
1,5	0,33	0,52	0,64	0,78	1,12	1,47	2,0	2,86
1,75	0,35	0,58	0,70	0,85	1,21	1,59	2,25	3,09
2,0	0,38	0,60	0,74	0,91	1,30	1,70	2,40	3,30
2,25	0,40	0,63	0,79	0,96	1,38	1,80	2,55	3,51
2,5	0,42	0,67	0,83	1,01	1,45	1,90	2,68	3,70
2,75	0,44	0,70	0,87	1,06	1,52	1,99	2,81	3,88
3,0	0,46	0,73	0,91	1,11	1,59	2,08	2,94	4,05
3,25	0,48	0,76	0,95	1,16	1,65	2,16	3,06	4,22
3,5	0,50	0,79	0,98	1,20	1,72	2,25	3,18	4,37
3,75	0,51	0,82	1,02	1,24	1,78	2,33	3,29	4,53
4,0	0,53	0,84	1,05	1,28	1,84	2,40	3,39	4,68

Source: Nozzle Selection Handbook
British Crop Protection Council

Table 17. Output of Hardi nozzles at pressure intervals, as can be used in the Hardi and other knapsack sprayers (drop spectra fine, medium and coarse according to table 4).

By selecting the type of nozzle and the pressure, the drop spectrum, the intensity of penetration in the crop and the sensitivity for drift (drop spectrum) are also chosen.

When working with a lance on a spray boom it is important to keep the distance to the target or surface constant. Dependent on the type of nozzle (spray angle) this distance should be 40 cm (spray angle 110°) or 85 cm (spray angle of hollow cone nozzle 65°).

For the Hardi knapsack sprayer a standard boom of 1.40 m width (4 nozzles spaced 34 cm apart) or a special boom of 2 m width (6 nozzles spaced 39 cm apart) is available. These booms are used with the Hardi flat spray nozzles mentioned in table 17. The output in liters per hectare at the nozzle spacings 50 cm (lance and boom), boom with nozzles at 34 cm apart and the special boom with nozzles at 39 cm is given in table 18.

Table 18. Output in liters per hectare at different walking speeds for Hardi 4110-10 and 4110-12 flat spray nozzles on a boom with nozzle spacing 35, 40 or 50 cm.

Nozzle type	Pressure in bars	VMD drops	Output l/min.	Liters per hectare, at speed in km/h		
				2	3	4
				at nozzle spacing 35 cm		
4110-10	2	129	0.38	326	217	163
4110-10	3	108	0.46	409	263	204
4110-12	2	181	0.60	515	345	257
4110-12	3	165	0.73	626	418	313
				at nozzle spacing 40 cm		
4110-10	2	129	0.38	285	190	143
4110-10	3	108	0.46	358	230	179
4110-12	2	181	0.60	450	300	225
4110-12	3	165	0.73	548	365	274
				at nozzle spacing 50 cm		
4110-10	2	129	0.38	...	...	...
4110-10	3	108	0.46	...	184	...
4110-12	2	181	0.60	...	...	...
4110-12	3	165	0.73	...	292	...

f. Final remarks on improved knapsack spraying

The results of improved knapsack spraying largely depend on the right combination of pressure and nozzle type. This can be difficult with 1 bar only, as found in tests done at PAGV (see also section 5.1).
It is therefore advised to work with the knapsack sprayer at pressures of 2 bars and above only.

A big disadvantage of knapsack spraying is that it requires regular pumping at a specific speed. This can also distract the operator's attention from the spraying itself.
A special field plot sprayer is still necessary for a more safe spraying technique in trials on experimental plots.
Another negative aspect of the knapsack sprayer is that for experimental field spraying the sprayer can never be emptied completely on the plot. The tank must contain several liters, to ensure that the sprayer operates accurately. This disadvantage means that the remaining liquid has to be collected and disposed of outside the field plot.

4.3. Controlled pressure sprayers

The traditional field plot sprayer is mostly a unit that can be carried by one man (figures 25 and 26). It is based on small brass canisters (containing 0.32, 0.7, 1, 2, 3, 4 or 5 liters liquid) and a small tank of propane gas (in tanks of 0.38 or 1.25 kg when filled). The propane gas is used for pressure.
The unit is carried by the operator on his front or on his back. Spraying is via a lance or a boom (figures 25 and 26). This is the standard method used by research institutes and chemical companies all over the world.
To obtain a correct coverage with the hollow cone or full cone nozzle (also traditionally used here) rather large amounts of liquid are sprayed (from about 500 l/ha upwards). The field size and the canister size is chosen in such a way that a field can be sprayed with one canister. This ensures that the right amounts of liquid chemical are sprayed accurately.
With this method of field plot spraying, special small Birchmeier Helico Saphir hollow cone nozzles are used for the drop spectrum, as is illustrated in figure 6. A hole of 1.3 or 0.6 mm can be drilled through the top to give a full cone. This makes the spray pattern more coarse.

In figure 25 the equipment has been improved by using already compressed air instead of propanes gas. Birchmeier Helico Saphir nozzles 33 cm apart are still used. In figure 26 the nozzles have been replaced by Teejet flat spray nozzles, which can be seen to be a major improvement.

Figure 25. Standard type of a portable field flat sprayer with two brass tanks of two liters and one of one liter. Nozzle distance 33 cm. Brass tubes supply compressed air to the boom.

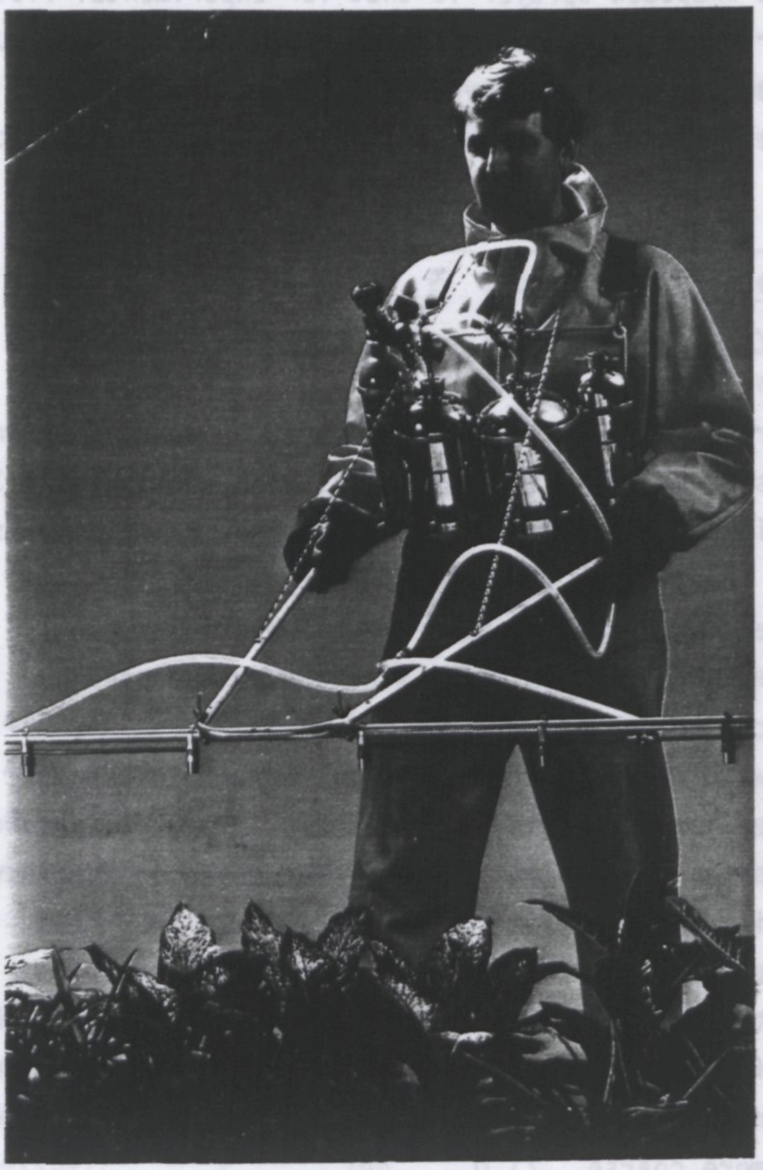
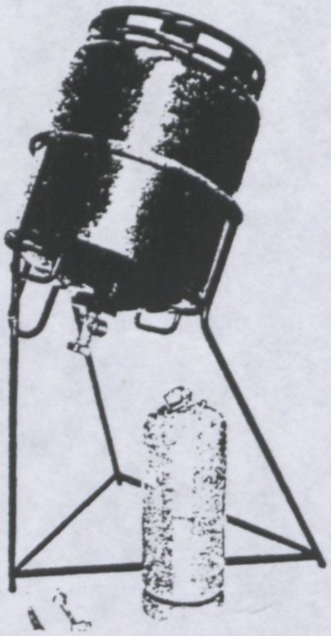


Figure 26. Standard type of portable field plot sprayer with two 5-liter brass tanks and a 5 liter compressed air tank at the back.

The basic equipment was manufactured by Birchmeier, a well-known company from Switzerland. AZO, Ede (the Netherlands) made a portable plot sprayer programme based on it. Birchmeier has since also modernized its programme.
The field plot sprayer could be improved in several ways, the main ones being:
a. compressed air instead of propane gas;
b. flat spray nozzles spaced 50 cm apart.

If propane gas or alternatively, carbon dioxide (CO_2-gas), is used, the small gas cylinder is filled by inverting the bigger tank. It is easy to do this in a frame (see figure 27). The small cylinder is filled because the gas flows downwards.



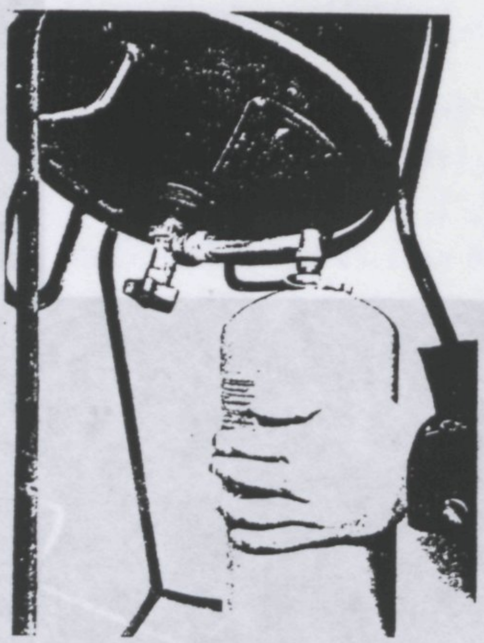


Figure 27. Filling small cylinders with propane (or carbon dioxide) from a bigger tank.

The heavier liquid gas flows from the bigger container into the cylinder placed under it. In several countries, propane gas is no longer favoured to create pressure for spraying because:
- the compressed gas in liquid form can wound people by contact;
- the gas is very flammable;
- in some countries it is forbidden to fill containers with liquid propane, except in proper depots;
- propane gas (and carbon dioxide) can react with chemicals in the spray;
- at low temperatures the gas can freeze.

Compressed air is a useful alternative.

4.4 Field plot sprayers with controlled pressure (using flat spray nozzles)

4.4.1 Field plot sprayer using compressed air or carbon dioxide (CO_2-gas)

A range of modern lightweight aluminium-based equipment has been developed for spraying experimental field plots. It includes three standard types of sprayer with a boom, see figures 28, 29 and 30, and one with a lance (type C).

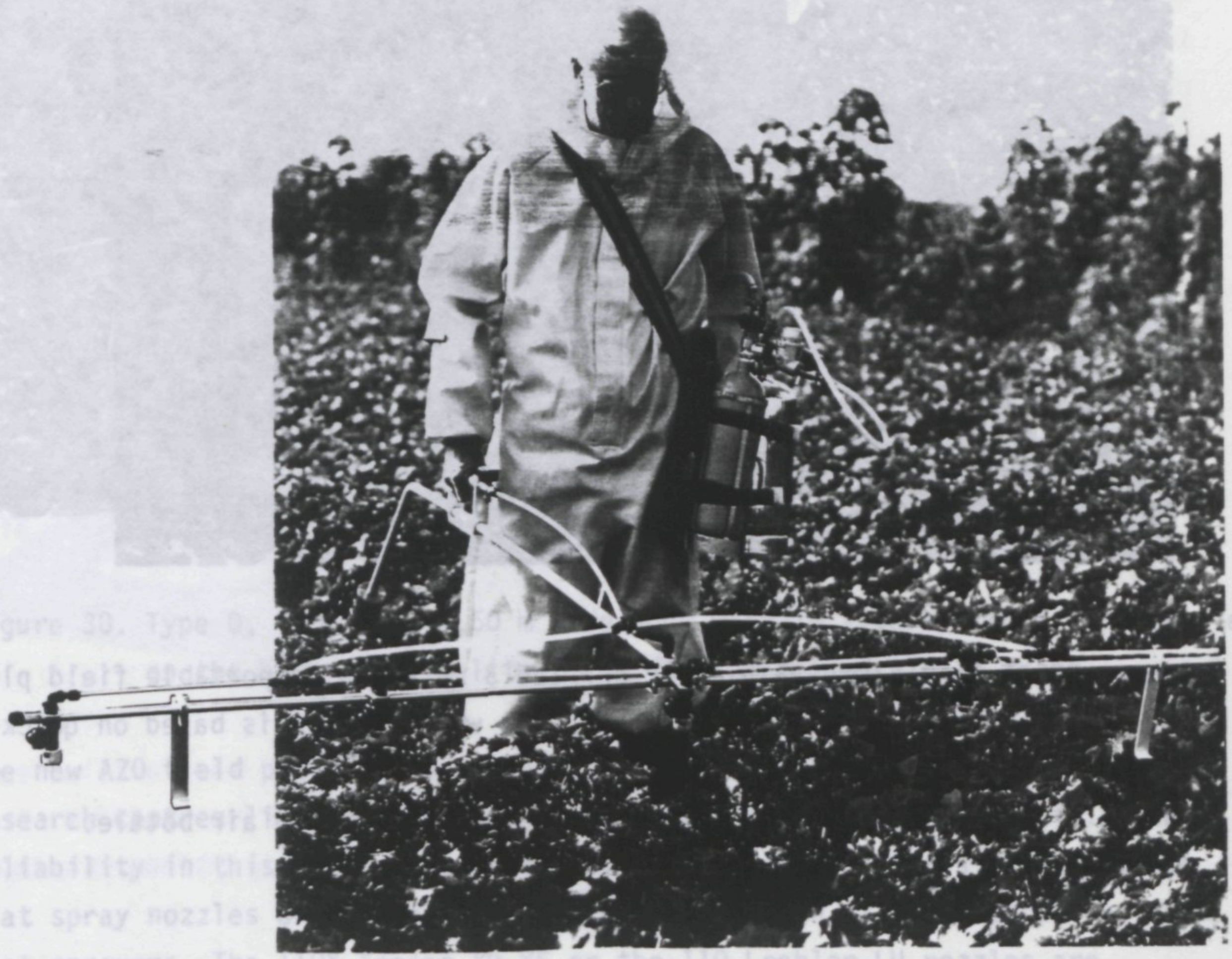


Figure 28. Type A, 1989. AZO-field plot sprayer 2 meters wide with boom and tanks (liquid and a 2 liter compressed air bottle) in front. Counterweight for balance. Manometer on the operator's right-hand side. In figures 28-30 the nozzle spacing is 50 cm, and each nozzle is filled with a membrane to prevent dripping after spraying has been stopped. A flat fan nozzle is mounted in the nozzle body, as described in section 3.2.1.2.

Figure 29. Type B, 1989. AZO chest-carried 3 meters wide portable field plot sprayer in another position. The whole system is based on quick-fit connections.
Two liter liquid bottle and 1 liter compressed air bottle.

Figure 30. Type D, 1989. AZO-2,50 m wide boom with 15 liters liquid tank carried on the back and a 2 liter tank for compressed air in front.

The new AZO field plot sprayers have been developed in close cooperation with research centres like PAGV. AZO has a worldwide reputation for precision and reliability in this type of equipment after more than 30 years of experience.
Flat spray nozzles are standard in the new generation of these portable field plot sprayers. The 110° Teejet XR-VS or the 110 Lechler LU nozzles are recommended (see section 3.2.1.2). In trials conducted by PAGV and others they were found to work very satisfactorily.
The use of standard size Teejet nozzle bodies with quick-fit caps based on the bayonet catch system enables nozzles to be fitted rapidly. Nozzle caps and nozzles can be bought in the same colour.
The quick-fit nozzle body is fitted with a membrane (diaphragm check valve). It opens at 0.3-1 bar pressure at the nozzle and prevent dripping once the tap has been closed. This is also an important improvement over the standard outfit.
The nozzles are fitted on a leightweight aluminium tube by a complete mounting kit. Holes 10 cm apart are bored in the tube to receive the nozzles. In the standard set-up the nozzles are spaced 50 cm apart.

The liquid is conveyed to the nozzle by a plastic tube 6 mm ∅ inside, via a plastic tube with quick couplings. A 8 mm ∅ inner plastic tube connects the nozzle to the tank. The whole system is very flexible.
A multipurpose carrier has been developed for the tanks, as can be seen in the illustrations.
A stopcock with an inner filter is used in the operator's right or left hand. A manometer can be placed behind the filter, which is advisable to control the real pressure near to the nozzles. In conjunction with AZO PAGV has developed a manometer to be fitted on the nozzle, enabling the real pressure at the nozzle to be controlled. The pressure is given by a cylinder of compressed air with a pressure up to 200 bars. One cylinder of 1 liter capacity is enough for spraying almost 100 liters liquid at 2 bars. Their own weight is 2 kg, 2.75 and 7.50 kg respectively.

Pressure cylinder are available in sizes of 1, 2 or 5 liters. A precision pressure valve controls the pressure in the pressure cylinder and the working pressure. A safety valve limited to 6 bars avoids problems.

Carbon dioxide is also sometimes used instead of propane gas or compressed air. Compressed air is preferable to CO_2 because air does not react with any of the pesticides.
Alkaline chemicals would react with the acid CO_2. Filling small bottles with CO_2-gas also gives problems with chemicals.

Special types of filling stations for highly compressed air are available for bottles of 1, 2 and 5 liters. The installation can either run on 220 V electricity or petrol. The machine stops automatically the cylinder is full.

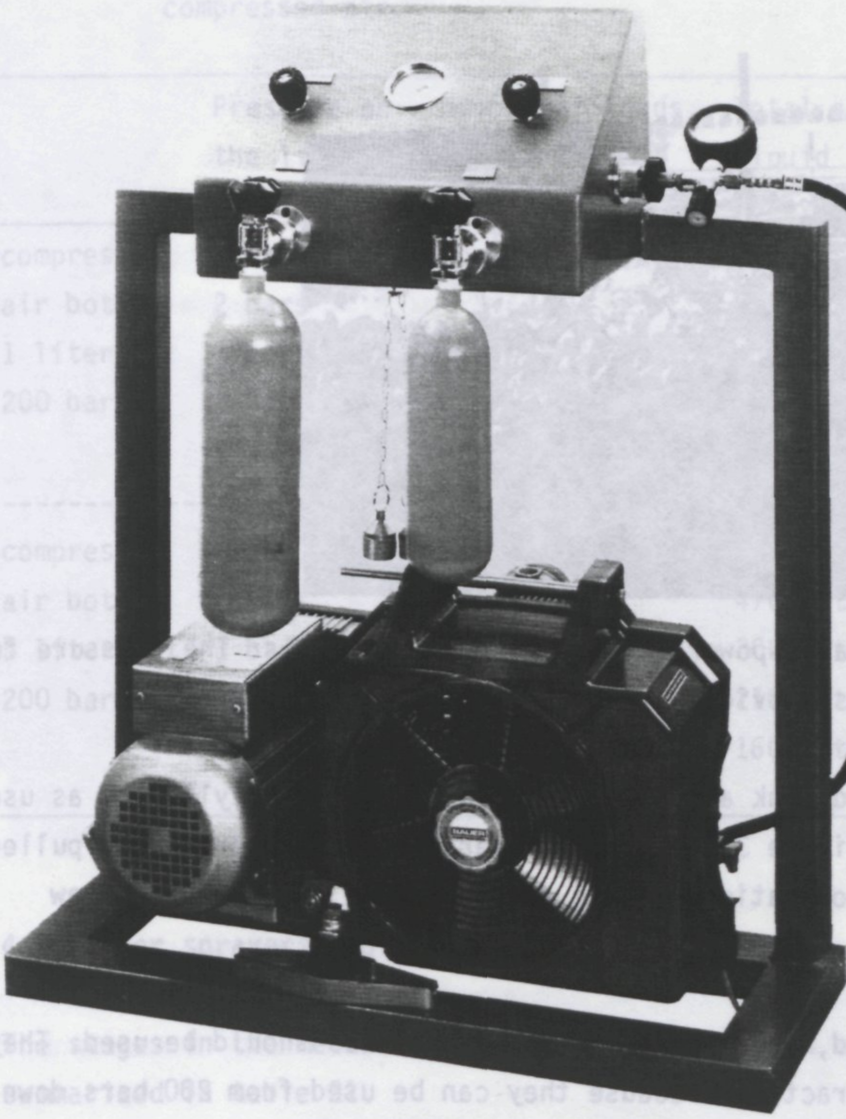


Figure 31. Filling station for compressed air cylinders of 1, 2 or 5 liters.

4.4.2 Special types of compressed air based sprayers

The compressed air unit can be connected to a 15 liters liquid mounted tank on a tractor or another mobile installation. Then a bigger field or strip can be sprayed. This is done at PAGV with various spray units.

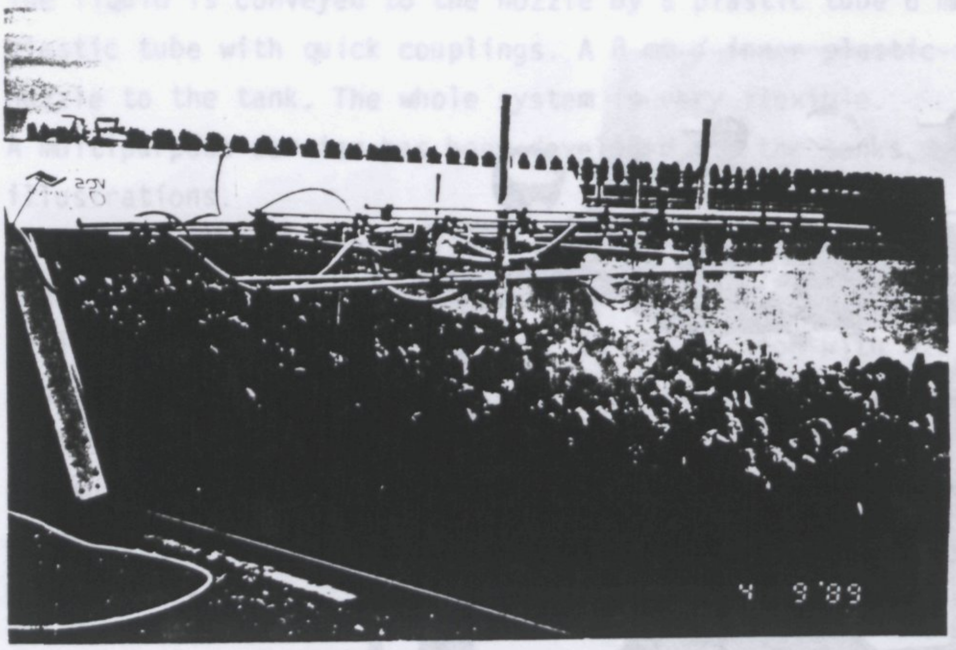


Figure 32. PAGV electrically-powered gantry sprayer on rails. The pressure for the sprayer is provided by compressed air.

The same 15 liters liquid tank and a 5 liters compressed air cylinder, as used in the system shown in figure 32 is used on various tractor-driven or pulled implements, so that the operations can be combined with surface or furrow spraying.

If compressed air is used, special tested safety bottles should be used. They have proved to be very practical because they can be used from 200 bars down, which gives a high capacity (see tabel 19).

Table 19. The capacity of 1 and 5 liters compressed air at 200 bars for spraying liquid.

Capacity output in spray liquid	
1 liter compressed air at:	5 liters compressed air at:
200 bars =	200 bar =
199 liters at 1 bars (199)	995 liters at 1 bars (995)
99 liters at 2 bars (196)	495 liters at 2 bars (980)
65 liters at 3 bars (192)	327 liters at 3 bars (954)
49 liters at 4 bars (184)	245 liters at 4 bars (920)
39 liters at 5 bars (175)	195 liters at 5 bars (875)

It can also be calculated how many tanks containing 10 liters liquid can be sprayed with one bottle of compressed air.

Table 20. Number of loads of a 10 liters liquid tank with a 1 or 5 liters bottle compressed air.

	Pressure on the liquid tank	Number of loads	Total amount of liquid to be sprayed
compressed air bottle 1 liter at 200 bars	1 bar	approx 18 loads	180 liters
	2 bars	" 9 "	90 liters
	3 bars	" 6 "	60 liters
	4 bars	" 4 "	40 liters
	5 bars	" 3 "	30 liters
compressed air bottle 5 liters at 200 bars	1 bar	approx 95 loads	950 liters (:5=190)
	2 bars	" 47 "	470 liters (:5= 94)
	3 bars	" 30 "	300 liters (:5= 60)
	4 bars	" 21 "	210 liters (:5= 42)
	5 bars	" 16 "	160 liters (:5= 32)

4.5. Other sprayers (motor sprayers)

The stages in the mechanization of the application of agrochemicals are summarized in table 21.

Table 21. Mechanization of spraying agrochemicals.

Type of spraying	Costs (in D.Fl.)
1. brusher	10
2. knapsack sprayer	150
3. improved knapsack sprayer	200
4. motor sprayers with lance + 2-man boom	1500-2500
5. portable sprayer (tractor-mounted) with boom (lance possible)	>5000

Figure 33. Motor sprayer that can be used with a lance or with a boom carried over the field by two men for plot spraying.

The motor sprayer or a power sprayer is the next step in the mechanization of spraying. Its capacity and accuracy are much greater than with a standard knapsack sprayer.

It can be used in agriculture and in horticulture. The modern versions (figure 33) have a transparent polythene tank. As an option an effective hydraulic or automatic mechanical agitator can be fitted in the tank.

The sprayer is usually used with a lance-like spray-gun. For spraying field plots it is possible to mount a boom at the end of the tube with a stopcock with manometer. This boom (with a maximum lenght of 4-5 meters) can be carried over the plots by two men, and is connected tot the tank by a tube up to 50 m long.

If a tractor with PTO is available (this is not usual in developing countries) then a tractor-mounted sprayer is preferable (figure 34). This portable sprayer can be used in all places where a reasonably flat surface and a certain area per field has to be sprayed.

Tractor-mounted sprayers may have a tank capacity from ± 200 liters upwards. Apart from their normal use for spraying crops (spraying with boom) these sprayers can also be used successfully for spraying with a lance or a vertical positioned boom and in combination with other accessories such as modified booms for spraying beds (e.g. of onions, strawberries).

The hand-operated foldable sprayboom (see figure 35) can be supplied in spray widths of 6 m and upwards.

With some modification the boom can also be carried by two men, independent of the machine. This method avoids making wheeltracks in the field. It is also possible to use half of the boom only.

The boom can be delivered with a turret nozzle holder for three sizes of nozzle, and with one closed nozzle body every 50 cm. This makes it possible to change the output or the spray pattern easily, while the boom width can be altered by closing the nozzles at 50 cm intervals too.

Figure 34. Simple tractor-mounted sprayer with a tank from 200 liters upwards and a boom length from 6m upwards.

Figure 35. The boom can be folded up for transport, so that the machine is only 184 cm wide.

The sprayer shown in figures 34 and 35 only weighs 81 kg excluding the spray boom (which weighs 42 kg and is 6 m wide).
Small four-wheel tractors, such as Iseki (16-48 HP), Kubota (12-45 HP), Yanmar (16-33 HP), Ford (16-32 HP), John Deere (16-24 HP) and Massey Ferguson (16-26 HP) can in most cases operate with 360 kg or more with their category I lift. In principle they are suitable for combining with the sprayer mentioned above. However, a lift capacity of about 600 kg, which several of these small tractors have, is preferable. If the lift is suitable for 350 kg only, the tank must not be filled with more than 200 liters.

There is a special type of motor sprayer without nozzles but with rotating discs. It is known as Controlled Droplet Application (CDA).

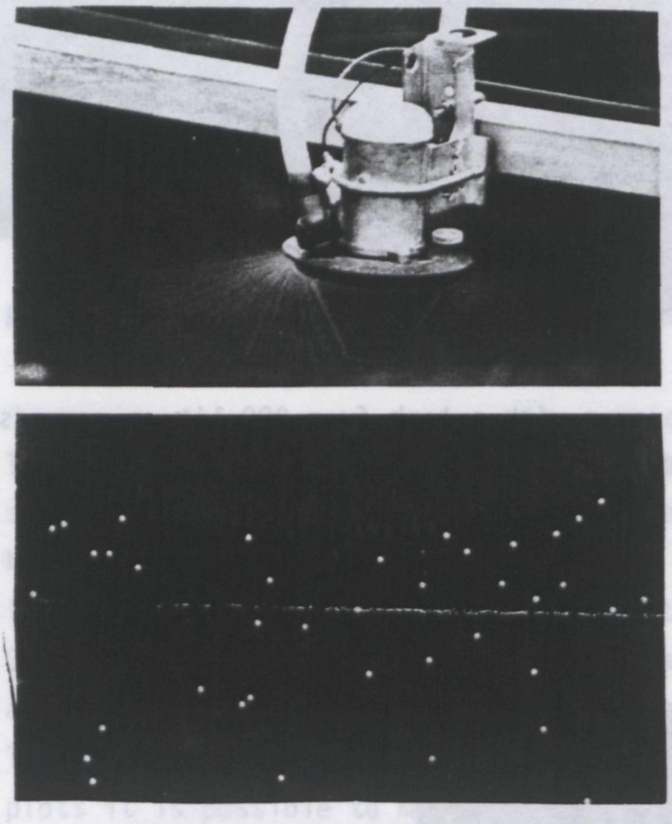


Figure 36. Rotating disc (driven by an electric engine) on a spray boom and the spray pattern produced.

In some types the discs rotate horizontally; in others they rotate vertically. The CDA sprayer can be used for very small amounts of liquid: from 25-40 liters is standard. They spray narrow and adjustable drop spectra. This makes them an interesting option.
The tractor-mounted CDA sprayer, however, is more expensive than the standard sprayer. At PAGV is has been found that the very fine drop spectra it produces are very susceptible to drift, while the penetration power is low. A fan helps to improve penetration.

Small, simple hand-operated rotating disc sprayers are also available. They are driven by a small electric engine on batteries or solar energy collectors which can also drive a fan to improve penetration.

Research is going on worldwide to study CDA spraying at volume rates around 1 l/ha only, using additives based on vegetable oil and other alternatives for water as the liquid. Centrally pre-mixed spray solutions are available on request. This might be an interesting topic for research on spraying techniques for developing countries.

Air-assisted spraying

Recently several techniques have been developed for improving the penetration power in crops of drops from field sprayers. Systems with air-liquid mixtures or air assistance are being introduced. In these systems the drops are ejected at higher speeds and the drift is decreased.

4.6 Types of lances and booms

The result of a spraying depends largely on the type of nozzle used and the accuracy practised. In principle, a spray lance is intended for spot application, not for surface application or for spraying in between tall crops. The spray lance can be lengthened to reach the tops of tall crops.
In practice, the use of the spray lance mostly demonstrates its shortcomings. The standard method is to move the lance above the spot north-south and east-west. This, is intended to give full, even coverage, but often fails to do so (as has been found in practice).
Moreover, far too much water is generally used. The poor results contribute to the need for frequently repeated spraying.
When beds are sprayed with a lance it is common for a substantial amount of the spray to fall outside on footpaths or in ditches. This because the operator can only reach the sides of the beds by holding the lance at an angle of 60° instead of vertically (i.e. an angle of 90°).
If a flat spray nozzle is used on the lance, 'brushing' is no longer necessary. One pass over the field at an acceptable walking speed is enough. The same method should be applied when using the lance in tall crops.

It is usually is better to use a spray boom instead of a lance, even with the knapsack sprayer. This gives a better spread on the target, because of the fixed distance between the nozzles on the sprayboom. Furthermore, the distance to the target is kept more constant. In tall crops a narrow boom can be used vertically.

When spraying crops in beds with a sprayboom, the width should be restricted to the crop rows. Figure 37 shows the strategy for crop rows spaced 50 cm or 34 cm apart.

n	n	n	n = 3 nozzles at 50 cm
			x = plant row
x	x	x	

n	n	n	n	n = 4 nozzles at 34 cm
x	x	x	x	

Figure 37. Spray width 1.50 m with 3 nozzles at 50 cm apart or 4 nozzles 34 cm apart. Nozzle type flat spray, top corner 110°.

When the operator has to spray the beds while walking in a ditch aside - like with onion beds of 1 metre width in Indonesia - the boom has to be connected to the operator at an angle of ± 60° with the horizontal.

In strawberry beds in countries like the Netherlands it has been found to be per bed beneficial to have two extra nozzles on the boom, to spray from the side. They are positioned in such a way that their spray does not touches.

A specially designed boom for application in crops growing in beds was developed for LEHRI-ATA 395 project. It can be used for one or two beds and is illustrated in figure 38.

Its pros and cons have to be tested in practice.

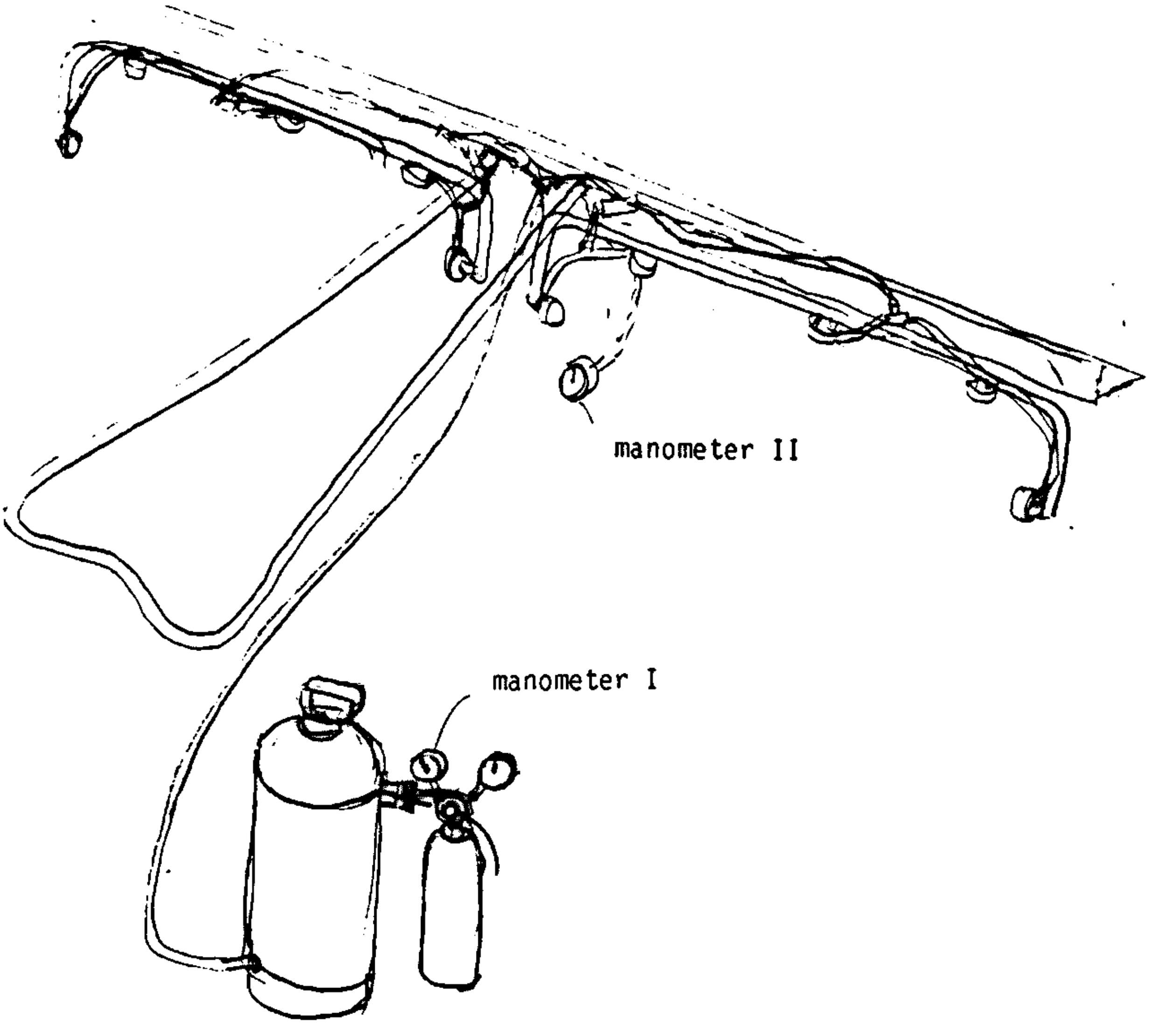


Figure 38. Specially designed boom for crops grown in beds, with two extra end nozzles that spray towards the inside of the bed.

The system might help to avoid pollution in practice. In figure 38 the device is shown connected to a portable field plot sprayer unit and with the pressure provided by compressed air.

5. IMPROVING SPRAYING TECHNIQUES

5.1. Checking spray pressure

Knapsack sprayer

It is advisable to examine common knapsack sprayers to find out what pressure is found at the nozzle. PAGV has developed a special technique to control this in the spray lance near the nozzle.
If a manometer is available as a standard or optional fitting on the knapsack sprayer it should be used, especially if the sprayer is used for field experiments.

Improved knapsack sprayer

This sprayer also has to be completed by a manometer.
The pressure in the boom of the Hardi knapsack sprayer with pressure regulator and the special 2 m boom was examined by PAGV. The nozzle type used in the boom is the Hardi 4110-10 flat spray nozzle. The set-up for measuring the pressure is illustrated in figure 39. The results are given in table 22.

Table 22. Control of spray pressure and nozzle output with a 2 m boom on a Hardi knapsack sprayer.

Pressure in bars at regulator	At manometers (see figure 39) I	II	III	Output l/min	Output in l/min according to table 17
3 (yellow)	3	3	3	0.48	0.46
2 (red)	1.8	1.8	2	0.38	0.38
1 (black)	1.5	1.5	1.75	0.34	0.33*

* at 1.5 bars

With pressures below 2 bars and the boom 2 meters wide (6 nozzles spaced 39 cm apart) pressure and output are below the amount intended. At 2 and 3 bars however, the results are good.

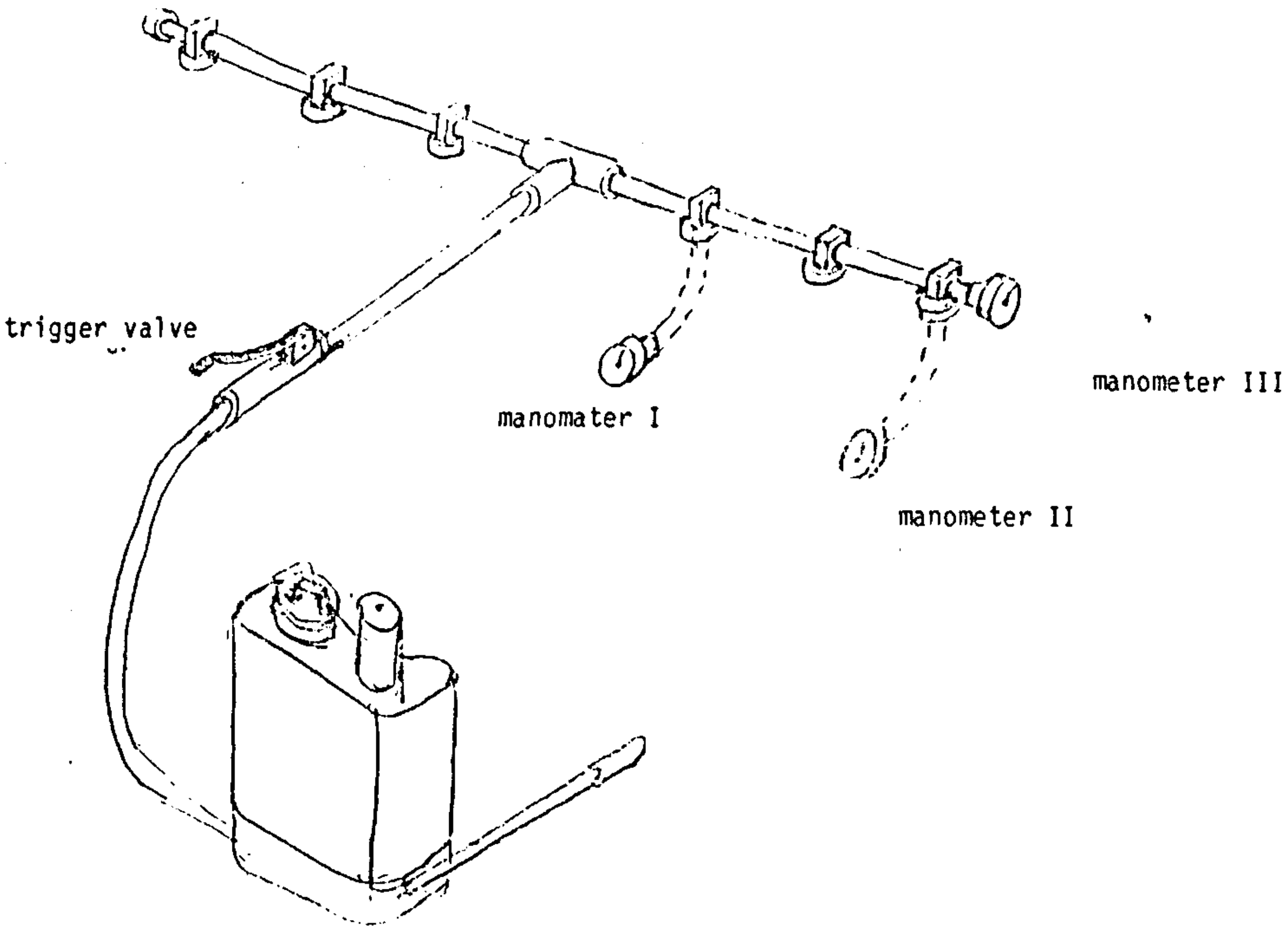


Figure 39. Checking the pressure and nozzle output of a special 2 m boom on a Hardi knapsack sprayer with pressure regulator.

Portable field plot sprayer

PAGV has carried out several tests to examine all types of new equipment and to measure the reduction in pressure. Narrow tubes, bends and changes in pipe diameter can lead to considerable losses of pressure. Figure 40 shows one of the testing set-ups used.

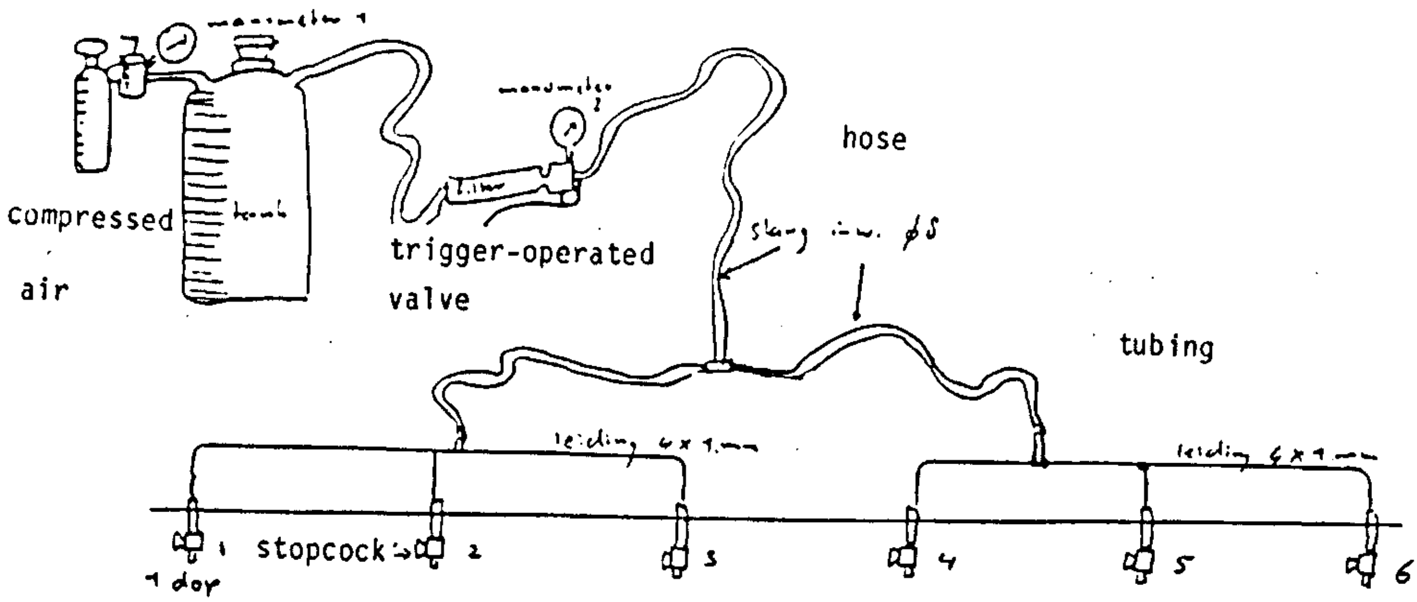


Figure 40. Experimental set-up for measuring pressure losses in portable compressed air spraying equipment for spraying plots.

The hose leaving the tank has an internal diameter of 8 mm and splits into two tubes of 6 mm internal diameter. Manometer 1 was on the tank, number 2 on the stopcock behind the filter and manometer no. 3 was fitted on the nozzle itself.

Table 23. Pressure (bars) measured at several positions of a compressed air field plot sprayer.

Manometer no. Nozzle type	(1) on the tank	(2) behind the filter	(3) at nozzle					
nozzle Teejet 110-15	1	0.7	0.5	0.5	0.5	0.5	0.5	0.5
	2.5	2.1	2	2	2	2	2	2
	5	4.2	4.0	4.1	4.1	4.1	4.1	4.1
nozzle Teejet 110-04	1	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	2.5	1.6	1.1	1.2	1.2	1.2	1.2	1.2
	5	3.4	2.7	2.7	2.7	2.7	2.7	2.7
nozzle Teejet 110-06	1	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	2.5	1.4	0.9	0.9	0.9	0.9	0.9	0.9
	5	2.7	1.7	1.8	1.8	1.8	1.8	1.9

The pressures measured at the various nozzles are fairly constant for any type of nozzle. However, the reduction in pressure between tank and nozzle is considerable, thus indicating the need to measure the pressure at or near the nozzle and the need to check the pressure properly.
In the case of a knapsack sprayer the pressure should be measured as close as possible to the nozzle. Some sprayers available in Indonesia can optionally be equipped with a manometer on the handle. A manometer is indispensable for calibration.

When two sizes of liquid tanks were compared, the pressure reductions were greater in the 10 liters tank than in the 2.5 liters/tank (see figure 41).

Nozzle Teejet 110 06
+ 50 Mesh filter
----------- = tank 2.5 l
___________ = tank 10 l

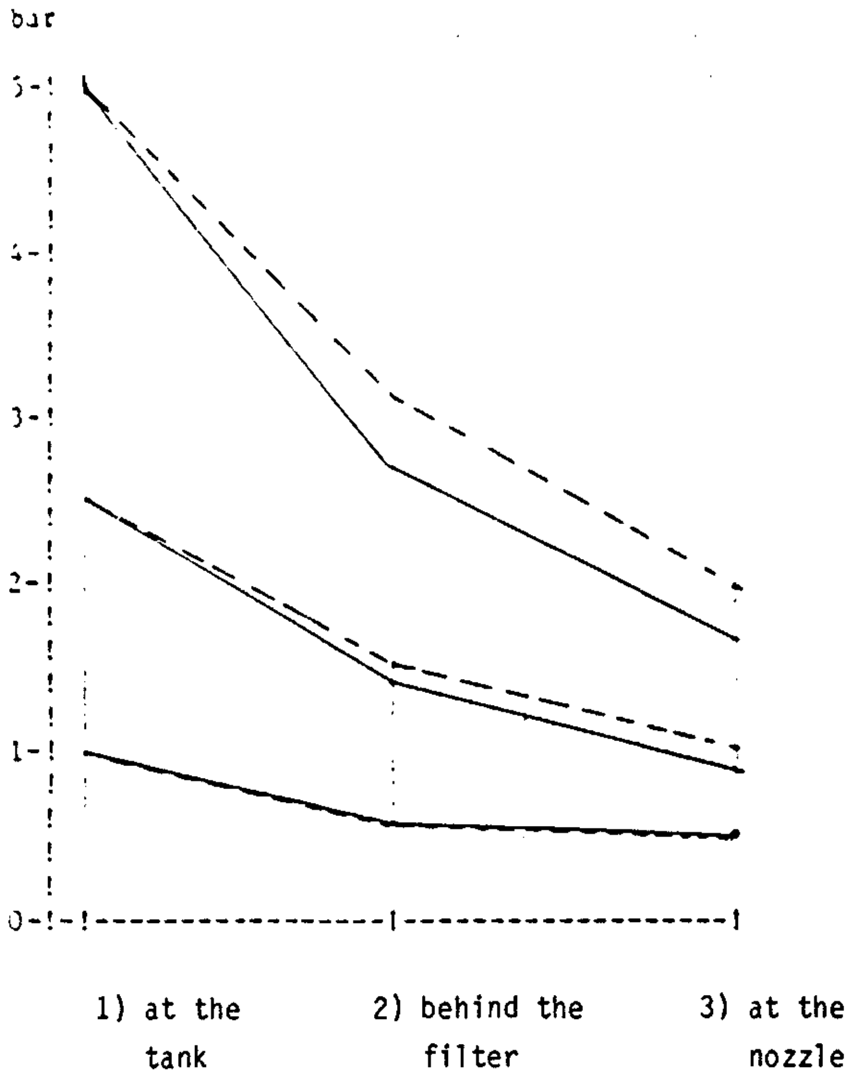


Figure 41. Manometer values (pressure) measured at various places in a compressed air field plot sprayer, for two liquid tanks (10 l and 2.5 l).

The results demonstrate clearly that with each system one should check the pressure after the filter and at the nozzle. If the relation is known, the pressure at the standard manometer can be adjusted.

5.2 Calibrating of knapsack and other lance sprayers

Calibration necessary

All nozzles should be calibrated for their output and their even distribution at least once a year or after each 10 hectares of spraying.
For a good spraying result and an economical use of pesticide it is necessary to know how many liters per field (calculated in liters per hectare) are used.
With hand-operated sprayers this amount depends on the walking speed, pressure, type of nozzle and operator.

Calibration with the help of a special bottle

The kalibottle is a handy aid that can be used to find out how many liters are sprayed per hectare. The kalibottle is a lightweight 1 liter plastic can. When measuring the output in l/ha, instead of spraying on a target the lance is placed in the bottle.
Step 1 is to measure out an area of 25 m^2, because the bottle is calibrated for this area. (Any other value is possible too, but then the result read on the bottle will have to be multiplied or divided according to the area sprayed.)
Step 2 is to spray this surface and to check the time needed and the pumping pressure used.
Step 3 is to spray into the kalibottle for the same time and in the same way.
Step 4 is to read off the amount of liquid sprayed per hectare from the scale on the bottle.
Step 5 is to calibrate by changing the forward speed or the pumping intensity until the desired amount (in l/ha) is obtained.
The procedure is illustrated in the figures 42 and 43 (see next pages).

KALIBOTTLE CALIBRATION

DIRECTIONS

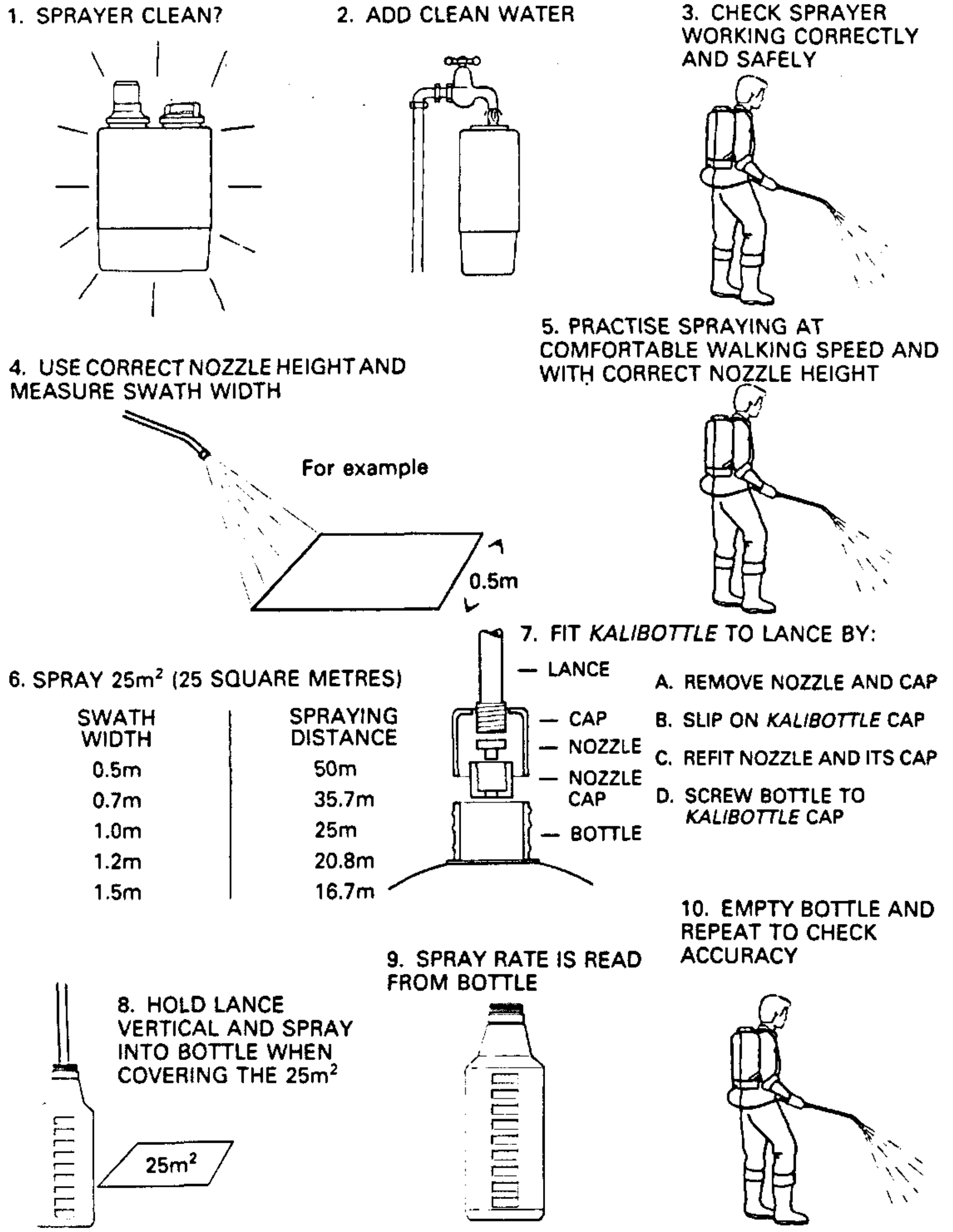
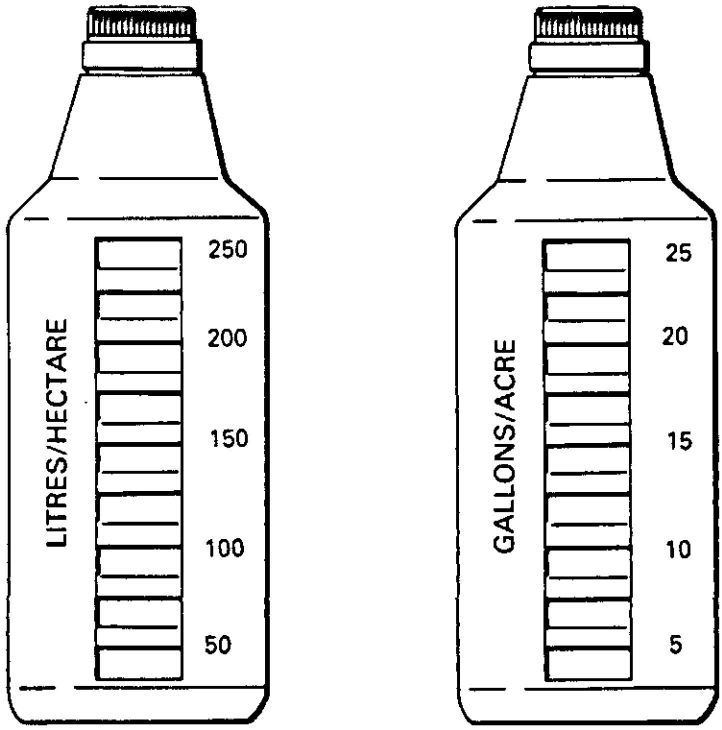


Figure 42. How to use the kalibottle to check the amount of water used (l/ha) with a knapsack sprayer and a spray lance.



FOR SIMPLE, QUICK CALIBRATION
Litres/hectare and gallons/acre
NO – SUMS, CALCULATORS

Figure 43. By timing how long it takes to spray 25 m^2 in the field and then spraying into the bottle for the same length of time, the output in liters per hectare can be read off the scale.

When using a spray lance with a full cone nozzle it is very difficult in practice to optimize the amount of liquid. This can easily lead to too much liquid and chemical being applied per hectare. (Usually applying too many liters also means that too much of the chemical is used.)

Calibration without a kalibottle

It is also possible to calibrate the sprayer without using a kalibottle. The procedure is as follows:

Step 1. Measure out an area of 100 m^2, for instance 50 meters long and 2 meters wide. Put clear markers on each corner and at points along each side.

Step 2. Completely fill the spray tank with water and pump up normally or otherwise put the intended pressure on the liquid.

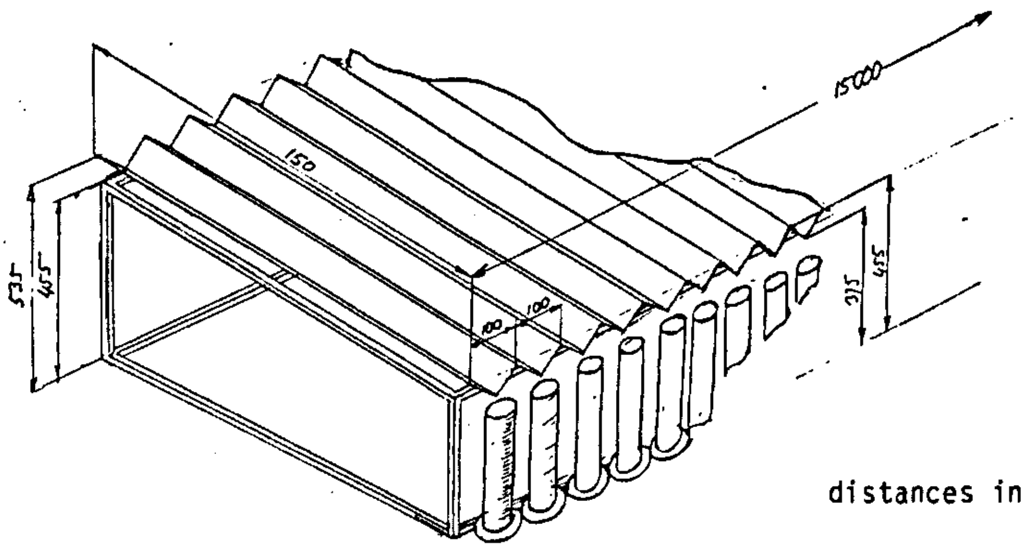
Step 3. Spray the marked area, walking at the speed usually used for spraying.

Step 4. Using a 1 liter measuring can, top up the spray tank, counting the number of liters required to fill it.

This is the amount of liquid sprayed on 100 square meters (= 0.01 hectare).
Step 5. Calculate how much liquid has to be sprayed on 1 hectare and repeat the procedure until the right output is reached.

5.3. ~~Control of~~ Checking spray booms

The desired output of a spray boom is given in tables, and is also known for each nozzle (in l/min). At least once a year or after each 100 hectares sprayed, a spray boom should be checked to find out its output per nozzle and whether the output per nozzle is distributed evenly.
Measuring cylinders have to be used to check the output per nozzle. One should be placed under each nozzle for one minute during stationary constant spraying at the right pressure.
Each nozzle should give the same amount. Deviant nozzles must be replaced.
The spray image can be analysed by carefully viewing from nozzle to nozzle of a boom. The regularity of the spray from a boom can be tested on a spray platform or table (see figure 44).



distances in mm

Figure 44. Spray platform to check the distribution of the liquid through nozzles on a boom.

Each cylinder in this system is calibrated in steps of 5 cc, so that the amount of liquid per cylinder can be measured. If the nozzles are working correctly the coefficient of variation has to be less than 10.

Appendix 1. Report on weather condition during the spraying of experimental plots.

Exp. No. ______________________________

Objectives of experiment : ______________________________

Day __________ Crop : ____________ Stage : ____________

1. Weather in the previous days (temperature : ______C, dry/wet : _____ mm, wind : _____ etc.)
2. Weather on day of spraying, but before spraying temp : ____ C, dry/wet : ____ mm, wind : ________
3. Weather during spraying

	at start of spraying	at the end of spraying	three hours after the spraying
a. sunshine (qualitatively: e.g. overcast, partially overcast, a few clouds, clear			
b. air temperature °C			
c. relative humidity %			
d. dry/wet			
mm precipitation			
e. direction of wind			
f. wind speed m/s			
g.			

Observations 3-10 days after spraying including effect of spraying in relation to weather:

____

____

____

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____

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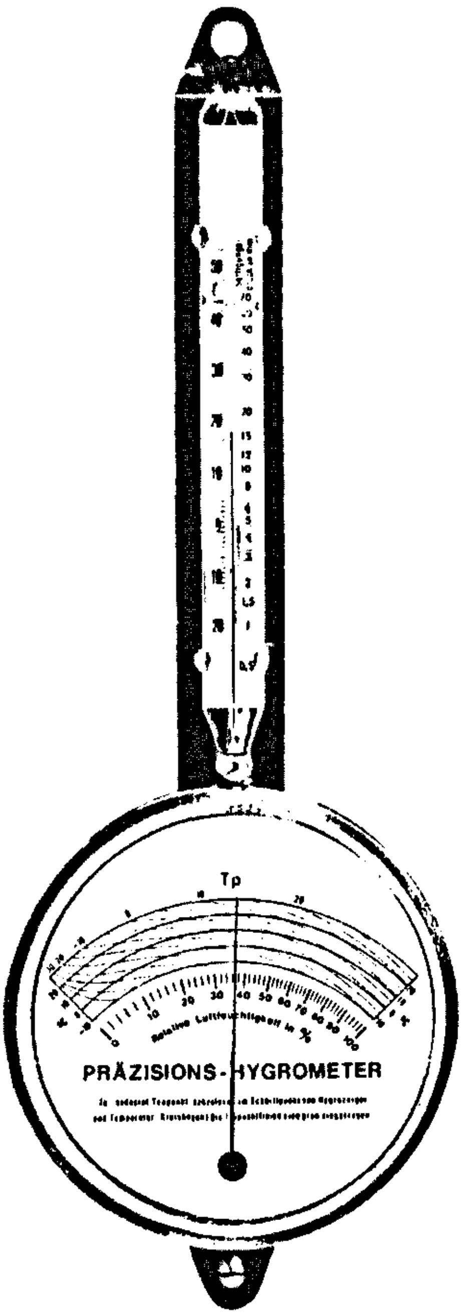
Appendix 2. Polymeter.

OPERATING INSTRUCTIONS



1. Before using the instrument, please remove the piece of styropor underneath the adjusting lever. The instrument is now unlocked and ready to operate.

2. The Relative Humidity can be seen directly on the dial 0 to 100%). Regeneration and control to be made by wrapping the whole instrument in a wet cloth. During this procedure the measuring element and adjusting lever have to remain movable and in working condition. After about 30 to 45 minutes the hand of the hygrometer should indicate 95%. If necessary, adjust the hand by turning the adjusting screw on top of the instrument with a screw driver while the instrument stays closely wrapped in its moist cloth. Control below saturation humidity is also possible by means of a hygrometer or a suitable psychrometer.

3. Temperature is shown on the mercury thermometer which is fixed by clips to the front metal plate. If during transport the mercury column becomes separated, shake the thermometer like a fiever thermometer to reunite the mercury.

4. Saturation pressure (mm Torr) is shown on the right side of the thermometer column.

5. Dew Point: Refer to the green marked arcs and read off the value where the hygrometer hand intersects the black arc which corresponds to the actual temperature.

6. Vapour pressure (mm Torr) to be seen on the dial showing the saturation pressure alongside the dew-point temperature. At normal temperatures the values for absolute humidity and vapour pressure are nearly the same.

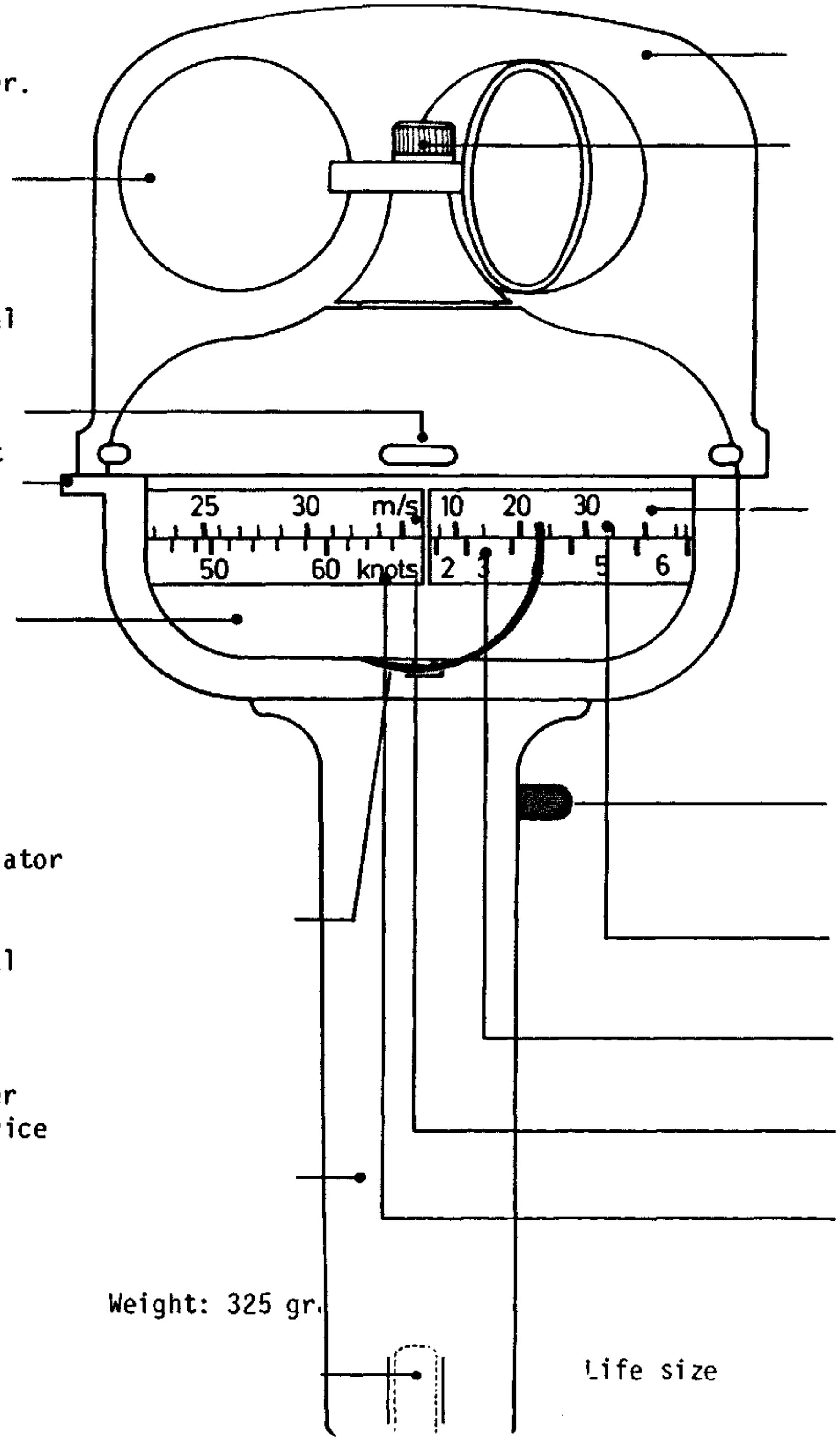
7. Saturation deficit means saturation pressure less vapour pressure.

8. Forecast of frost during night: If shortly before sunset the dew point is already at the freezing point (0°C) or below, it is likely that night frost will set in. If the temperature reaches 5°C or less it is also probable that night frost will set in in clear nights even if the dew point is at 1° to 2°C.

9. Thunderstorms: In the summertime very high dew point values of 16°C and more forecast storms, especially when the atmospheric pressure is low and still falling.

10. Cloud formations H in rising air: In this situation the following formula applies:
Height = 122,6 x (Temperature less Dew Point)

Appendix 3. Anemometer.



Appendix 4. Report on deposition of spray on water-sensitive paper and as revealed by fluorescent.

Analysis of effect of spraying Exp.No.: ____________

Objectives of experiment : ______________________________

Day of spraying : _________ Crop: _________ Stage: ________

A. Apparatus + method of spraying used per variant:

1. Type of sprayer : _____________
2. Lance or boom : ____________ Boom widths: ___________ m
3. Nozzle distance : ______ cm. Number of nozzles: __________
4. Size and type of nozzles used :__________________________
5. Liters/ha sprayed : _________________________________
6. Type and amount of chemicals(s) used: __________________
7. Pressure sprayed with : _______ bar.
8. Speed of walking/driving while spraying: ___________ km

B. Deposition on water-sensitive paper. In three replicates per crop/level:

1.1. Average drop size : ______ microns on top of crop

1.2. Number of visible drops: ______ per/cm^2 on top of crop

2.1. Average drop size : ______ microns, 1/3 from top of crop

2.2. Number of visible drops: ______ per cm^2 1/3 from top of crop

3.1. Average drop size: _____ microns, 2/3 from top of crop

3.2. Number of visible drops:______ per cm^2 2/3 from top of crop

4.1. Average drop size on the soil under the crop ____ microns

4.2. Number of visible drops : ______ per cm^2 on the soil.

C. Penetration in the crop (visual impression)

1. on top : _______________________ underside of leaves : ______________
2. 1/3 from top : __________________ underside of leaves : ______________
3. 2/3 from top : __________________ underside of leaves : ______________
4. on the soil :

D. Penetration in the crop measured by fluorecent:

1. on top : _______________________ underside of leaves: ___________
2. 1/3 from top : __________________ underside of leaves: ___________
3. 2/3 from top : __________________ underside of leaves: ___________
4. on the soil :

D. Penetration in the crop measured by fluorecent

1. on top : ________________ underside of leaves: ___________
2. 1/3 from top : ___________ underside of leaves: ___________
3. 2/3 from top : ___________ underside of leaves: ___________
4. on the soil :

E. Other remarks

Appendix 5a. Output (in l/m), VDM and D10 + D90 of various nozzles at 1-6 bars.

Output VMD	1	1.5	2	3	4	5	6
	01 Nozzle or comparables						
Type of nozzle							
Albuz:	Not available						
Colour black							
Hardi 4110-10	0.27/ 198		0.38/ 129	0.47/ 108	0.54/ 102	0.60/ 94	
D 10 - D 90	78-329		54-260	50-217	46-220	40-214	
Hardi 4110-12	0.45/ 243		0.64/ 181	0.78/ 165	0.90/ 151	1.01/ 148	
D 10 - D 90	91-411		62-362	55-319	51-300	50-290	
Lechler:	Not available						
Colour orange or steel							
Teejet 110 - 01 VS	0.23/ 183		0.33/ 125	0.40/ 115	0.46/ 113	0.52/ 109	
D 10 - D 90	74-319		56-237	55-227	48-220	44-223	
Teejet 110-01 VA			0.32/ 135		0.46/ 114		0.56/ 102
D 10 - D 90			72-283		61-227		52-203
Teejet 110-01 LP-SS	0.37/ 160		0.52/ 126	0.64/ 108	0.74/ 102	0.82/ 96	
D 10 - D 90	68-294		55-261	50-249	44-246	41-216	
Teejet 110-01 XR-VS	0.23/ 140	0.28 VF= 17 1)	0.33/ 102	0.40/ 92	0.46 85	0.52/ 80	
D 10 - D 90	65-254		54-213	50-206	42-200	39-189	

1) VF is drop spectrum of 80-150 microns.

Appendix 5b.

Output VMD	1	1.5	2	3	4	5	6
	015 Nozzle or comparables						
Type of nozzle							
Albuz:	Not available						
Colour black							
Hardi 4110-10	0.27/ 198		0.38/ 129	0.47/ 108	0.54/ 102	0.60/ 94	
D 10 - D 90	78-329		54-260	50-217	46-220	40-214	
Hardi 4110-12	0.45/ 243		0.64/ 181	0.78/ 165	0.90/ 151	1.01/ 148	
D 10 - D 90	91-411		62-362	55-319	51-300	50-290	
Colour green or steel							
Lechler LU 347-015	0.34/ 167	0.42/ 162	0.48/ 158	0.53/ 148		0.79/ 136	
D 10 - D 90	94-304	86-300	83-282	79-257		73-226	
Teejet 110-015 SS							
D 10 - D 90							
Teejet 110-015 VA			0.48/ 168		0.68/ 140		0.83/ 123
D 10 - D 90			82-349		67-282		58-248
Teejet 110-015 XR-VS							
D 10 - D 90							

Appendix 5c.

Output VMD	1	1.5	2	3	4	5	6
	02 Nozzle or comparables						
Type of nozzle							
Albuz APG 110 yellow			0.49/ F 1)	0.61 F	0.70 F	0.78 VF 1)	0.86 VF
D 10 - D 90							
Albuz APG 110-orange			0.70/ F	0.86/ F	0.99/ VF	1.10/ VF	1.21/ VF
D 10 - D 90							
Colour black							
Hardi 4110-12	0.45/ 243		0.64/ 181	0.78/ 165	0.90/ 151	1.01/ 148	
D 10 - D 90	91-411		62-362	55-319	51-300	50-290	
Hardi 4110-14	0.53/ 254		0.75/ 196	0.91/ 173	1.05/ 160	1.17/ 155	
D 10 - D 90	104-411		61-389	54-348	53-332	50-325	
Colour yellow or steel							
Lechler LU 367-02	0.45/ 192	0.55/ 181	0.63/ 175	0.77/ 166		1.00/ 152	
D 10 - D 90	103-405	95-394	90-349	85-309		80-268	
Teejet 110-02 H-SS	0.47/ 214		0.67/ 167	0.82/ 155	0.94 145	1.06/ 137	
D 10 - D 90	78-379		57-298	53-300	52-288	47-280	
Teejet 110-02 VA			0.65/ 189	0.79/ 158	0.91/ 156		1.12/ 136
D 10 - D 90			84-403	71-332	69-326		60-299
Teejet 110-02 LP-SS	0.81/ 238		1.15/ 200	1.41/ 184	1.62/ 178	1.82/ 173	
D 10 - D 90	80-427		63-416	56-375	55-374	51-345	
Teejet 110-02 XR-VS	0.49/ 190	0.56/ F	0.69/ 147	0.85/ 136	0.98/ 124	1.09/ 121	
	73-357		55-293	51-276	46-269	45-261	

1) VF and F are drops spectra of 80-150 and 150-200 microns.

Appendix 5d.

Output VMD	1	1.5	2	3	4	5	6
	03 Nozzle or comparables						
Type of nozzle							
Albuz APG 110 yellow			0.49/ F 1)	0.61/ F	0.70/ F	0.78/ VF 1)	0.86/ VF
D 10 - D 90							
Albuz APG 110 orange			0.70/ F	0.86/ F	0.99/ VF	1.10/ VF	1.21/ VF
D 10 - D 90							
Albuz APG 110 red			0.99/ F	1.21/ F	1.40/ F	1.56/ F	1.71/ F
D 10 - D 90							
Colour black							
Hardi 4110-14	0.53/ 254		0.75/ 196	0.91/ 173	1.05 160	1.17/ 155	
D 10 - D 90	104-411		61-389	54-348	53-332	50-325	
Hardi 4110-16	0.67/ 280		0.95/ 221	1.16/ 201	1.34/ 195	1.50/ 185	
D 10 - D 90	112-518		65-410	58-395	55-386	54-393	
Hardi 4110-18	0.77/ 272		1.08/ 222	1.32/ 197	1.53/ 185	1.71/ 185	
D 10 - D 90	102-551		62-402	57-405	57-398	52-391	
Colour blue or steel							
Lechler LU 407-03	0.71/ 242	0.87/ 228	1.00/ 203	1.22/ 173		1.58/ 163	
D 10 - D 90	106-679	100-678	94-557	87-343		84-337	
Teejet 110-03 H-SS	0.74/ 225		1.04/ 194	1.27/ 178	1.48/ 169	1.64/ 164	
D 10 - D 90	77-392		62-376	57-372	54-351	52-349	
Teejet 110-03-VA							
D 10 - D 90							
Teejet 110-03-LP-SS							
D 10 - D 90							
Teejet 110-03 XR-VS	0.68/ N 1)	0.84/ N	0.77/ N	1.18/ F	1.37. F		1.68/ F

1) VF, F and N are drop spectra of respectively 80-150, 150-200 and 200-300 microns.

Appendix 5e.

Output VMD	1	1.5	2	3	4	5	6
	04 Nozzle or comparables						
Type of nozzle							
Albuz APG 110 orange D 10 - D 90			0.70/ F 1)	0.86/ F	0.99/ VF	1.10/ VF	1.21/ VF
Albuz APG 110 red D 10 - D 90			0.99/ F	1.21/ F	1.40/ F	1.56/ F	1.71/ F
Albuz APG 110 blue D 10 - D 90			1.98/ M	2.42/ M	2.79/ M	3.12/ M	3.42/ M
Colour black							
Hardi 4110-16 D 10 - D 90	0.67/ 280 112-518		0.95/ 221 65-410	1.16/ 201 58-395	1.34/ 195 55-386	1.50/ 185 54-393	
Hardi 4110-18 D 10 - D 90	0.77/ 272 102-551		1.08/ 222 62-402	1.32/ 197 57-405	1.53/ 185 57-398	1.71/ 185 52-391	
Hardi 4110-20 D 10 - D 90	0.92/ 314 121-563		1.30/ 261 80-550	1.59/ 245 72-475	1.84/ 236 70-446	2.06/ 231 65-442	
Colour red or steel							
Lechler LU 447-04 D 10 - D 90	0.88/ 297 118-684	1.08/ 255 104-675	1.25/ 229 100-617	1.53/ 203 93-572		1.98/ 188 89-363	
Teejet 110-04 H-SS D 10 - D 90							
Teejet 110-04- VA D 10 - D 90			1.29/ 259 97-505	1.58/ 244 95-477	1.82/ 217 83-422		2.23/ 199 78-403
Teejet 110-04 LP-SS D 10 - D 90							
Teejet 110-04 XR-VS D 10 - D 90	0.91/ RC	1.12/ M	1.29/ M	1.58/ M	1.82/ F		2.24/ F

1) VF, F, M and RC are drop spectra of respectively 80-150, 150-200, 200-300 and 300-400 microns.

Appendix 6. Analyses of Indonesian spray nozzles by the Institute for Agricultural Engineering (IMAG) Wageningen, the Netherlands, done at the request of PAGV.

MALVERN 2600 ETYPE PARTICLE SIZER VN.C

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

APOLO
1 BAR
20 GRADEN
44 PROCENT

RESULTS

RUN NUMBER= 2 DATE=000000 LOG DIFFERENCE= 4.07

SAMPLE % VOLUME CONCENTRATION= 0.0042 BEAM OBSCURATION= 0.15

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	98.9	1503.9-	697.6	1.1	529	511
427.6	90.8	697.6-	427.6	8.2	818	809
300.8	72.1	427.6	300.8	18.7	1096	1094
224.8	51.4	300.8-	224.8	20.7	1344	1349
172.4	38.0	224.8	172.4	13.4	1583	1570
133.8	28.6	172.4-	133.8	9.3	1744	1729
104.8	20.8	133.8-	104.8	7.9	1906	1890
80.9	13.1	104.8-	80.9	7.7	1991	1975
63.1	7.1	80.9-	63.1	6.0	2047	2047
49.2	4.5	63.1-	49.2	2.6	1951	1906
38.6	2.6	49.2-	38.6	1.9	1699	1687
30.4	1.8	38.6-	30.4	1.0	1404	1419
24.1	0.7	30.4-	24.1	0.3	1162	1147
19.3	0.6	24.1-	19.3	0.1	961	850
15.5	0.4	19.3-	15.5	0.2	745	600

D(50%) (UM)= 219.29	V M D (UM)= 244.86	S M D (UM)= 139.45
D(10%) (UM)= 71.74	D(90%)(UM)= 422.38	SPAN = 1.60

MALVERN 2600 CTYPC PARTICLE SIZER VA.6

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

APOLO
3 BAR
20 GRADEN
44 PROCENT

RESULTS

RUN NUMBER= 5 DATE=080388 LOG DIFFERENCE= 3.50

SAMPLE % VOLUME CONCENTRATION= 0.5459 BEAM OBSCURATION= 0.20

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	99.7	1503.9-	697.6	0.3	228	217
427.6	97.7	697.6-	427.6	2.0	367	368
300.8	90.0	427.6-	300.8	7.7	542	544
224.9	77.5	300.8-	224.8	12.4	749	756
172.4	62.8	224.8-	172.4	14.7	1080	1088
133.8	49.0	172.4-	133.8	13.8	1282	1295
104.0	39.1	133.8-	104.0	9.9	1574	1574
80.9	27.7	104.0-	80.9	11.4	1883	1885
63.1	16.3	80.9-	63.1	11.4	1968	1997
49.2	10.4	63.1-	49.2	5.8	2047	2047
38.6	7.0	49.2-	38.6	3.4	1937	1914
30.4	3.8	38.6-	30.4	3.2	1684	1714
24.1	1.4	30.4-	24.1	2.4	1454	1401
19.3	0.4	24.1-	19.3	1.0	1276	1246
15.5	0.1	19.3-	15.5	0.3	997	994

D(50%) (UM)= 136.58	V M D (UM)= 163.52	S M D (UM)= 95.02
D(10%) (UM)= 47.91	D(90%)(UM)= 301.57	SPAN = 1.86

MALVERN 2600 ETYPC PARTICLE SIZER VA.6
IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

APOLO
5 BAR
20 GRADEN
44 PROCENT

RESULTS

RUN NUMBER= 10 DATE=880308 LOG DIFFERENCE= 3.17

SAMPLE % VOLUME CONCENTRATION= 0.0728 BEAM OBSCURATION= 0.20

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	99.9	1503.9-	697.6	0.1	176	180
427.6	98.2	697.6-	427.6	1.7	297	293
300.8	92.2	427.6-	300.8	6.0	445	444
224.8	80.7	300.8-	224.8	11.5	624	629
172.4	67.8	224.8-	172.4	12.9	856	860
133.8	55.8	172.4-	133.8	12.0	1116	1120
104.0	45.4	133.8-	104.0	10.4	1409	1414
80.9	33.6	104.0-	80.9	11.8	1678	1680
63.1	21.4	80.9-	63.1	12.1	1909	1930
49.2	13.9	63.1-	49.2	7.5	2047	2047
38.6	8.9	49.2-	38.6	5.0	1907	1902
30.4	5.2	38.6-	30.4	3.7	1807	1803
24.1	2.6	30.4-	24.1	2.6	1585	1588
19.3	1.1	24.1-	19.3	1.5	1379	1366
15.5	0.4	19.3-	15.5	0.7	1120	1122

D(50%) (UM)= 117.15 | V M D (UM)= 147.59 | S M D (UM)= 83.17

D(10%) (UM)= 48.09 | D(90%)(UM)= 286.22 | SPAN = 2.03

MALVERN 2600 ETYPE PARTICLE SIZER VA.6

USER EXPERIMENTAL AND SAMPLE DETAILS

APOLO
1 BAR
20 GRADEN
RV 44 PROCENT
IETS OPENGEDRAAID

RESULTS

RUN NUMBER= 12   DATE=000000   LOG DIFFERENCE= 3.98

SAMPLE % VOLUME CONCENTRATION= 1.0000   BEAM OBSCURATION= 0.18

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	80.8	1503.9-	697.6	19.2	1933	1866
427.6	36.9	697.6-	427.6	43.9	2047	2047
300.8	17.7	427.6-	300.8	19.2	1897	1078
224.8	7.9	300.8-	224.8	9.8	1513	1501
172.4	4.7	224.8-	172.4	3.2	1247	1255
133.8	2.9	172.4-	133.8	1.8	1073	1018
104.0	1.3	133.8-	104.0	1.5	881	897
80.9	0.8	104.0-	80.9	0.5	768	756
63.1	0.5	80.9-	63.1	0.3	696	645
49.2	0.2	63.1-	49.2	0.4	543	543
38.6	0.0	49.2-	38.6	0.1	420	432
30.4	0.0	38.6-	30.4	0.0	365	335
24.1	0.0	30.4-	24.1	0.0	267	235
19.3	0.0	24.1-	19.3	0.0	174	180
15.5	0.0	19.3-	15.5	0.0	144	144

D(50%) (UM)= 500.00 | V M D (UM)= 566.22 | S M D (UM)= 309.46

D(10%) (UM)= 241.27 | D(90%)(UM)= 1004.28 | SPAN = 1.66

MALVERN 2600 ETYPE PARTICLE SIZER VN.C
IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

APOLO
3 BAR
20 GRADEN
RV 44 PROCENT
IETS OPENGEDRAAID

RESULTS

RUN NUMBER= 3 DATE=000000 LOG DIFFERENCE= 3.75

SAMPLE % VOLUME CONCENTRATION= 1.0070 BEAM OBSCURATION= 0.23

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	94.6	1503.9-	697.6	5.4	1245	1213
427.6	71.2	697.6-	427.6	23.4	1680	1701
308.8	44.9	427.6-	308.8	26.3	1943	1927
224.8	26.6	308.8-	224.8	18.4	2021	2047
172.4	18.0	224.8-	172.4	8.5	2047	2020
133.8	10.7	172.4-	133.8	7.3	1958	1970
104.0	6.7	133.8-	104.0	4.0	1857	1874
80.9	4.4	104.0-	80.9	2.3	1758	1729
63.1	2.3	80.9-	63.1	2.1	1591	1594
49.2	1.1	63.1-	49.2	1.2	1372	1402
38.6	0.6	49.2-	38.6	0.5	1204	1175
30.4	0.3	38.6-	30.4	0.3	963	949
24.1	0.2	30.4-	24.1	0.1	711	747
19.3	0.2	24.1-	19.3	0.0	561	549
15.5	0.1	19.3-	15.5	0.1	458	448

D(50%) (UM)= 325.17	V M D (UM)= 372.40	S M D (UM)= 231.05
D(10%) (UM)= 128.31	D(90%)(UM)= 644.12	SPAN = 1.59

MALVERN 2600 ETYPE PARTICLE SIZER VA.C
IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

APOLO
5 BAR
20 GRADEN
RV 44 PROCENT
IETS OPENGEDRAAID

RESULTS

RUN NUMBER= 5 DATE=080308 LOG DIFFERENCE= 4.18

SAMPLE % VOLUME CONCENTRATION= 0.4261 BEAM OBSCURATION= 0.12

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1583.9	100.0					
697.6	96.9	1583.9-	697.6	3.2	962	973
427.6	79.1	697.6-	427.6	17.8	1066	1341
300.0	49.2	427.6-	300.0	29.8	1653	1696
224.0	36.2	300.0-	224.0	13.0	1794	1790
172.4	26.8	224.0-	172.4	9.4	1800	1884
133.8	16.1	172.4-	133.8	10.7	1901	1920
104.0	10.1	133.8-	104.0	5.9	2016	2047
80.9	7.6	104.0-	80.9	2.5	2017	1903
63.1	4.7	80.9-	63.1	2.9	1017	1060
49.2	2.2	63.1-	49.2	2.5	1666	1715
38.6	1.0	49.2-	38.6	1.2	1581	1525
30.4	0.6	38.6-	30.4	0.4	1317	1294
24.1	0.4	30.4-	24.1	0.2	954	1007
19.3	0.2	24.1-	19.3	0.2	753	783
15.5	0.1	19.3-	15.5	0.1	651	623

D(50%) (UM)= 304.00	V M D (UM)= 326.46	S M D (UM)= 192.87
D(10%) (UM)= 102.72	D(90%)(UM)= 593.56	SPAN = 1.61

MALVERN 2600 ETYPE PARTICLE SIZER VN.C

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

JANTUNG
1 bar
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 12 DATE=080388 LOG DIFFERENCE= 3.78

SAMPLE % VOLUME CONCENTRATION= 1.9601 BEAM OBSCURATION= 0.21

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	60.5	1503.9-	697.6	39.5	2047	2047
427.6	22.3	697.6-	427.6	38.1	1708	1790
300.8	10.9	427.6-	300.8	11.4	1413	1416
224.8	4.9	300.8-	224.8	6.0	1030	1058
172.4	2.7	224.8-	172.4	2.2	821	844
133.8	1.7	172.4-	133.8	1.0	720	702
104.0	0.9	133.8-	104.0	0.8	500	599
80.9	0.5	104.0-	80.9	0.4	480	515
63.1	0.3	80.9-	63.1	0.1	449	420
49.2	0.2	63.1-	49.2	0.2	350	353
38.6	0.1	49.2-	38.6	0.1	276	295
30.4	0.1	38.6-	30.4	0.0	234	227
24.1	0.1	30.4-	24.1	0.0	188	168
19.3	0.1	24.1-	19.3	0.0	135	120
15.5	0.0	19.3-	15.5	0.0	109	102

D(50%) (UM)= 623.50	V M D (UM)= 714.74	S M D (UM)= 493.25
D(10%) (UM)= 289.36	D(90%)(UM)= 1299.99	SPAN = 1.62

MALVERN 2600 ETYPE PARTICLE SIZER VN.6
IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

JANTUNG
3 ber
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 14 DATE=080380 LOG DIFFERENCE= 4.25

SAMPLE % VOLUME CONCENTRATION= 1.4940 BEAM OBSCURATION= 0.25

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1583.9	100.0					
697.6	82.9	1583.9-	697.6	17.2	1042	1775
427.6	47.0	697.6-	427.6	35.9	2047	2047
300.8	29.3	427.6-	300.8	17.7	2036	1967
224.8	15.5	300.8	224.8	13.8	1839	1820
172.4	10.4	224.8-	172.4	5.1	1731	1695
133.8	6.5	172.4-	133.8	3.9	1637	1502
104.0	3.8	133.8-	104.0	2.7	1474	1471
80.9	2.4	104.0-	80.9	1.3	1350	1331
63.1	1.4	80.9-	63.1	1.1	1268	1205
49.2	0.7	63.1-	49.2	0.7	1047	1040
38.6	0.3	49.2-	38.6	0.4	883	877
30.4	0.1	38.6-	30.4	0.2	740	711
24.1	0.1	30.4-	24.1	0.0	556	547
19.3	0.1	24.1-	19.3	0.0	400	393
15.5	0.1	19.3-	15.5	0.0	320	313

D(50%) (UM)= 450.44 | V M D (UM)= 513.31 | S M D (UM)= 318.23

D(10%) (UM)= 168.13 | D(90%)(UM)= 1030.63 | SPAN = 1.92

MALVERN 2600 ETYPE PARTICLE SIZER VA.0
IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

JANTUNG
5 bar
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 15 DATE=080308 LOG DIFFERENCE= 3.78

SAMPLE % VOLUME CONCENTRATION= 7.0130 BEAM OBSCURATION= 0.04

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	85.9	1503.9-	697.6	14.1	1446	1452
427.6	63.4	697.6-	427.6	22.5	1705	1704
300.8	41.2	427.6-	300.8	22.2	1932	1941
224.8	26.9	300.8-	224.8	14.3	1996	2003
172.4	17.6	224.8-	172.4	9.3	2047	2006
133.8	11.1	172.4-	133.8	6.5	2020	2047
104.0	7.7	133.8-	104.0	3.4	1989	1992
80.9	5.1	104.0-	80.9	2.6	1908	1860
63.1	2.8	80.9-	63.1	2.3	1753	1798
49.2	1.5	63.1-	49.2	1.3	1631	1632
38.6	0.7	49.2-	38.6	0.8	1455	1420
30.4	0.2	38.6-	30.4	0.4	1161	1173
24.1	0.1	30.4-	24.1	0.1	881	905
19.3	0.1	24.1-	19.3	0.0	691	693
15.5	0.0	19.3-	15.5	0.0	518	493

D(50%) (UM)= 351.14	V M D (UM)= 438.36	S M D (UM)= 240.34
D(10%) (UM)= 124.16	D(90%)(UM)= 930.05	SPAN = 2.30

MALVERN 2600 ETYPE PARTICLE SIZER VN.C
IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

KEPALA DUA
1 BAR
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 9 DATE=080388 LOG DIFFERENCE= 3.60

SAMPLE % VOLUME CONCENTRATION= 0.7492 BEAM OBSCURATION= 0.24

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	MEASURED
1503.9	100.0					
697.6	99.1	1503.9-	697.6	0.9	643	610
427.6	85.9	697.6-	427.6	13.2	967	986
300.8	68.4	427.6-	300.8	17.5	1245	1240
224.8	45.5	300.8-	224.8	22.9	1471	1491
172.4	32.6	224.8-	172.4	12.9	1699	1712
133.8	25.0	172.4-	133.8	7.6	1838	1840
104.8	17.9	133.8-	104.8	7.0	1915	1939
80.9	10.4	104.8-	80.9	7.5	1975	2003
63.1	5.6	80.9-	63.1	4.8	2047	2047
49.2	3.3	63.1-	49.2	2.3	1916	1926
38.6	1.6	49.2-	38.6	1.7	1617	1651
30.4	0.4	38.6-	30.4	1.2	1318	1326
24.1	0.1	30.4-	24.1	0.3	1063	1036
19.3	0.1	24.1-	19.3	0.1	816	770
15.5	0.0	19.3-	15.5	0.0	581	579

D(50%) (UM)= 239.70 | V M D (UM)= 266.97 | S M D (UM)= 162.20

D(10%) (UM)= 79.44 | D(90%)(UM)= 511.39 | SPAN = 1.80

MALVERN 2600 ETYPE PARTICLE SIZER VA.6

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

KEFALA DUA
3 BAR
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 11	DATE=000000	LOG DIFFERENCE= 3.60
SAMPLE % VOLUME CONCENTRATION= 0.5403		BEAM OBSCURATION= 0.26

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS	%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0				
697.6	99.6	1503.9- 697.6	0.4	285	274
427.6	96.1	697.6- 427.6	3.5	465	467
300.8	86.7	427.6- 300.8	9.4	679	674
224.8	70.5	300.8- 224.8	16.3	896	905
172.4	53.2	224.8- 172.4	17.2	1164	1176
133.8	41.2	172.4- 133.8	12.0	1415	1420
104.0	32.9	133.8- 104.0	8.3	1646	1654
80.9	23.5	104.0- 80.9	9.4	1809	1827
63.1	14.2	80.9- 63.1	9.3	1958	1992
49.2	9.2	63.1- 49.2	5.0	2047	2047
38.6	5.9	49.2- 38.6	3.3	1940	1907
30.4	2.8	38.6- 30.4	3.1	1704	1747
24.1	0.7	30.4- 24.1	2.1	1474	1496
19.3	0.1	24.1- 19.3	0.6	1247	1224
15.5	0.0	19.3- 15.5	0.1	921	924

D(50%) (UM)= 162.01	V M D (UM)= 184.92	S M D (UM)= 107.57
D(10%) (UM)= 51.47	D(90%)(UM)= 345.27	SPAN = 1.81

MALVERN 2600 ETYPE PARTICLE SIZER VA.6

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

KEPALA TUA
5 BAR
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 14 DATE=890308 LOG DIFFERENCE= 3.42

SAMPLE % VOLUME CONCENTRATION= 0.2618 BEAM OBSCURATION= 0.17

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1500.0	100.0					
697.6	99.6	1500.0-	697.6	1.4	206	211
427.6	96.1	697.6-	427.6	2.5	333	332
300.8	88.9	427.6-	300.8	7.3	490	478
224.8	74.3	300.8-	224.8	14.6	674	697
172.4	62.6	224.8-	172.4	11.6	981	993
133.8	50.4	172.4-	133.8	12.2	1104	1137
104.0	40.2	133.8-	104.0	10.2	1384	1402
80.9	31.5	104.0-	80.9	8.7	1621	1624
63.1	22.9	80.9-	63.1	8.7	1844	1847
49.2	15.6	63.1-	49.2	7.3	1985	2012
38.6	10.3	49.2-	38.6	5.3	2047	2047
30.4	6.2	38.6-	30.4	4.1	1991	1989
24.1	3.3	30.4-	24.1	3.0	1812	1848
19.3	1.5	24.1-	19.3	1.7	1586	1608
15.5	0.6	19.3-	15.5	0.9	1320	1324

D(50%) (UM)= 132.58	V M D (UM)= 171.45	S M D (UM)= 82.95
D(10%) (UM)= 37.97	D(90%)(UM)= 320.66	SPAN = 2.13

MALVERN 2600 ETYPE PARTICLE SIZER VA.6
IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

KEPALA SATU
1 BAR
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 16 DATE=000000 LOG DIFFERENCE= 3.01

SAMPLE % VOLUME CONCENTRATION= 0.5342 BEAM OBSCURATION= 0.15

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	96.6	1503.9-	697.6	3.4	1859	1847
427.6	78.8	697.6-	427.6	17.8	1492	1521
300.8	52.7	427.6-	300.8	26.1	1806	1888
224.8	29.3	300.8-	224.8	23.4	1966	2082
172.4	21.5	224.8-	172.4	7.8	2047	2047
133.8	15.7	172.4-	133.8	5.8	1970	1975
104.0	10.4	133.8-	104.0	5.3	1881	1921
80.9	6.9	104.0-	80.9	3.5	1887	1893
63.1	4.4	80.9-	63.1	2.5	1912	1898
49.2	2.4	63.1-	49.2	2.0	1732	1775
38.6	1.1	49.2-	38.6	1.4	1540	1567
30.4	0.5	38.6-	30.4	0.5	1328	1307
24.1	0.5	30.4-	24.1	0.1	1023	1027
19.3	0.4	24.1-	19.3	0.2	739	770
15.5	0.3	19.3-	15.5	0.1	600	615

D(50%) (UM)= 291.96	V M D (UM)= 331.98	S M D (UM)= 192.90
D(10%) (UM)= 101.54	D(90%)(UM)= 597.71	SPAN = 1.70

MALVERN 2600 ETYPE PARTICLE SIZER VA.6

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

KERALA SATU
3 BAR
20 GRADEN RV 44 PROCENT

RESULTS

RUN NUMBER= 10 DATE=000000 LOG DIFFERENCE= 3.52

SAMPLE % VOLUME CONCENTRATION= 0.4901 BEAM OBSCURATION= 0.22

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	99.6	1503.9-	697.6	0.4	293	281
427.6	95.9	697.6-	427.6	3.7	477	478
300.8	84.5	427.6-	300.8	11.4	683	681
224.8	67.8	300.8-	224.8	16.7	905	907
172.4	53.2	224.8-	172.4	14.6	1164	1163
133.8	42.3	172.4-	133.8	10.9	1411	1410
104.0	32.8	133.8-	104.0	9.5	1667	1664
80.9	21.6	104.0-	80.9	11.2	1880	1883
63.1	11.1	80.9-	63.1	10.5	2041	2047
49.2	4.9	63.1-	49.2	6.2	2047	2033
38.6	1.6	49.2-	38.6	3.3	1792	1798
30.4	0.4	38.6-	30.4	1.2	1386	1404
24.1	0.3	30.4-	24.1	0.2	1004	900
19.3	0.3	24.1-	19.3	0.0	728	661
15.5	0.2	19.3-	15.5	0.1	506	519

D(50%) (UM)= 161.87	V M D (UM)= 191.89	S M D (UM)= 110.07
D(10%) (UM)= 63.58	D(90%)(UM)= 362.14	SPAN = 1.87

MALVERN 2600 CTYPE PARTICLE SIZER VA.C
IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS
KEPALA SATU 5 BAR 20 GRADEN RV 44 PROCENT

RESULTS

RUN NUMBER= 20 DATE=000000 LOG DIFFERENCE= 3.56

SAMPLE % VOLUME CONCENTRATION= 0.4602 BEAM OBSCURATION= 0.24

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	99.3	1503.9-	697.6	0.7	204	192
427.6	95.8	697.6-	427.6	3.5	335	330
300.8	87.7	427.6-	300.8	8.1	490	491
224.8	75.6	300.8-	224.8	12.1	678	670
172.4	62.5	224.8-	172.4	13.2	899	906
133.8	50.9	172.4-	133.8	11.5	1149	1154
104.0	41.1	133.8-	104.0	9.9	1408	1430
80.9	30.4	104.0-	80.9	10.7	1686	1606
63.1	18.8	80.9-	63.1	11.6	1911	1939
49.2	10.1	63.1-	49.2	8.7	2047	2047
38.6	4.2	49.2-	38.6	5.9	1959	1949
30.4	1.1	38.6-	30.4	3.1	1663	1696
24.1	0.2	30.4-	24.1	0.9	1205	1301
19.3	0.1	24.1-	19.3	0.2	931	807
15.5	0.0	19.3-	15.5	0.0	624	600

D(50%) (UM)= 130.94	V M D (UM)= 171.05	S M D (UM)= 99.70
D(10%) (UM)= 49.10	D(90%)(UM)= 336.85	SPAN = 2.20

MALVERN 2600 ETYPE PARTICLE SIZER VN.C

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

LAMPA DUDUK
1 BAR
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 23 DATE=000000 LOG DIFFERENCE= 3.57

SAMPLE % VOLUME CONCENTRATION= 0.7099 BEAM OBSCURATION= 0.22

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	99.3	1503.9-	697.6	0.7	692	657
427.6	89.8	697.6-	427.6	9.5	1069	1062
300.8	67.6	427.6-	300.8	22.2	1414	1417
224.8	45.2	300.8-	224.8	22.3	1696	1700
172.4	29.4	224.8-	172.4	15.9	1904	1920
133.8	18.7	172.4-	133.8	10.7	2029	2039
104.0	12.3	133.8-	104.0	6.4	2047	2047
80.9	6.7	104.0-	80.9	5.7	1959	1945
63.1	2.2	80.9-	63.1	4.5	1803	1828
49.2	0.7	63.1-	49.2	1.5	1578	1573
38.6	0.2	49.2-	38.6	0.4	1244	1222
30.4	0.1	38.6-	30.4	0.2	853	869
24.1	0.0	30.4-	24.1	0.0	586	605
19.3	0.0	24.1-	19.3	0.0	473	446
15.5	0.0	19.3-	15.5	0.0	375	368

D(50%) (UM)= 240.00	V M D (UM)= 266.09	S M D (UM)= 185.09
D(10%) (UM)= 94.54	D(90%)(UM)= 433.05	SPAN = 1.40

MALVERN 2600 ETYPE PARTICLE SIZER VA.6

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

JAMPA DUKUK
3 BAR
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 26 DATE=000000 LOG DIFFERENCE= 3.03

SAMPLE % VOLUME CONCENTRATION= 1.1650 BEAM OBSCURATION= 0.40

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	99.8	1503.9-	697.6	0.2	212	196
427.6	98.3	697.6-	427.6	1.5	362	350
300.8	93.7	427.6-	300.8	4.6	552	538
224.8	83.0	300.8-	224.8	10.7	790	781
172.4	67.1	224.8-	172.4	15.9	1103	1097
133.8	49.6	172.4-	133.8	17.5	1446	1438
104.0	34.9	133.8-	104.0	14.7	1785	1773
80.9	22.8	104.0-	80.9	12.1	1991	1955
63.1	11.9	80.9-	63.1	10.9	2047	2047
49.2	5.3	63.1-	49.2	6.6	1966	1947
38.6	2.1	49.2-	38.6	3.2	1718	1681
30.4	0.8	38.6-	30.4	1.3	1344	1340
24.1	0.4	30.4-	24.1	0.4	971	980
19.3	0.2	24.1-	19.3	0.2	730	715
15.5	0.1	19.3-	15.5	0.1	565	552

D(50%) (UM)= 134.67	V M D (UM)= 156.26	S M D (UM)= 107.74
D(10%) (UM)= 59.85	D(90%)(UM)= 274.62	SPAN = 1.59

MALVERN 2600 CTYPE PARTICLE SIZER VA.C
IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

JAMPA DUKUK
5 BAR
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 27 DATE=080388 LOG DIFFERENCE= 3.12

SAMPLE % VOLUME CONCENTRATION= 1.3561 BEAM OBSCURATION= 0.78

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	MEASURED
1503.9	100.0					
697.6	99.9	1503.9-	697.6	0.1	92	88
427.6	99.4	697.6-	427.6	0.5	162	157
300.8	97.9	427.6-	300.8	1.5	258	253
224.8	94.3	300.8-	224.8	3.6	391	307
172.4	87.1	224.8-	172.4	7.2	598	591
133.8	76.1	172.4-	133.8	11.0	856	860
104.8	63.0	133.8	104.8	13.2	1233	1236
80.9	47.4	104.8-	80.9	15.6	1558	1548
63.1	31.1	80.9-	63.1	16.3	1855	1878
49.2	19.6	63.1-	49.2	11.5	2047	2047
38.6	11.8	49.2-	38.6	7.8	2028	2013
30.4	6.5	38.6-	30.4	5.3	1847	1862
24.1	3.4	30.4-	24.1	3.1	1593	1687
19.3	1.6	24.1-	19.3	1.8	1346	1332
15.5	0.6	19.3-	15.5	1.0	1077	1074

D(50%) (UM)= 84.78 | V M D (UM)= 104.75 | S M D (UM)= 66.69

D(10%) (UM)= 35.87 | D(90%)(UM)= 193.53 | SPAN = 1.86

MALVERN 2600 ETYPE PARTICLE SIZER VA.6

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

LAMPA DUDUK
1 bar
20 GRADEN
44 PROCENT
IETS GEDRAAID

RESULTS

RUN NUMBER= 2 DATE=080388 LOG DIFFERENCE= 4.42

SAMPLE % VOLUME CONCENTRATION= 3.5480 BEAM OBSCURATION= 0.00

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1500.9	100.0					
697.6	63.8	1500.9-	697.6	36.2	2047	2047
427.6	19.1	697.6-	427.6	44.7	1795	1922
300.8	10.1	427.6-	300.8	8.9	1433	1408
224.8	3.1	300.8-	224.8	7.0	935	1030
172.4	1.7	224.8-	172.4	1.4	750	786
133.8	1.2	172.4-	133.8	0.5	670	623
104.0	0.5	133.8-	104.0	0.8	507	526
80.9	0.2	104.0-	80.9	0.2	393	427
63.1	0.2	80.9-	63.1	0.1	400	354
49.2	0.1	63.1-	49.2	0.1	284	283
38.6	0.0	49.2-	38.6	0.1	203	225
30.4	0.0	38.6-	30.4	0.0	179	176
24.1	0.0	30.4-	24.1	0.0	147	125
19.3	0.0	24.1-	19.3	0.0	102	93
15.5	0.0	19.3-	15.5	0.0	82	80

D(50%) (UM)= 614.42	V M D (UM)= 786.17	S M D (UM)= 522.25
D(10%) (UM)= 299.39	D(90%)(UM)= 1201.40	SPAN = 1.32

MALVERN 2600 ETYPE PARTICLE SIZER VA.6

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

LAMPA DUDUK
3 bar
20 GRADEN
44 PROCENT
IETS GEDRAAID

RESULTS

RUN NUMBER= 3 DATE=080388 LOG DIFFERENCE= 3.22

SAMPLE % VOLUME CONCENTRATION= 3.3603 BEAM OBSCURATION= 0.49

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	88.6	1503.9-	697.6	11.4	1613	1601
427.6	55.4	697.6-	427.6	33.2	1953	1961
300.8	31.5	427.6-	300.8	23.9	2047	2047
224.0	18.6	300.8	224.0	12.9	1916	1918
172.4	10.9	224.0-	172.4	7.7	1805	1811
133.8	6.1	172.4-	133.8	4.8	1671	1671
104.0	3.9	133.8-	104.0	2.2	1517	1519
80.9	2.3	104.0-	80.9	1.6	1359	1352
63.1	1.0	80.9-	63.1	1.2	1173	1198
49.2	0.5	63.1-	49.2	0.5	1018	1011
38.6	0.3	49.2-	38.6	0.3	839	823
30.4	0.1	38.6-	30.4	0.2	639	649
24.1	0.0	30.4-	24.1	0.0	486	497
19.3	0.0	24.1-	19.3	0.0	392	378
15.5	0.0	19.3-	15.5	0.0	298	289

D(50%) (UM)= 398.96	V M D (UM)= 461.40	S M D (UM)= 290.86
D(10%) (UM)= 165.28	D(90%)(UM)= 795.60	SPAN = 1.58

MALVERN 2600 ETYPE PARTICLE SIZER VA.6
IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

LAMPA BUDUK
5 bar
20 GRADEN
44 PROCENT
IETS GEDRAAID

RESULTS

RUN NUMBER= 5 DATE=080380 LOG DIFFERENCE= 3.22

SAMPLE % VOLUME CONCENTRATION= 3.0158 BEAM OBSCURATION= 0.54

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	92.7	1503.9-	697.6	7.3	1285	1275
427.6	66.5	697.6-	427.6	26.3	1665	1686
308.8	45.8	427.6-	308.8	20.7	1880	1879
224.0	29.2	308.8-	224.0	16.5	1943	1950
172.4	19.0	224.0-	172.4	10.2	2028	2040
133.0	11.7	172.4-	133.0	7.3	2047	2047
104.0	7.5	133.0-	104.0	4.2	1986	2008
80.9	4.5	104.0-	80.9	2.9	1862	1867
63.1	2.3	80.9-	63.1	2.2	1705	1714
49.2	1.3	63.1-	49.2	1.0	1492	1501
38.6	0.7	49.2-	38.6	0.7	1200	1265
30.4	0.3	38.6-	30.4	0.4	1019	1033
24.1	0.1	30.4-	24.1	0.2	797	881
19.3	0.0	24.1-	19.3	0.1	620	620
15.5	0.0	19.3-	15.5	0.0	470	470

D(50%) (UM)= 326.69 | V M D (UM)= 388.40 | S M D (UM)= 232.07

D(10%) (UM)= 121.71 | D(90%)(UM)= 669.36 | SPAN = 1.68

MALVERN 2600 ETYPE PARTICLE SIZER VA.C

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

SEGI EVAM
1 bar
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 8 DATE=080388 LOG DIFFERENCE= 4.18

SAMPLE % VOLUME CONCENTRATION= 0.0896 BEAM OBSCURATION= 0.11

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	85.9	1503.9-	697.6	14.1	1020	1752
427.6	37.4	697.6-	427.6	48.5	2047	2047
300.8	20.3	427.6-	300.8	17.2	1904	1838
224.8	10.7	300.8-	224.8	9.6	1508	1497
172.4	7.5	224.8-	172.4	3.2	1279	1258
133.8	4.9	172.4-	133.8	2.6	1193	1141
104.8	2.7	133.8-	104.8	2.1	1072	1069
80.9	1.3	104.8-	80.9	1.4	996	998
63.1	0.5	80.9-	63.1	0.8	930	887
49.2	0.1	63.1-	49.2	0.4	732	723
38.6	0.1	49.2-	38.6	0.1	548	555
30.4	0.0	38.6-	30.4	0.1	420	388
24.1	0.0	30.4-	24.1	0.0	312	314
19.3	0.0	24.1-	19.3	0.0	231	222
15.5	0.0	19.3-	15.5	0.0	189	180

D(50%) (UM)= 497.47	V M D (UM)= 538.39	S M D (UM)= 364.79
D(10%) (UM)= 213.56	D(90%)(UM)= 929.72	SPAN = 1.44

MALVERN 2600 ETYPE PARTICLE SIZER VA.6

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

CEGI CUAM

3 bar

20 GRADEN

RV 44 PROCENT

RESULTS

RUN NUMBER= 9 DATE=080388 LOG DIFFERENCE= 4.31

SAMPLE % VOLUME CONCENTRATION= 0.0026 BEAM OBSCURATION= 0.15

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS	%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0				
697.6	98.5	1503.9- 697.6	1.5	418	374
427.6	90.5	697.6- 427.6	8.0	648	624
300.8	76.6	427.6- 300.8	13.9	874	860
224.8	60.9	300.8- 224.8	15.7	1189	1092
172.4	46.1	224.8- 172.4	14.8	1370	1358
133.8	33.7	172.4- 133.8	12.4	1624	1605
104.0	24.9	133.8- 104.0	8.8	1850	1821
80.9	15.9	104.0- 80.9	8.9	1999	1940
63.1	7.4	80.9- 63.1	8.5	2047	2047
49.2	3.4	63.1- 49.2	4.1	1980	1931
38.6	1.8	49.2- 38.6	1.6	1699	1625
30.4	0.9	38.6- 30.4	0.9	1273	1259
24.1	0.3	30.4- 24.1	0.6	952	981
19.3	0.1	24.1- 19.3	0.2	806	753
15.5	0.0	19.3- 15.5	0.1	637	508

D(50%) (UM)= 186.27	V M D (UM)= 230.19	S M D (UM)= 106.17
D(10%) (UM)= 68.43	D(90%)(UM)= 422.96	SPAN = 1.90

MALVERN 2600 ETYPE PARTICLE SIZER VA.C

IMAG WAGENINGEN

USER EXPERIMENTAL AND SAMPLE DETAILS

SEGI EWAM
5 bar
20 GRADEN
RV 44 PROCENT

RESULTS

RUN NUMBER= 11 DATE=880308 LOG DIFFERENCE= 3.57

SAMPLE % VOLUME CONCENTRATION= 0.4422 BEAM OBSCURATION= 0.21

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS		%	LIGHT ENERGY CALCULATED	LIGHT ENERGY MEASURED
1503.9	100.0					
697.6	99.7	1503.9-	697.6	0.3	280	278
427.6	95.2	697.6-	427.6	4.5	466	460
300.8	85.5	427.6-	300.8	9.7	664	672
224.8	68.8	300.8	224.8	16.7	901	902
172.4	52.3	224.8-	172.4	16.5	1139	1162
133.8	42.4	172.4-	133.8	9.9	1384	1382
104.0	33.5	133.8-	104.0	8.9	1619	1604
80.9	23.0	104.0-	80.9	10.5	1808	1828
63.1	12.6	80.9-	63.1	10.4	1986	2013
49.2	7.1	63.1-	49.2	5.5	2047	2047
38.6	4.2	49.2-	38.6	2.9	1849	1860
30.4	2.3	38.6-	30.4	1.9	1532	1570
24.1	0.7	30.4-	24.1	1.6	1249	1252
19.3	0.1	24.1-	19.3	0.6	1033	1030
15.5	0.0	19.3-	15.5	0.1	798	798

D(50%) (UM)= 163.30	V M D (UM)= 189.40	S M D (UM)= 111.70
D(10%) (UM)= 56.53	D(90%)(UM)= 359.03	SPAN = 1.85