FAO COMMISSION FOR CONTROLLING THE DESERT LOCUST IN THE NEAR EAST

WORKSHOP ON SPRAY EQUIPMENT USED IN DESERT LOCUST CONTROL

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CAIRO EGYPT

REGIONAL OFFICE FOR THE NEAR EAST
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Introduction

The Desert Locust (*Schistocerca gregaria*, Forskål) has threatened agricultural crops in the desertic and semi-desertic zones of northern Africa, the Near East and South-West Asia for thousands of years. Despite the development of improved monitoring and control technologies, this threat continues to the present day. For example, there have been eight major Desert Locust plagues since 1860, some lasting more than ten years, and several upsurges during the last 25 years, the most recent being 1992-1994.

When locust upsurges and plagues develop, large scale control campaigns must be mounted on an emergency basis. These campaigns are expensive, use large quantities of pesticides and involve external assistance. During the last plague of 1986-89, some 40 countries were affected and more than 14 million hectares were treated. The total amount of assistance provide by the international community during the plague was about US$ 250 million.

Ground and aerial application of chemical pesticides is the only viable method of locust control at present. Until the late 1980s, dieldrin was the most effective pesticide used in locust control due to its high toxicity and long persistency and relatively easy method of application. It was commonly applied as barriers on vegetation in locust infested areas. However this pesticide has now been withdrawn from use because of its potential effects on the environment and has been replaced by less toxic, more environmentally benign pesticides. These pesticides are highly concentrated and applied at ultra-low volumes specifically onto the locusts themselves as recommended by FAO. Consequently, this requires much greater precision in terms of the application equipment and methodology than earlier control techniques.

1. Purpose

The workshop was organized by the FAO Regional Office for the Near East in collaboration with the FAO Emergency Centre for Locust Operations (ECLO) in response to a recommendation from the 19th Session of the FAO Commission for Controlling the Desert Locust in the Near East held in Cairo in October 1993.

The objective of the workshop was to demonstrate and evaluate hand-held, knapsack and vehicle-mounted sprayers commonly used in Desert Locust control. The aim of the workshop was to provide an objective evaluation in order to assist users and donors in choosing spray equipment rather than recommending specific spray equipment for Desert Locust control. Such an evaluation may also be useful to manufacturers to identify notable features and shortcomings of their equipment.

2. Sprayer manufacturers

Representatives from those manufacturers known to FAO who have provided equipment for Desert Locust control operations were invited to attend the workshop. Invitations were sent out three months in advance and included the performance criteria to be examined during the workshop. It is regretted that there were undoubtedly some manufacturers unknown to FAO who may have supplied

spray equipment to locust affected countries for control operations but were not invited to participate in the workshop. Manufacturers who participated in the workshop are listed in Annex 1.

3. Sprayer evaluation panel

Application experts from international institutes and organizations involved in Desert Locust control as well as from main locust affected countries within the Near East Region were invited to the workshop in order to evaluate the performance of spray equipment in a fair and objective manner in the field (Annex 1).

4. Programme

The first day of the workshop consisted of sprayer presentations by the manufacturers (Annex 2). Performance criteria and testing methodology were also discussed and agreed upon by the manufacturers and evaluation panel. During the second day, equipment was evaluated and tested in the presence of the manufacturers at a field site outside of Cairo. Data was analyzed during the third day and preliminary results of pesticide efficiency were discussed with the manufacturers; results of the other evaluations were still being assessed and were not available for discussion.

5. Spray equipment evaluated

Manufacturers were invited to bring sprayers to the workshop capable of producing 80% of the droplets within 40-120 microns (µm) and an emission rate to give volume applications of between about 0.4 and 2.0 l/ha as per the FAO Desert Locust Guidelines. Sprayers presented and tested during the workshop are listed in Annex 3.

Manufacturers were requested to bring (1) evidence of droplet spectrum, (2) flow rate calibrations with ULV products, (3) equipment prices, (4) equipment operating and maintenance manuals, (5) distribution of sprayers in locust affected countries, (6) any reports of operational use in these countries, and (7) any literature.

6. Field site and materials

The performance testing of the vehicle-mounted sprayers was undertaken at a field site (29°54'18" N / 31°05'24" E) approximately 25 km west of Cairo. The site was a flat firmly packed sandy desertic plain, treeless, with a few small sandy outcroppings and depressions not more than 1 m in height or depth, interspersed with low sandy ridges up to 5 m in height. There was a complete absence of buildings and animal corrals. The weather was sunny and cloudless with low relative humidity; temperature was 31-36°C and winds were 4-6 m/s. Temperature and wind conditions as well as site characteristics were similar to conditions encountered during actual locust control operations. The site was accessed by the tarmac road fromFaiyum to Cairo between the 75 and 77 km marker.

Dursban 45% (chlorpyriphos) ULV formulation was used during the performance testing. Sprayer manufacturers agreed prior to the testing that this product was satisfactory for performance evaluation of their equipment.

7. Performance criteria

Droplet spectrum

This is the most important parameter under our control. It influences the distribution of the spray downwind (small drops carried further), the losses as fall out (large drops sediment onto soil) and

the impaction efficiency on locusts and vegetation (very small drops impact less efficiently). As a result, the size of droplets will influence work rate, biological efficacy and possibly environmental impact.

Spectrum width: There is an optimal drop size for each pest control situation, and drops larger or smaller than this size will be less biologically effective. However, no commercial sprayer can produce uniformly sized drops and the best that can be done is to aim for a relatively narrow drop spectrum.

Droplet size: Evidence suggests that droplets less than 50 μm will either be dispersed beyond the target area or largely fail to impact, and that drops larger than 100 μm are more likely to fall onto bare soil relatively close to the sprayer. The optimum droplet size will be somewhere in between these two figures but for practical purposes Volume Median Diameter, Number Median Diameter and the ratio of the two were used to judge the quality of the sprayer spectrum.

Flow rate

Sprayers must have a flow rate range that allows them to apply the correct volume application rate and hence dose of the ULV insecticides. This varies according to the forward speed of the spray vehicle and the track spacing possible while still giving a reasonably uniform deposit. The volume application rate of locust insecticides is usually between 0.4 l/ha and 2.0 l/ha so for example a vehicle-mounted sprayer travelling at 7 km/hr and using a track spacing of 25 m must have a flow rate adjustable between 116 ml/min and 584 ml/min.

Ease/security of calibration

Ease of setting flow rate and the likelihood that it will remain as set are important factors in efficient use of pesticides. The flow rate should not alter with time nor be likely to be altered accidentally.

Ease of filling/spraying/cleaning

A locust sprayer should be designed for easy operation - if tasks are difficult, they will not be carried out, leading to pesticide misuse or sprayer breakdown.

Durability/maintenance

This is a critical factor for any successful locust sprayer but difficult to gauge without long term testing. However, certain subjective indicators can be used such as construction materials for tank, pump seals, piping and drive belts - are they strong, resistant to ULV formulations and sunlight etc. Level of maintenance required is an important consideration - usually subjective except where manufacturers give routine maintenance intervals. Stability on the vehicle is also important since locust spraying often involves travelling over rough terrain and if sprayers are not securely mounted on the vehicle, or rigidly constructed, they may quickly be damaged.

Safety (operator/environment)

Inherent features of the sprayer can help or hinder its safe operation. This can be assessed on the basis of several factors such as positioning of controls for the sprayer, method of flow rate measurement/adjustment, tank design, drop size (small drops are more likely to drift uncontrollably).

Cost

Sometimes this is a consideration, but it is usually small in relation to the value of the pesticide dispensed from the machine.

Work rate

This is simply a function of forward speed and track spacing. Track spacing is determined by the pattern and downwind distance of the pesticide deposit (the swath) and should be as wide as possible while still producing a relatively uniform cumulative deposit when the individual swaths overlap. The emission height is important since it influences the swath width. If it is adjustable, range and method of adjustment are relevant. Airblast volume and velocity determine the distance the spray is projected which will influence the swath width resulting from the increased effective emission height. Airblast is also marginally significant for penetration of dense vegetation or densely roosting locusts, and the ability to treat locusts in medium sized trees.

8. Desert Locust sprayer questionnaire

FAO prepared and distributed a questionnaire to English-speaking locust affected countries in July 1994. Completed questionnaires were received from nearly half of these countries; results are summarized in Annex 4 and reviewed in Annex 5.

9. Evaluation of locust spray equipment

Methodology

In order to evaluate the 11 sprayers brought to the workshop (Annex 3) in one day, rapid appraisal techniques were required. These involved various tests of three main factors: pesticide efficiency, sustainability and socio-economic merit which address the evaluation criteria mentioned earlier - some of them quantitative and others subjective. Members of the evaluation team were divided into three groups so that work could continue on three sprayers simultaneously and standard forms were provided to each group for collection of data, observations and judgements (Annex 7).

Droplet spectrum

In order to assess pesticide efficiency, it was essential to have information on the fundamental aspect of droplet spectrum. Manufacturers were asked to provide data but not all have carried out reliable analyses and it was necessary to make measurements during the workshop. It is a difficult task even in a laboratory to measure the emitted spectrum due to the need to sample a representative portion of the spray cloud and the fact that different types of analytical machinery produce different results from the same sprayer. Spectrum will also vary with the type of spray formulation used and the flow rate. In the field it is even more difficult with factors such as meteorological conditions, and vibration of the spray head while the spray vehicle is in motion introducing further variation. Nevertheless, a technique was developed to sample and analyse spray from each of the sprayers while they were being operated in typical fashion in the field (Annex 8). This involved spraying Dursban 45% ULV (chlorpyriphos) labelled with Lumogen fluorescent dye suspended at around 0.5 % concentration. Spray was collected on NRI rotary samplers and the droplets size measured using a microscope equipped with a Porton Graticule and ultra violet illumination of the slide from a Blak Ray lamp.

The problem with field sampling of sprays is that small drops (<30 μm) tend to drift around objects (especially large objects) rather than impacting on them. This problem is partially solved by using rotating samplers which sweep the droplets more efficiently from the air. Even so, drops of < 20 μm are collected at less than 50 % efficiency so it is necessary to apply a correction factor (derived in a wind tunnel at NRI) to the number of small drops collected.

The sampling surface was magnesium oxide, deposited onto glass slides (6 mm wide) by burning magnesium ribbon under them. The advantage of this surface is that size of the craters formed is directly proportional to the size of the droplets. The drop diameter is obtained by multiplying

the crater diameter by 0.86. Oil sensitive papers are easier to handle but the spread factor is not constant - larger drops spread more than smaller ones and the magnitude of the spread depends on the spray formulation and the batch of paper used.

After application of the two correction factors for collection efficiency and spread factor, the data was entered into a spreadsheet to calculate Volume Median Diameter (VMD) and Number Median Diameter (NMD) and the ratio of the two.

Nine rotating samplers were deployed on 1.2m high poles in positions estimated to cover the area of maximum deposit of spray from a single pass of the sprayer (different distances for different types of sprayer). The slide with most drops on it - assumed to have been nearest to the centre of the spray cloud - was analysed for VMD, NMD and ratio (Annex 9).

It must be emphasised that this rather crude sampling method does not represent a scientific evaluation of the sprayers' emitted spectrum and should only be considered a rough guide. However, the technique would be more likely to exaggerate the narrowness of the droplet spectrum than the reverse since the very large droplets may have fallen to the ground and the very small droplets may have been carried upwards by convection before the cloud reached the samplers. If the samplers collected many large and many small droplets they can only have come from the sprayer under test.

Swath width

The single spray pass to assess droplet spectrum also provided the opportunity to investigate swath width of each sprayer under the prevailing conditions (Annex 8). This was achieved by mounting thin strips of oil sensitive paper vertically on 30 cm sticks at distances downwind of the spray pass. Distances used were 0, 2, 5, 8, 12, 16, 20, 25, 30, 35, 40, 50, 60, 80, 100, 130 and 180 m. A single spray pass was made at right angles to the wind and to the sampling line and the time, temperature, wind speed, humidity, wind speed were recorded. Later, the number of droplets per cm^2 was counted and a graph produced of number of droplets per cm^2 against distance downwind (Annex 10).

Again, this must not be considered a definitive assessment of the swath width performance, nor strict comparisons made between machines since the evaluations were carried out at different times of the day with different temperature and wind speeds. Also, if this sort of test is carried out several times, each graph will be slightly different due to the variations in sprayer output and meteorological conditions from moment to moment. In addition, deposit has been assessed on the basis of number of drops per cm^2. This is not accurate for sprayers with a wide drop spectrum since the small number of large droplets falling close to the sprayer account for a large proportion of the volume. However, the graphs can be used as a rough guide to estimate the scale of magnitude of the track spacing which could provide a reasonably uniform pesticide deposit.

Other aspects tested (Annex 7)

The residual volume in the sprayer after emptying has a bearing on sprayer safety. This was measured by putting 2 litres of pesticide into the dry sprayer, priming the pesticide line and measuring the volume recovered from it at the drain pipe. Flow rate reliability over a short space of time was assessed by measuring the flow rate three times in a row. This also allowed assessment of ease of calibration. Airblast range was estimated visually for the air-assisted machines by directing the spray vertically upwards next to a calibrated pole. Stability of the sprayer was assessed for the vehicle mounted sprayers by driving the vehicle over a piece of bumpy ground and noting any excessive movement of the sprayer or its components.

Observations/collection of information (Annex 7)

Various aspects of the configuration and specification of the sprayers were gathered by examining the sprayer, the operators handbook, and by discussion with the manufacturers. This

process was intended to familiarise the evaluation team with the sprayers and to bring out any design and performance features which might have a bearing on the evaluation.

Judgements (Annex 7)

The evaluation team was also asked to make certain judgements on the sprayers. For example the ease of filling, calibration, emptying and cleaning were judged subjectively based on the team's experience of the sprayer before and during the workshop.

10. Summarising the findings

When data collection was complete, the twelve members of the evaluation team met to discuss and summarise the findings. This was done by dividing the 3 main assessment factors into 9 individual parameters (Annex 11) and assigning a star rating to each. The rating applies to each sprayer in relation to the other sprayers in its class (either vehicle-mounted or portable). Each member of the team gave a rating from 1 star (inappropriate for locust control) to 5 stars (excellent for locust control) and the average of the total count gave the number of stars. Where averages fell between whole numbers, the figures were rounded up or down e.g. 3.5 and above was rounded up to 4. This resulted in a small loss of detail in the data, but was considered preferable to complicating the evaluation with decimals. At the foot of the table is the average of the ratings for all parameters which gives an overall rating for the sprayer. These are a combined assessment including all factors of performance, practicality, durability, safety, cost and work rate. Notes were taken on particular aspects of each sprayer design which justified the rating given and these are summarised below.

Although Francome Fabrications tried to arrange for an exhaust nozzle sprayer to be brought from a neighbouring country, it did not arrive in time for the workshop. This was unfortunate since it is still the mainstay of ground control in some countries and the newer machines must be evaluated in the context of current technology. Consequently, an evaluation by seven of the evaluation team - those who have first hand experience of the machine - was made on the basis of past experience. This is inevitably not as definitive as the other evaluations since no machine was available to test in the standard way, but provides a useful guide in the context of this assessment.

11. Evaluation summary

Please refer to Annexes 7 - 11.

Francome Fabrications Exhaust Nozzle Sprayer Mk II (overall rating: ♦♦)

This is still the standard vehicle mounted locust sprayer in many countries and it was felt important to evaluate it as the benchmark against which other sprayers should be judged. It was rated as poor overall with notable points for and against listed below:

- ✙ relative simplicity (few moving parts)
- ✙ rugged construction (mostly steel)
- ✙ low relative cost coupled with reasonable work rate

- ▫ droplet spectrum is wide in comparison with rotary atomisers.
- ▫ flow rate is difficult to control and measure.
- ▫ droplet size and flow rate fluctuate during operation since they are dependent on exhaust pressure which varies as throttle settings vary when travelling over rough or sandy terrain.
- ▫ filter box gaskets are not compatible with some ULV formulations.

- sprayer controls are on the machine itself and require that an operator stand beside the machine where there is a risk of pesticide exposure.
- filler opening is very small (around 5 cm). A funnel or pesticide pump is required for safe filling but these are often not available.
- there is anecdotal evidence of the exhaust back pressure causing damage to the vehicle.
- soot from the exhaust gases tends to mix with the pesticide and to accumulate in the tank and filters.

Berthoud Puma (overall rating: ♦♦)

This air-assisted sprayer was originally designed for higher volume spraying of emulsifiable concentrates on field crops and as a result has serious shortcomings as a locust sprayer. It was rated overall as poor with notable features described below:

- the dosing valve (flow control) was easy to adjust and monitor.
- the tank opening is the widest on test which reduces the chances of operator exposure.

- the engine was difficult to start and although this was a chance problem affecting this particular machine, it highlights the potential problems of independent engines powering locust sprayers.
- the rotary atomiser fitted to the sprayer was adapted from a Berthoud knapsack machine and became blocked - it may not be compatible with the viscosity of ULV locust formulations. The drop size evaluation had to be carried out using the standard air shear nozzle.
- although VMD of drops was appropriate (67 μm) the droplet spectrum was very wide with many large and small drops (VMD/NMD ratio 4.1). This also influenced the rating for safety since large numbers of small droplets are an environmental hazard.
- the sprayer as seen had no method of fixing to the vehicle - it stood free on 4 rubber feet - and was unstable when travelling over the bumpy track.
- calibration was difficult, requiring that the spray head be removed from the airblast duct.
- the draining system - a screw cap on the base of the tank - was inconvenient and likely to contaminate the operator in use.
- some components are not compatible with some ULV pesticides which would result in breakdown.

MAT Airbi Drift Air (overall rating: ♦♦♦)

This passive drift machine is designed specifically for locust and grasshopper control and as such has some very good features. However, it also has some drawbacks which reduce its rating to average. Notable features were:

- the flat power cable is good and allows the vehicle door to be closed on it without damage.
- the lockable tool box attached to the sprayer was useful for storing tools, spare orifice plates etc.
- the mast could be adjusted to different heights to cope with different wind conditions and could be retracted into a safe transport position without tools.
- the deep filter at the tank opening will prevent splashing during filling.

- the sampled drop size was too large for efficient use of pesticide (VMD 141 μm) and there is no method of adjusting it. This conflicts with independently collected data provided by the manufacturer. The team observed pulsing as the spray cloud was being emitted probably as a result of mast movement, even though the spray area was relatively flat. This may be the result of there being no liquid back pressure at the spray head and/or the mast suspension problems described below.

- the spring suspension on the mast designed to prevent damage in the event of hitting an obstacle allowed excessive movement of the spray head (bending over 30 degrees) when driving over the bumpy track. This was considered a serious durability shortcoming for desert locust spraying.
- the diaphragm pump seals are not resistant to all solvents. This would lead to rapid breakdown when using pesticides such as bendiocarb.
- this cost of this sprayer is almost double that of the two other passive drift sprayers.
- the filter bowl was horizontal resulting in spillage of pesticide when cleaning.
- the drain tube was not long enough to extend over the tailgate of the vehicle for draining.

Micron Ulvamast Mk II (overall rating: ♦♦♦♦)

This passive drift sprayer is designed for locust and grasshopper spraying and emerged with the highest rating of the vehicle mounted sprayers. However, there were some shortcomings and it was rated as good rather than excellent overall. Notable features were:

- droplet spectrum is relatively narrow (VMD/NMD ratio 1.75).
- the flushing tank is useful in that the pesticide line, including atomiser, can be flushed without emptying the main pesticide tank. This influences ease of use and safety.
- the webbing straps holding the tank on are resistant to pesticides and spread the loads during travel over rough terrain.
- the magnetic impeller pump has no seals in contact with pesticide and as such will not be damaged whichever pesticide is being used.
- the deep filter at the wide tank opening allows safe filling.

- the filter bowl is too close to the frame to be easily removed and even though mounted vertically, spills pesticide during cleaning.
- flow control was considered too easy to alter and not easy to monitor. Some method of fixing it (secure locking screw) or monitoring it (pressure gauge) is needed.
- the drive belt cover was weak and the screws likely to be lost resulting in it being left off. The drive belt itself is not compatible with some ULV pesticides so may have to be changed regularly.
- the lack of a non-return valve meant several seconds delay after switching on the pump before pesticide issued from the atomiser.
- wiring and piping leading to the atomiser head were loose and looked vulnerable as they moved around while driving over rough terrain.

Micronair AU8110 (overall rating: ♦♦♦)

This air-assisted machine has been designed for migratory pest control including locusts and uses a version of the atomiser used in most aerial spraying operations. Although it has some good features it was rated overall as average due to some shortcomings. These and other notable features are described below:

- flow rate control is positive and easy to adjust with provision for easy collection of spray liquid during calibration.
- the atomiser head is tried and tested, and seems robust and well protected.
- work rate is high for a vehicle mounted sprayer due to the greater effective emission height provided by the airblast.

- droplet size VMD was within but near the bottom of the acceptable range (55 µm) but the spectrum was rather wider than the other rotary atomisers on test (VMD/NMD ratio 2.6). The spectrum may be narrower if overall drop size were increased by altering the blade angle settings.
- the option allowing the sprayer head to be removed for spot treatments was not considered an advantage for locust control since it could result in local overdosing.
- the sprayer is relatively sophisticated and would require a quality of care and maintenance which is sometimes lacking during locust operations.

Micronair AU7010 (overall rating: ♦♦♦)

This is a relatively new passive drift sprayer with rotary atomiser designed for locust and grasshopper control. It was rated as average due to some shortcomings as a locust sprayer. These and other notable features are as below:

- droplet size is appropriate for locust control and spectrum width is adequate (VMD/NMD ratio 2.07).
- flow rate control was good with the advantage that it could be locked with an allen key.
- the optional atomiser fan blades are likely to throw the pesticide away from the sprayer and vehicle, resulting in reduced contamination and also may help the initial dispersal of the spray cloud and assist distribution of the spray.
- the small flushing tank is useful in that it allows the pesticide line including atomiser to be flushed clean without emptying the main pesticide tank.

- the pump seals are not compatible with all solvents which would mean rapid breakdown when using pesticides such as bendiocarb.
- the filter bowl is mounted horizontally and results in spillage of pesticide when cleaning.
- there is no transport position for the atomiser mast which might mean damage to the atomiser head or mast during transit.
- the metal tray under the sprayer is likely to collect pesticide.
- some electrical cables are not protected from (nor resistant to) ULV pesticide and may deteriorate in use.
- it was necessary to remove the fan blade cover before removing the pulley belt cover and it was felt that access should have been easier. The screws are also likely to be lost.
- the small flushing tank was not adequately fixed at its base and might break loose during use in rough terrain.

Tifa 100E (overall rating: ♦♦)

This is a sprayer designed for thermal fogging and several other types of pesticide application. The droplet spectrum of thermal fogs is too small for locust spraying, but with the burner switched off it operates as a simple airblast machine with an air shear nozzle. The overall rating was poor, due to problems with the droplet size and spectrum, durability with ULV pesticides, safety and cost. Notable features are as below:

- the reverse flow flushing system in which air is forced back through the pesticide piping is advantageous although this may not clean all of the pipes.
- the control valve for drop size was easy to adjust and check.

- the drop size as measured is too small for locust control. It may be possible to reduce the rpm of the engine which would reduce the airblast and increase drop size, but it was not known whether this engine was designed to be operated at less than normal speed (with corresponding reduction in cooling air).

- some components, for example pump seal, are not compatible with some ULV pesticides and would degrade quickly in use.
- the control for drop size also controls flow rate so it is not possible to adjust these two parameters independently.
- there is no integral tank and pesticide must be supplied from a separate container such as a pesticide drum by way of a pipe put through the drum opening. This would lead to spillage of the pesticide from the drum during travel over rough terrain.
- cost was considered very high in relation to other vehicle mounted locust sprayers.

Jacto PL50 (overall rating: ♦♦♦)

This sprayer is a standard motorised knapsack sprayer fitted with a fan driven rotary disc. It was originally designed for mosquito control but has been adapted with a slower disc speed for locust control. It was rated average with several good features being offset by some bad points.

- the machine is relatively quiet at 92 db.
- the centrifugal pump keeps the flow rate constant at different atomiser elevations.
- the tank opening is wide and therefore easy to fill.
- no tools are needed for changing the flow rate (restrictor nozzle).
- the spray head is comparatively lightweight.

- the drop size is considered too small for locust spraying.
- some components, for example pipes, are not compatible with ULV pesticide which would lead to rupture in use.

Micronair AU8000 (overall rating: ♦♦♦)

This sprayer is a motorised knapsack mist blower fitted with a rotary cage atomiser. It is designed for migratory pest control and is rated as average with notable points below:

- the atomiser is rugged.
- the drop size is adjustable by altering the blade angles.
- airblast is relatively strong allowing a greater effective emission height and a greater work rate.
- ergonomics of control are good (apart from one negative point below).

- the droplet spectrum as measured in the field (VMD/NMD ratio 2.45) was wider than independently collected data. However, pulsing was observed during spraying and the machine may not have been operating in typical fashion.
- the throttle was close to the lever controlling the pesticide pump and was accidentally operated while adjusting the throttle.
- flow rate calibration required detachment of the pesticide pipe from the atomiser. A quickly detachable union would make the process easier.

Berthoud C5 (overall rating: ♦♦♦♦)

This is a battery operated spinning disc sprayer which was rated as good overall. Good and bad points as below:

- The restrictor nozzle can be removed without removing the sprayer bottle.
- the on-off switch is easy to operate and seems durable.

- ✙ the quick coupling to the optional backpack tank is well thought out.

- ▫ the droplet size as sampled at this workshop (VMD 104 µm) was too large for locust control. This may have been due to the fact that the atomiser disc has no teeth from which the pesticide can issue in smaller drops or some problem with the batteries/contacts causing the disc to spin too slowly. Despite the rating of good, this droplet size problem needs to be investigated before further use against locusts.
- ▫ despite apparent torque limitations (disc speed drops considerably with pesticide flow on), power consumption of the electric motor is almost twice that of the other spinning disc sprayers tested. This means that batteries would last less long.

Micron Ulva+ (overall rating: ♦♦♦♦)

This is a battery operated spinning disc sprayer which was rated as good overall. Good and bad points are as below:

- ✙ drop size and spectrum are good.
- ✙ restrictor nozzles can be changed without removing the sprayer bottle.
- ✙ durability seems good with aluminium handle and a breather tube for the motor to prevent pesticide being drawn into the motor housing during heating and cooling.
- ✙ spare restrictor nozzles are clipped onto the sprayer so are less likely to be lost than if kept loose.
- ✙ the disc can be removed without tools for cleaning.

- ▫ the on-off switch is not captive and could be lost.
- ▫ the sprayer is slightly more expensive than the other portable spinning disc sprayers.

Micron MicroUlva (overall rating: ♦♦♦♦)

This is a battery operated spinning disc sprayer which was rated as good overall. Notable good and bad points are as below:

- ✙ drop size is good and the spectrum as measured at the workshop was the narrowest on test.
- ✙ safety was rated marginally higher than the other two portable spinning disc sprayers due to the narrow spectrum with few very small driftable drops and the presence of a gauze filter at the nozzle which would reduce the need to clean it. (However, see below for a negative safety feature.)

- ▫ it is necessary to take off the bottle to change restrictor nozzle to alter flow rate, which increases the chances of operator exposure to pesticide.
- ▫ unlike the other two portable spinning disc sprayers, electric current is carried to the motor by wiring inside the sprayer handle. This may be less reliable than using metal handle components to carry the current.

12. Discussion and conclusions

Large quantities of pesticide are applied by ground based means during locust campaigns and the quality of the spraying is critically dependent on the sprayer used. Almost any sprayer can kill locusts but this is not the only criterion for consideration. A sprayer should be capable of distributing the correct pesticide dose safely, rapidly and reasonably uniformly over the target area. Further considerations are how easy it is to achieve this aim - for example if calibration is difficult, it will be carried out less often, if at all. Reliability is also important since control operations are usually carried out in a rush, far from workshop facilities and spares supplies. Capital and running costs may be

important considerations although the cost of pesticide sprayed will always be the major expense for any large ground control operation.

This workshop brought together the major manufacturers and their locust sprayers and experts from FAO, locust affected countries and locust-related institutions. This unique gathering offered the opportunity to critically evaluate the strengths and weaknesses of current machinery. Time constraints prevented very detailed analysis or long term assessment but the essentials were examined in a standardised way and important factors on each sprayer compared.

All sprayers tested had good points and bad points and it is clear that there is no perfect locust sprayer. To a certain extent, the most suitable type of sprayer will depend on the size and type of target - portable sprayers for small/medium bands and vehicle-mounted sprayers for medium/large bands and in some instances small swarms. Also different countries have different technical requirements and priorities. As a result, it should be emphasised that this report does not recommend purchase of one type of sprayer, nor advise against purchase of another. However, the summary evaluation table (Annex 11) represents an independent assessment of the relative suitability for locust control of the sprayers tested and as such should be a useful guide to national locust organisations, donors and manufacturers.

After a day of field testing, nine important sprayer parameters were judged in turn by 12 independent experts from locust affected countries and institutions working in the field of locust control. The average of these individual ratings is shown for each sprayer in Annex 11 and where ratings are better or worse than average, the major factors influencing the ratings are detailed for each sprayer in the evaluation summary. The overall rating is calculated from the mean of the individual parameter ratings and represents a measure of the overall suitability of the sprayer for locust spraying. Any sprayer with an overall rating of 3 or more stars should be considered more suitable for locust control. Any sprayer with 2 or less stars should be considered less suitable, with some important features requiring significant improvement.

The parameters are weighted evenly in the overall rating for simplicity, but some may be considered more important than others. For example, the droplet spectrum is of fundamental importance to the efficacy and efficiency of pesticide use and it could be argued that a poor spectrum should rule a sprayer out. Similarly, if some sprayer components are not compatible with ULV pesticide formulations, the machine is likely to break down rapidly which is unacceptable. If these bad points are offset by other good points the sprayer may still have achieved an average rating so it is important to examine the individual parameter ratings in addition to the overall rating. Attention has been drawn to any serious negative points so that manufacturers can address the problem if they wish.

The individual parameter ratings are also of value since they may have particular relevance in particular situations. For example, in a country with good workshop support facilities, the work rate of a sprayer may be considered a higher priority than durability, and a motorised sprayer may be chosen instead of an electrically driven passive drift sprayer.

Performance requirements for locust sprayers have become much more rigorous in recent years with the discontinuation of dieldrin barrier spraying and the greater emphasis on pesticide efficiency and safety. It is clear from this evaluation that older style sprayers and those designed predominantly for other types of pesticide application fall short in comparison to more recent dedicated locust sprayers. However, most of the more modern locust sprayers are yet to prove themselves reliable and effective through the rigours of operational control.

13. Recommendations

1. This report be circulated to all interested parties.

The workshop provided the opportunity for rapid technical assessment of the current range of locust spray machinery. Evaluation procedures and criteria were discussed and agreed with experts and manufacturers on the first day of the workshop. Manufacturers were on hand to explain and assist with testing and collection of information and data. In this way, all interested parties participated in the design and execution of the evaluation which should lend credibility to the findings. The information should be of use to FAO, donors, national locust organisations and manufacturers.

2. Further information be gathered on the practicality, reliability and biological efficacy of locust spraying equipment when opportunities arise.

There is a need for longer term testing of locust spraying equipment - this evaluation was necessarily brief. This would involve both laboratory trials - for example soaking vulnerable components in different pesticide formulations - and field trials - for example carrying out field control trials using the sprayers or close monitoring of their performance during operational control.

3. A similar workshop be held within the space of 3 to 5 years to evaluate additional, new or improved machinery for locust control.

It is hoped that feedback to manufacturers will be useful and that it will help them address areas identified as needing improvement. It is also possible that other manufacturers will propose existing or new sprayers as potential locust sprayers. In the light of this continuing development of the technology, and with a view to providing up to date information to donors and users, a follow-up workshop would be useful.

Acknowledgments

The organizers of the workshop wish to express their sincere appreciation to the Government of Egypt and its Ministry of Agriculture for providing vehicles, equipment and labour as required for the Workshop.

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Annex 2. Workshop programme

21 August

FAO Near East Regional Office meeting room

8:00	- 8:30	registration
8:30	- 9:00	meeting of evaluation panel
9:00	- 9:15	opening
9:15	- 12:30	presentation of equipment by manufacturers
12:30	- 14:00	lunch
14:00	- 18:00	mounting of equipment

22 August

field site 25 km west of Cairo

7:00	- 7:30	transport to field site
7:30	- 20:00	field evaluation performance
20:00	- 20:30	transport from field site

23 August

FAO Near East Regional Office

8:00	- 15:00	assessment of field evaluation data by panel
15:00	- 16:30	presentation of pesticide efficiency results and discussion with manufacturers
16:30	- 21:00	assessment of field evaluation data by panel (cont.)

Annex 3. Sprayers presented and tested during the workshop

Berthoud, France

C5 ULV handheld sprayer
PUMA vehicle mounted sprayer

Jacto, Brazil

PL50 motorized backpack sprayer

MAT Airbi, France

Drift Air vehicle mounted sprayer

Micron Sprayers Ltd., UK

MicroUlva handheld sprayer
Ulva+ handheld/backpack sprayer
Ulvamast MKII vehicle mounted sprayer

Micronair, UK

AU8110 vehicle mounted sprayer
AU8000 backpack sprayer
AU7010 vehicle mounted sprayer

TIFA (C.I.), USA

100E vehicle mounted sprayer

Sprayer Name	Quantity					Type				Kind					Performance			Ease of Use			Durability			Safety			Maintenance			Lifespan (years)			
	DLCO	EGY	OMN	SAU	YEM	HH	BP	VM	AC	A	D	F	N	ULV	P	A	E	S	A	D	R	A	W	S	A	N	S	A	D	DLCO	OMN	SAU	YEM
Airbi Drift Air					8			x						x		1	1	1	1		1		1	1	1		1	1					4
Arnitsu		1					x					x					1	1				1			1			1					
Berthoud PUMA		40						x		x		x		x		1				1		1			1					1			
Cifarelli Nuvola		65					x				x	x					1	1				1			1			1					
Clavio K90		1400					x				x	x				1			1				1		1					1			
ENS	28	1	2	200	15			x						x		2	2	3	1		4			1	2	1	2	2		4+		4	5+
Kubota		170					x				x	x					1	1				1			1			1					
Micron micro ULVA		1				x								x		1			1				1		1		1						
Micron ULVAMAST			5		8			x						x			1	1	1			1		1			1						
Micron ULVAMAST X10				30				x						x			1	1				1		1				1			3		
Micronair AU4000	32								x					x			1		1		1			1				1		2-4			
Micronair AU7010		1	20	20				x						x		1	1	1	1			1	1	1	1				1			1	
Micronair AU8000			10				x							x		1						1			1			1					
Micronair AU8110		2	5		11			x						x			1	1			1			1			1						
Semco Mini-Citizen		15						x		x		x		x		1				1		1			1				1				
Solo Port 423		100					x					x						1				1			1			1					
Tifa 100E			1					x				x					1	1			1			1				1					
high pressure			50					x						x			1		1		1				1		1						

DLCO = DLCO-EA
EGY = Egypt
OMN = Oman
SAU = Saudi Arabia
YEM = Yemen

HH = hand held
BP = backpack
VM = vehicle mount
AC = aircraft

A = airblast
D = duster
F = fogger
N = nozzle
ULV = Ultra low volume

P = poor
A = average
E = excellent

S = simple
A = average
D = difficult

R = robust
A = average
W = weak

S = very safe
A = average
N = not safe

S = simple
A = average
D = difficult

Questionnaire prepared by ECLO and sent by fax on 12.7.1994
No responses received from:

Eritrea
Ethiopia
India
Iran
Pakistan
Somalia
Sudan

Sprayer Name	Performance	Ease of Use	Durability	Safety	Maintenance
Airbi Drift Air	only works with ULV	easy to control		operator sprayed during ops	must replace seals often
Berthoud PUMA	difficult to calibrate; cannot use EC formulation		mounting brackets break on rough road		must replace seals often
ENS	cannot calibrate; calibration not required; cannot use EC formulation	cannot control easily	mounting brackets break on rough road; very durable	operator sprayed during ops not safe	must replace seals often; easy to maintain
Micron ULVAMAST	not used in YEM yet				
Micron ULVAMAST X10	easily calibrated; cannot use EC formulation	easy to use	mounting brackets break on rough road	safe to use	requires too much maintenance
Micronair AU7010	calibration easy-difficult cannot use EC formulation	easy to use	mounting brackets break on rough road	safe to use	must replace seals often; requires too much maintenance
Micronair AU8110	not used in YEM and EGY yet				
Semco Mini-Citizen	difficult to calibrate; cannot use EC formulation				must replace seals often

Annex 5. Brief review of sprayer questionnaire results

Questionnaire response

The questionnaire was distributed to the Plant Protection Departments of English-speaking locust affected countries. Of these, 42% responded to the questionnaire:

- received: DLCO-EA, Egypt, Oman, Saudi Arabia and Yemen
- not received: Eritrea, Ethiopia, India, Iran, Pakistan, Somalia, Sudan

Sprayer quantities

Egypt reported the greatest number of different sprayers for locust control followed by Oman, Yemen, Saudi Arabia and DLCO-EA. All responders have ENS, three countries have Micronair AU7000 and AU8110 and two countries have Micron Ulvamast.

Sprayer types

The most common type of sprayer used for locust control was vehicle mounted sprayers, followed by backpack and hand-held and aircraft; DLCO-EA was the only response that had aerial sprayers.

Sprayer kinds

Most sprayers were ULV, followed by foggers, multi-purpose, dusters and atomisers.

Sprayer performance

Most sprayers were reported as excellent followed by average; no sprayers were reported to perform poorly.

Sprayer ease of use

Most sprayers were reported as easy to use, followed by average; ENS was found to be very easy to use; two sprayers (Berthoud Puma and Semco Mini-Citizen) were difficult to use.

Sprayer durability

Most sprayers were reported to be durable, followed by robust; the ENS was reported to be robust by all responses; two sprayers (Clavio K90 and Micron MicroUlva) were reported to be weak, two other sprayers (Airbi Drift Air and Micronair AU7000) varied from robust and average to weak.

Sprayer safety

Most sprayers were reported to be of average safety, followed by very safe. One sprayer (ENS) varied from safe to not safe, this was the only sprayer reported as being not safe.

Sprayer maintenance

Maintenance was reported to be average for most sprayers, followed by simple. Four sprayers (Berthoud Puma, Clavio K90, Micronair AU7000, Semco Mini-Citizen) were reported to be difficult to maintain; three of these are multi-purpose sprayers suggesting that such sprayer are more difficult to service.

Sprayer lifespan

Only a few responses were received. The lifespan for ENS was 4-5+ years, Airbi Drift Air 4 years, Micron Ulvamast 3 years, Micronair AU4000 2-4 years and Micronair AU7000 one year; no information was received for other sprayers.

Comments

- There were several remarks that sprayers could not use EC formulated pesticides and most required replacement of seals too often.
- Some sprayers were difficult to calibrate (Berthoud Puma, Micronair AU7000, Semco Mini-Citizen).
- Mounting brackets break on rough roads (Berthoud Puma, ENS, Micron Ulvamast, Micronair AU7000).
- Operators are sprayed during operations (Airbi Drift Air, ENS).
- Newer sprayers (Micron Ulvamast and Micronair AU8110) had not been extensively used in some countries.

Annex 6. Sprayer evaluation schedule

1. Make sure sprayer tank, pipes, filter bowl etc are empty
2. Put in a small measured volume of pesticide
3. Drain the sprayer with it standing on level ground and measure the volume recovered
4. Calculate the volume retained in the sprayer

5. Groups 2 and 3 begin the evaluation in the following order:

Monday	Group 2	Group 3	Tuesday	Group 2	Group 3
09.00	Drift Air	AU7010	08.00	C5	Ulva Plus
10.00	AU7010	Ulvamast	09.00	Micro-Ulva	C5
11.00	Ulvamast	Airbi	10.00	PL50	Micro-Ulva
14.00	AU8110	Puma	11.00	AU8000	PL50
15.00	Tifa 100 E	AU8110	12.00	Ulva+	AU8000
16.00	Puma	Tifa 100 E			

6. Group 1 will try to complete drop size and swath width sampling for all the sprayers on Monday morning in the order below. This will mean interrupting groups 2 and 3 during their assessment of the vehicle mounted drift sprayers. If conditions become unsuitable the portable sprayers will be assessed on Tuesday morning.

Monday	Group 1
09.00	Ulvamast
09.20	Drift Air
09.40	AU7010
10.00	AU8110
10.20	Puma
10.40	Tifa 100 E
11.00	PL50
11.20	Micro-Ulva
11.40	C5
12.00	Ulva+
12.20	AU8000

7. Set the flow rate to apply 1 l/ha at 7 km/hr assuming a track spacing which will give a reasonably uniform deposit (use the formula below), then begin testing.

$$\text{Flow rate (ml/min)} = \frac{\text{Volume Application Rate (ml/ha) x speed (m/min) x track spacing (m)}}{10{,}000}$$

Annex 7a. Sprayer evaluation sheets for vehicle mounted sprayers

	VEHICLE MOUNTED SPRAYERS					
	Berthoud Puma	**MAT Airbi Drift Air**	**Micron MKII UlvaMast**	**Micronair AU8110**	**Micronair AU7010**	**Tifa 100e**
Basic specifications						
pesticide tank capacity (litres)	85	200	70	65	65	no tank
sprayer unit weight empty (kg)	80	35	55	132	48	260
dimensions (length x width x height)	0.92 x 0.76 x 1.08 m	1.10 x 0.60 x 0.90	1.05 x 0.52 x 1.25 m	1.15 x 0.77 x 0.60 m	1.25 x 0.75 x 0.64	0.81 x 0.63 x 0.96 m
minimum pickup bed length	1.00 m	1.10 m	1.05 m	1.15 m	1.25 m	ca 1.82 m
method of atomisation	air shear nozzle	rotary cage	spinning disc (10)	rotary cage airblast	rotary cage	pneumatic
source of energy for atomisation	self-contained petrol motor	car battery	car battery	motorized fan	car battery	turbine blower
engine/motor power/consumption	32 hp	4-5 amps (12V DC)	4-8 amps (12V DC)	11 hp	12V / 250 w	11 hp (12V battery)
type of pump	centrifugal	centrifugal	magnetic coupled centrifugal	centrifugal	diaphragmal	sucking centrifugal
Flow rate						
range of flow rates (manufacturer)	0.22 - 3.2 l/min	0.15 - 12.0 l/min	0.1 - 2.0 l/min	0.02 - 2.0 l/min	0 - 2.0 l/min	0.08 - 2.5 l/min
method of measuring (manufacturer)	bucket collection from hose	manometer	bucket under head	bucket under hose connected to calibration tube	bucket under head	bucket collection from pipes
method of adjustment	nozzles and vru	orifice plates + pressure	needle valve or orifice plates	vru + pressure	graduated needle valve	valve
variability (measured 3 times at manufacturer's chosen flow rate; ml/min)	150, 130, 130	350, 350, 390 (orifice 4916-32; 2 bar)	340, 340, 340 (needle) 640, 640, 640 (orifice 49)	430, 435, 410	95, 100, 100	250, 270, 250 (valve selection 1)
flow rate fluctuation during spraying	no	no	no	no	no	no
Emission height						
adjustable or fixed spray head	fixed	adjustable on mast - 5 steps	fixed	adjustable head angle (-45° to 90°)	fixed	fixed
height of spray head (above vehicle floor)	1.08 - 1.50 m	1.70 - 1.97 m	1.85 m	1.40 m	1.70 m	0.5 m
transport position	no	yes	yes	yes	yes	no
Operator safety						
sprayer control location	on the back of vehicle	inside cab (remote)	inside cab (remote)	inside cab (remote)	inside cab (remote)	inside cab (remote)
diameter of filler opening	21 cm	15 cm	20 cm	15 cm	15 cm	NA
pressurized tank	no	no	no	no	no	NA
method of emptying tank	drainage	drain pipes	drain valve + flushing	drain valve	drain valve + flushing	decanting and sucking pump with motor running
residual volume in sprayer	480 ml	410 ml	300 ml	200 ml	200 ml	NA
location of residual volume	pipes, filters	pipes	pipes	pipes	pipes	NA
method of filter maintenance	remove & flush in diesel	external cleaning	external cleaning	unscrew and clean	unscrew valve	removeable and clean in diesal
flow rate adjustment method	nozzles and vru	orifice plates + pressure	needle valve or orifice plates	vru + pressure	graduated needle valve	valve
guards for moving parts	fan & tank protection	metal sheet guard for head	branch deflector	yes	head	NA
method of cleaning pesticide line/filters/atomisers	flushing	drain pipes	flushing	drain	flushing	cleaning valve & flush with diesal

NA = not applicable

Annex 7a. Sprayer evaluation sheets for vehicle mounted sprayers (cont.)

	VEHICLE MOUNTED SPRAYERS					
	Berthoud Puma	**MAT Airbi Drift Air**	**Micron MKII UlvaMast**	**Micronair AU8110**	**Micronair AU7010**	**Tifa 100e**
Airblast						
volume	3000 m3/hr	NA	NA	2400 m3/hr	NA	250m3/hr
velocity	40 m/s	NA	NA	100 m/s	NA	56 m/s
directable	yes - all	NA	NA	yes - 45°	NA	yes - all
est. vertical range at 10 kph (wind speed)	15-20 m above head	NA	NA	50-100 m	NA	(test declined)
manufacturer estimate	10 m above head in no wind	NA	NA	1.5 m above head; 3m;	NA	50 m
Durability						
tank material	compatible	compatible	compatible	compatible	compatible	NA
piping	some incompatibilty	compatible	compatible	compatible	some incompatibilty	some incompatibilty
pump seal	some incompatibilty	some incompatibilty	compatible	some incompatibilty	some incompatibilty	incompatible
drive belt	incompatible	NA	some incompatibilty	incompatible	compatible	incompatible
filler filter	compatible	compatible	compatible	compatible	compatible	compatible
in line filter and type	compatible	compatible	compatible	compatible	compatible	compatible
method of fixing to vehicle and stability	not fixed	4 bolts	4 bolts	4 bolts	screw on plate form	not fixed
sprayer design	moderate	simple	simple	moderate	simple	complex
vulnerable/fragile parts	spray head	pressure reg filter	spray head	spray head	spray head	none
life span estimate (years)	5-10	5	2 - 5	10	5	20
Maintenance						
quality of operator/maintenance manual	fair	good	fair	good	complex	fair
languages	English, French	English, French, Arabic	English, French, Arabic	English, Arabic	English	English, French, Arabic +9
adequacy of tool kit / spares supplied	none	fair	good / some spares	good	fair	good
daily tasks	check pump, filters, nozzle	flushing & cleaning	flushing & cleaning	check oil, atomiser; cleaning	flushing & cleaning	cleaning; motor
weekly tasks	check pump, filters, nozzle	grease spray head	filter cleaning	atomiser, belts, filters	check drift & spray head	pump cleaning
ease of maintenance	routine	easy	easy	routine	easy	easy
special tools required for routine tasks	none	none	none	none	L key	none
Ease of Use						
filling	easy	easy	easy	easy	easy	easy
flow rate calibration	simple	simple	simple	simple	simple	simple
switching on and off	poor	easy	easy	easy	easy	easy
emptying/cleaning	difficult	easy	easy	easy	easy	easy
Cost						
factors to consider in running costs	petrol	motor brushes	drive belt of spray head	petrol	drive belt of spray head	fuel, oil

NA = not applicable

Annex 7b. Sprayer evaluation sheets for portable sprayers

	BACKPACK SPRAYERS		HANDHELD SPRAYERS		
	Jacto PL50	**Micronair AU8000**	**Berthoud C5**	**Micron Ulva**	**Micron Ulva+**
Basic specifications					
pesticide tank capacity (litres)	13	12	1.5	1.25	1.25
sprayer unit weight empty (kg)	12.7	12	1.5	0.65	0.8
carrying method	backpack	backpack	handheld	handheld	handheld
method of atomisation	rotary	rotating cage airblast	rotary disc	spinning disc	spinning disc
source of energy for atomisation	2 stroke engine	motorized fan	up to 6 batteries	4-6 batteries	6-8 batteries
engine/motor power/consumption	1.6 hp	3.6 kw (5 hp)	7-8 w	1-3 w	1.5 - 3 w
type of pump	centrifugal	gravity or centrifugal	gravity	gravity	gravity
Flow rate					
range of flow rates (manufacturer)	0.017-0.135 l/min	0.02 - 1.2 l/min	0.020-0.125 l/min	0.015 - 0.100 l/min	0.015 - 0.150 ml/min
method of measuring (manufacturer)	bucket collection from hose with motor running	bucket collection from calibration tube with motor running	cup under head	cup under head	cup under head
method of adjustment	nozzle, vru, pressure	interchangeable restrictors (5)	variable nozzles	variable nozzles (5)	variable nozzles (7)
variability (measured 3 times at manufacturer's chosen flow rate; ml/min)	40, 40, 40	110, 110, 100	65, 65, 70	65, 64, 64 (red nozzle)	72, 73, 73 (red nozzle)
flow rate fluctuation during spraying	no	some without pump	no	no	no
Emission height					
adjustable - method	manual	manual	manual	manual	manual
height of spray head (above ground)	1-3 m	1 - 1.5 m	1-2 m	1-2 m	1-2 m
Operator safety					
sprayer control location	spray head & back of engine	blower unit and head	battery case; flip over	battery case; flip over	battery case; flip over
diameter of filler opening	14 cm	11 cm	4 cm (12 cm backpack)	35 mm	35 mm
proximity of pesticide to operator	close	close	far	far	far
absorbent carrying straps	slightly	slightly	NA	NA	NA
pressurized tank	yes	yes	no	no	no
method of emptying tank	drain or invert sprayer	gravity drain through head hose or invert sprayer	remove bottle lid and turn over	remove bottle lid and turn over	remove bottle lid and turn over
residual volume in sprayer	ca. 2 ml	few ml	not measured	not measured	not measured
location of residual volume	hoses	hose	NA	NA	NA
method of filter maintenance	remove from nozzle	removeable filters	NA	NA	NA
flow rate adjustment method	nozzle, rvu, pressure	interchangeable restrictors (5)	nozzle selection	nozzle selection	nozzle selection
guards for moving parts	engine & fan	yes	NA	NA	NA
guard for exhaust pipe	partial	yes	NA	NA	NA
method of cleaning pesticide line/filters/atomisers	flushing through head	flush with solvent while engine running	flush with diesel	flush with diesel	flush with diesel
Options			5 and 10 l backpack tank	5, 10, 15 l tanks	

NA = not applicable

Annex 7b. Sprayer evaluation sheets for portable sprayers (cont.)

	BACKPACK SPRAYERS		HANDHELD SPRAYERS		
	Jacto PL50	**Micronair AU8000**	**Berthoud C5**	**Micron Ulva**	**Micron Ulva+**
Airblast					
volume	12.6 m3/min	20 m3/min	NA	NA	NA
velocity	85 m/s	100-125 m/s	NA	NA	NA
directable	yes	yes	NA	NA	NA
est. vertical range at 1.5 m/s (wind speed)	3 m (8 m/s)	3-4 m (8 m/s)	NA	NA	NA
manufacturer estimate	not available	5-7 m	NA	NA	NA
Durability					
tank material	compatible	compatible	compatible	compatible	compatible
piping	some incompatibilty	some incompatibilty	NA	NA	NA
pump seal	compatible	some incompatibilty	NA	NA	NA
drive belt	some incompatibilty	NA	NA	NA	NA
filler filter	compatible	compatible	NA	NA	NA
in line filter and type	compatible	compatible	NA	metal mesh	metal mesh
sprayer design	simple	simple	simple	simple	simple
vulnerable/fragile parts	head	none	disc, case	disc, case	disc
life span estimate (years)	3	3	3-5	5	7
Maintenance					
quality of operator/maintenance manual	fair	good	fair	good	good
languages	English, French, Spanish	English, French	English, French, Spanish	English, French, Spanish	English, French, Spanish
adequacy of tool kit / spares supplied	good / spare filter	basic	none	none	none
daily tasks	cleaning	cleaning & flushing	clean tank	cleaning	cleaning
weekly tasks	engine outlet, spark plugs	spray head	clean tank	cleaning	cleaning
ease of maintenance	easy	easy	easy	easy	easy
special tools required for routine tasks	none	none	none	none	none
Ease of Use					
filling	easy	easy	easy	easy	easy
flow rate calibration	easy	not practical	easy	fairly easy	easy
switching on and off	easy	easy	easy	easy	easy
emptying/cleaning	simple	simple	simple	simple	simple
Cost					
factors to consider in running costs	petrol & oil	petrol	batteries	batteries	batteries

NA = not applicable

Annex 8. Summary of spraying details for drop size and swath width evaluations

	VEHICLE-MOUNTED					
	Berthoud	**MAT Airbi**	**Micron**	**Micronair**	**Micronair**	**Tifa**
	Puma	Drift Air	MKII Ulvamast	AU8110	AU7010	100 E
time	19.12	11.10	11.30	12.10	10.55	13.17
temperature (degrees C)	31.9	31.1	30.5	34.1	30.8	35.7
relative humidity (%)	41	44	49	32	44	27
windspeed (m/s)	4	5	4	5	5	5
forward speed	11.2 km/hr	9.9 km/hr	9.2 km/hr	10.7 km/hr	11.2 km/hr	9.9 km/hr
nozzle/restrictor	18/10 nozzle	not known	n/a	n/a	n/a	not known
regulator position	position 8	n/a	n/a	VRU 2	not known	not known
angle of blades/pulley setting	n/a	fixed	fast pulley	not known	not known	n/a
number of batteries if applicable	n/a	n/a	n/a	n/a	n/a	n/a
pump pressure	not known	not known	fixed	1.2 bar	not known	not known
emission height (assuming 1 m mounting height for vehicles)	2 m	2.7 m	2.85 m	2.4 m	2.7 m	1.5 m
flow rate	1.25 l/min	0.39 l/min	0.35 l/min	0.4 l/min	0.29 l/min	0.2 l/min
spray formulation	Dursban 45 % ULV	Dursban 45 % ULV	Dursban 45 % ULV	Dursban 45 % ULV	Dursban 45 % ULV	Dursban 45 % ULV

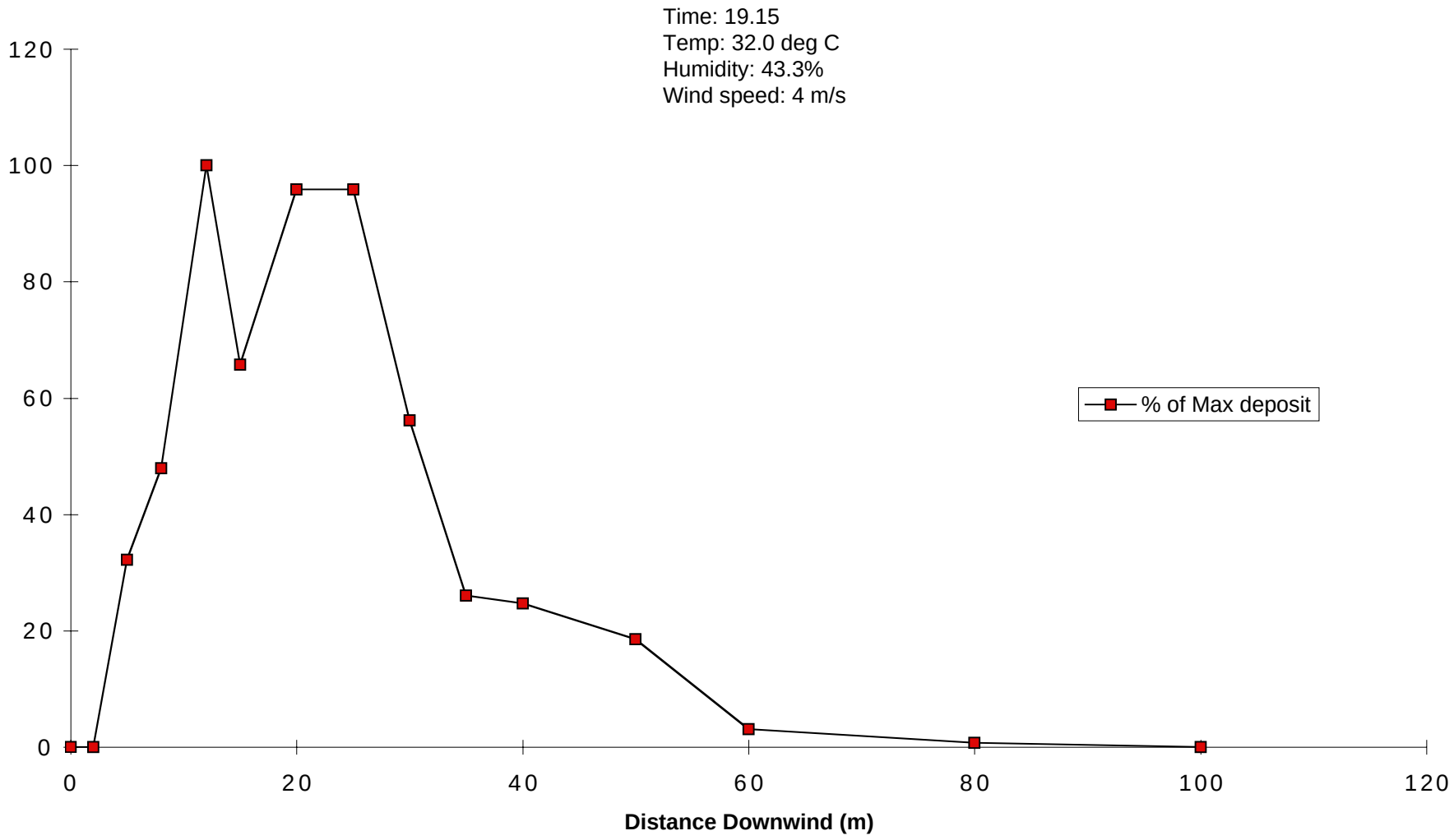
	PORTABLE				
	Jacto	**Micronair**	**Berthoud**	**Micron**	**Micron**
	PL 50	AU8000	C5	Ulva+	MicroUlva
time	13.40	18.35	12.55	12.35	14.20
temperature (degrees C)	est 35	34.2	34.7	34.3	est 36
relative humidity (%)	est 30	34	28	30	est 30
windspeed (m/s)	4	5	4	6	4
forward speed	est 5 km/hr	5.5 km/hr	5.7 km/hr	4.8 km/hr	est. 5 km/hr
nozzle/restrictor	not known	not known	1.5	red nozzle	red nozzle
regulator position	n/a	n/a	n/a	n/a	n/a
angle of blades/pulley setting	fixed	not known	n/a	n/a	n/a
number of batteries if applicable	n/a	n/a	5	6	5
pump pressure	fixed	fixed	n/a	n/a	n/a
emission height (assuming 1 m mounting height for vehicles)	1.5 m	1.5 m	1.5 m	1.5 m	1.5 m
flow rate	0.135	0.11 l/min	0.073 l/min	0.06 l/min	0.065 l/min
spray formulation	Dursban 45 % ULV	Dursban 45 % ULV	Dursban 45 % ULV	Dursban 45 % ULV	Dursban 45 % ULV

Annex 9. Summary of droplet sizing data

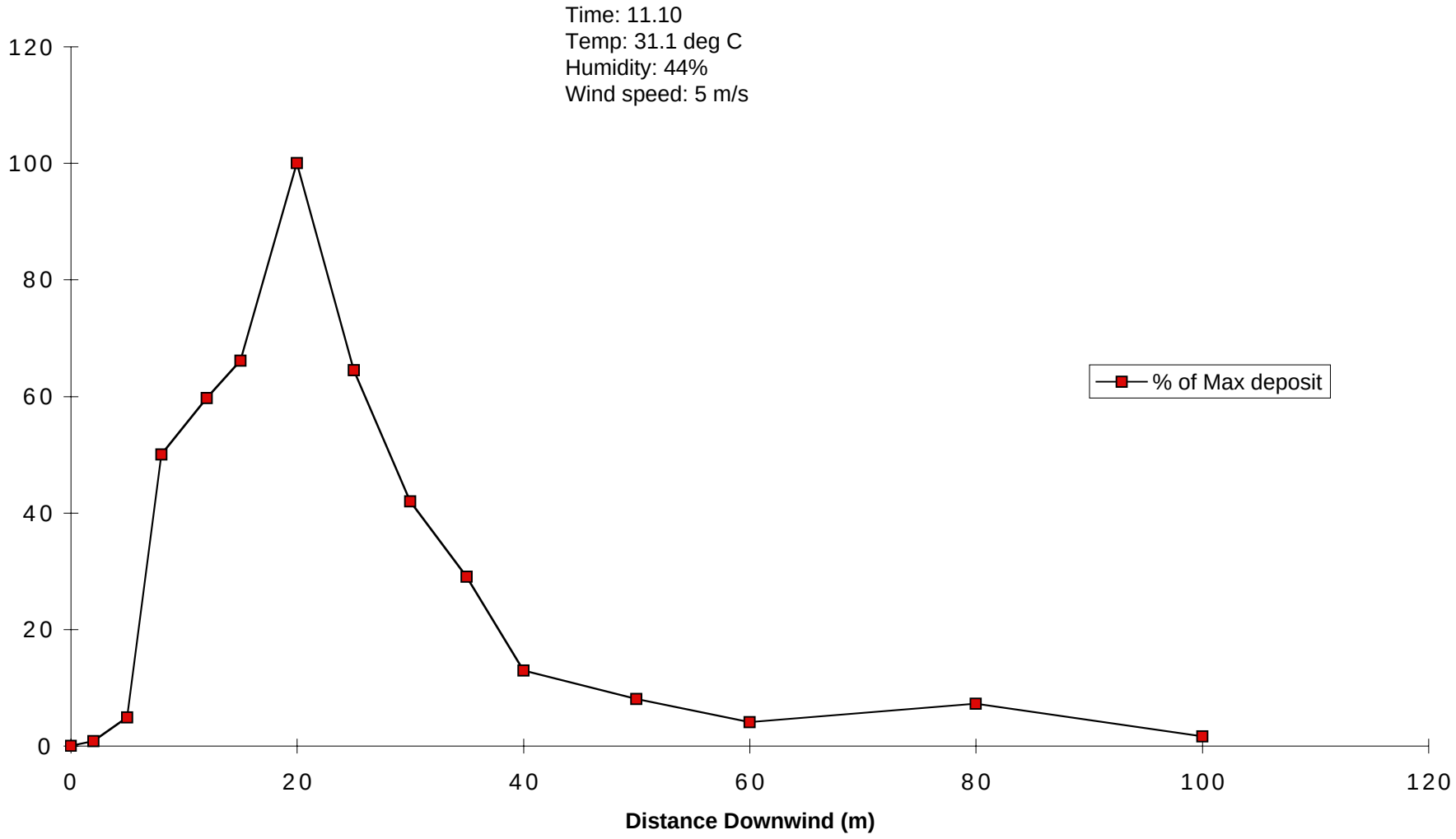
Only one slide per sprayer has been analysed - the slide with most drops

Sprayer types	Make and model	VMD	NMD	Ratio
Vehicle mounted (passive drift)				
	Airbi Drift Air	141	43	3.26
	Micron Ulvamast	61	35	1.75
	Micronair 7010	61	30	2.07
Vehicle mounted (air-assist)				
	Micronair AU8110	55	21	2.6
	Berthoud Puma	67	16	4.1
	Tifa 100 SE	44	17	2.64
Hand-held spinning disc				
	Berthoud C5	104	60	1.71
	Micron Ulva+	79	46	1.71
	Micron Micro-Ulva	62	55	1.13
Motorised knapsack with rotary atomisers				
	Jacto	47	22	2.18
	Micronair AU8000	50	20	2.45

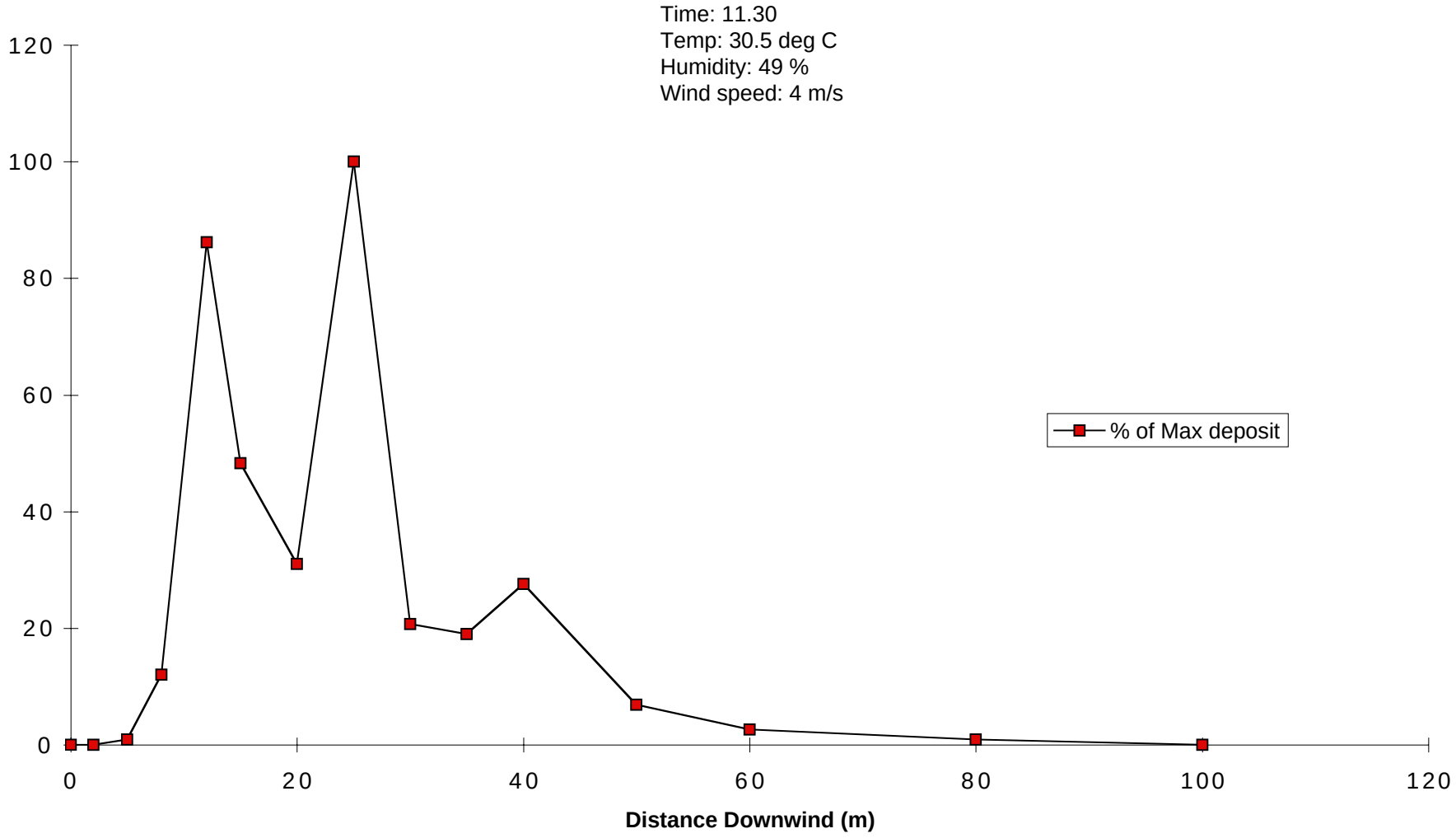
Annex 10a. Berthoud Puma



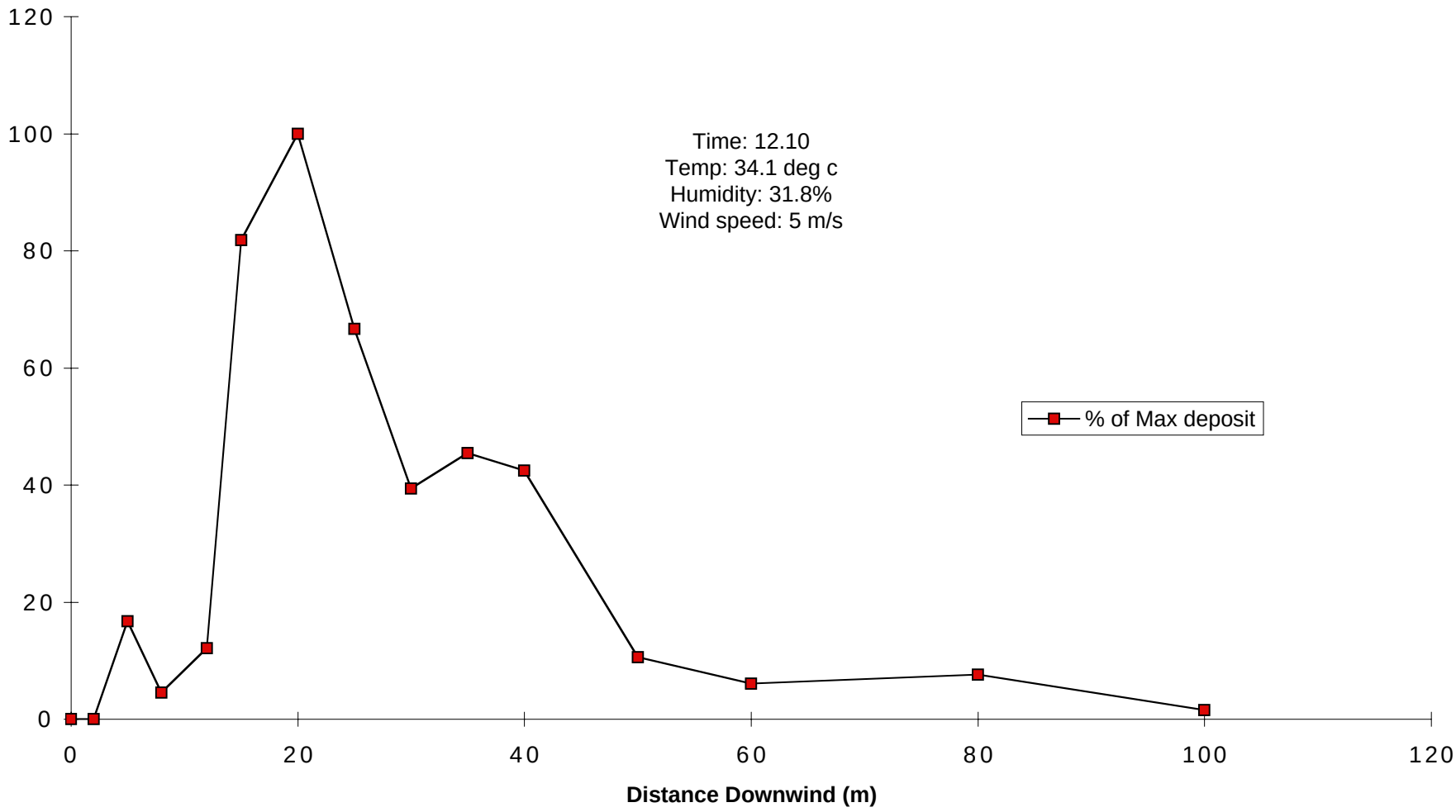
Annex 10b. MAT Airbi Drift Air



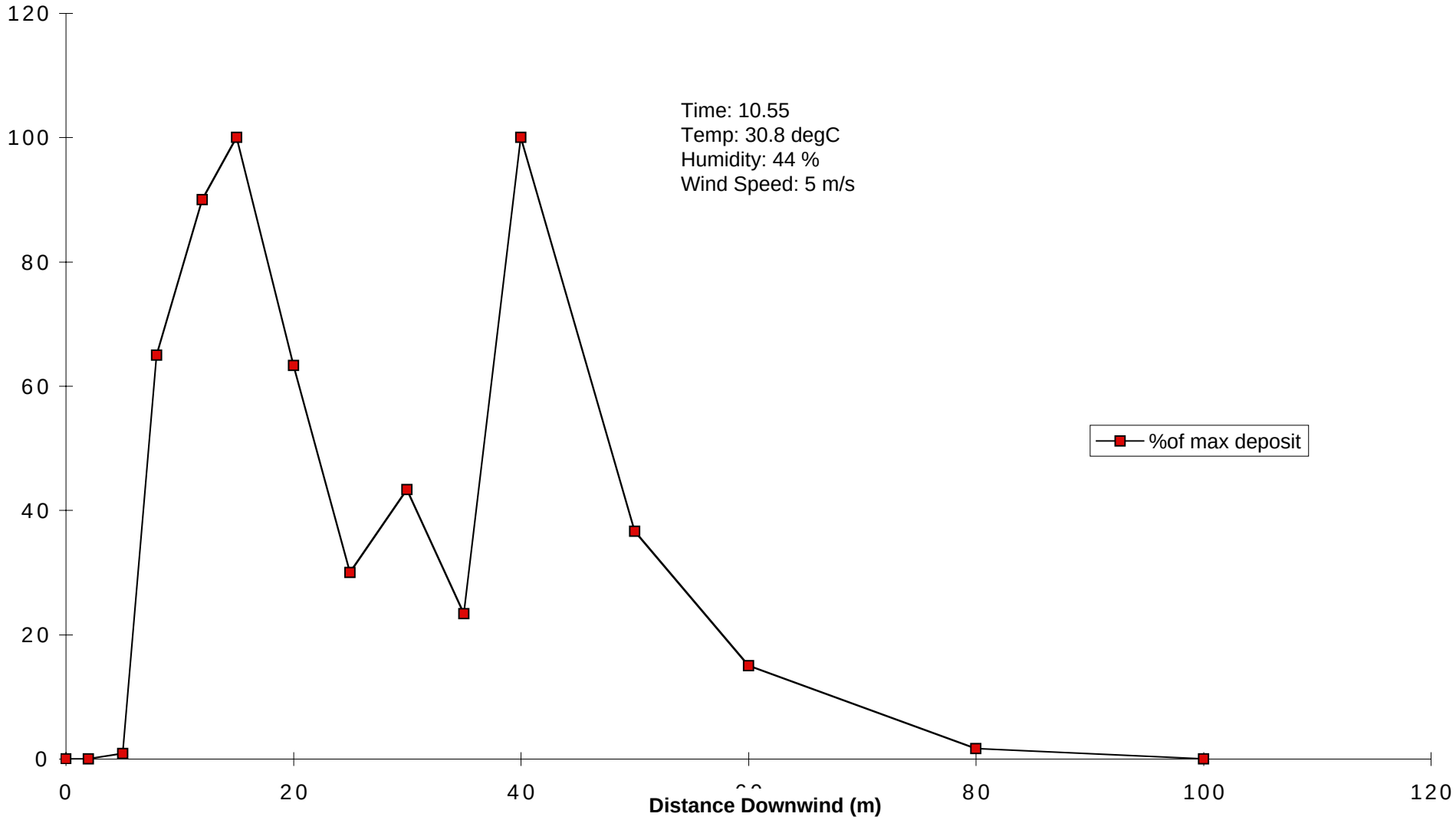
Annex 10c. Micron Ulvamast MKII



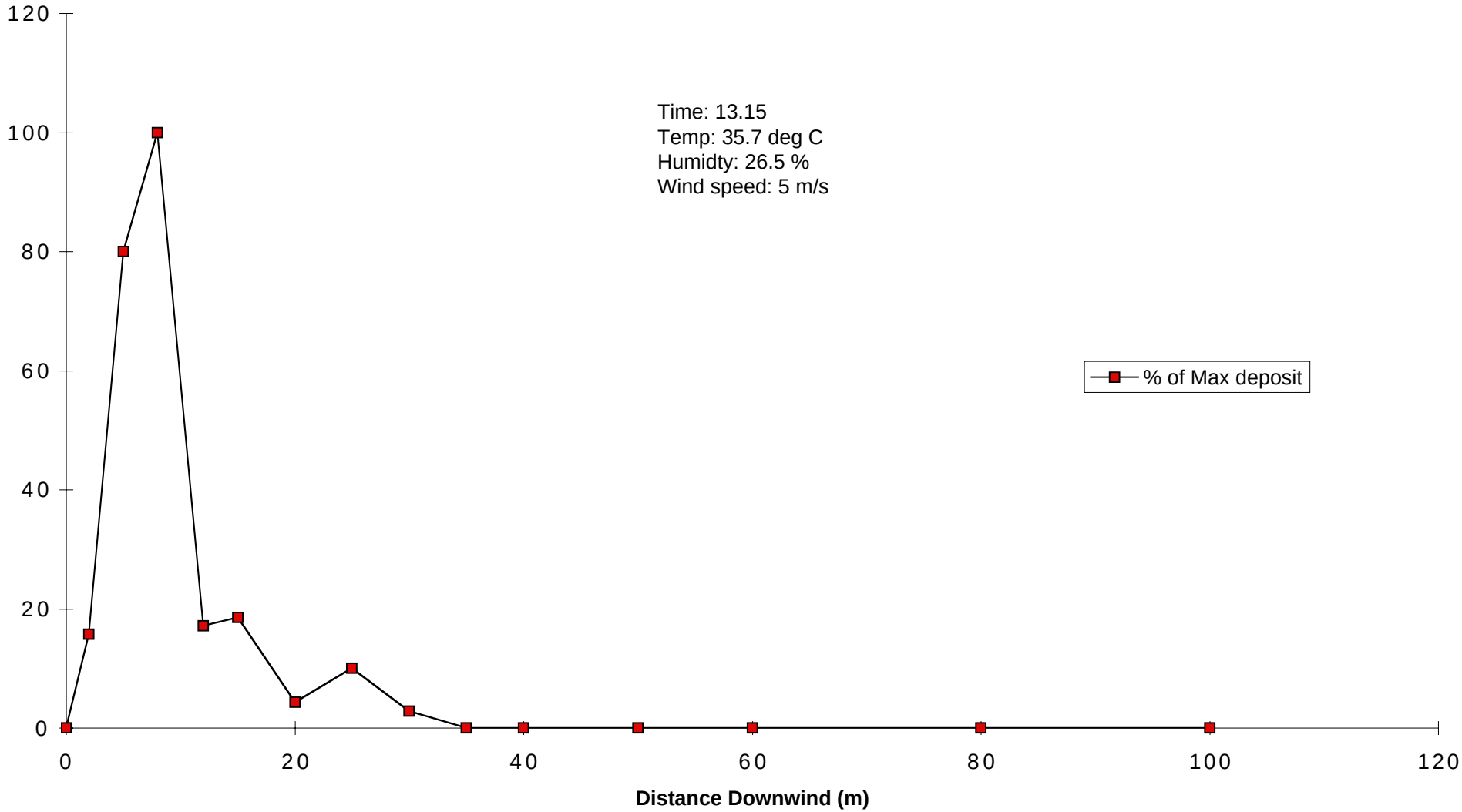
Annex 10d. Micronair AU8110



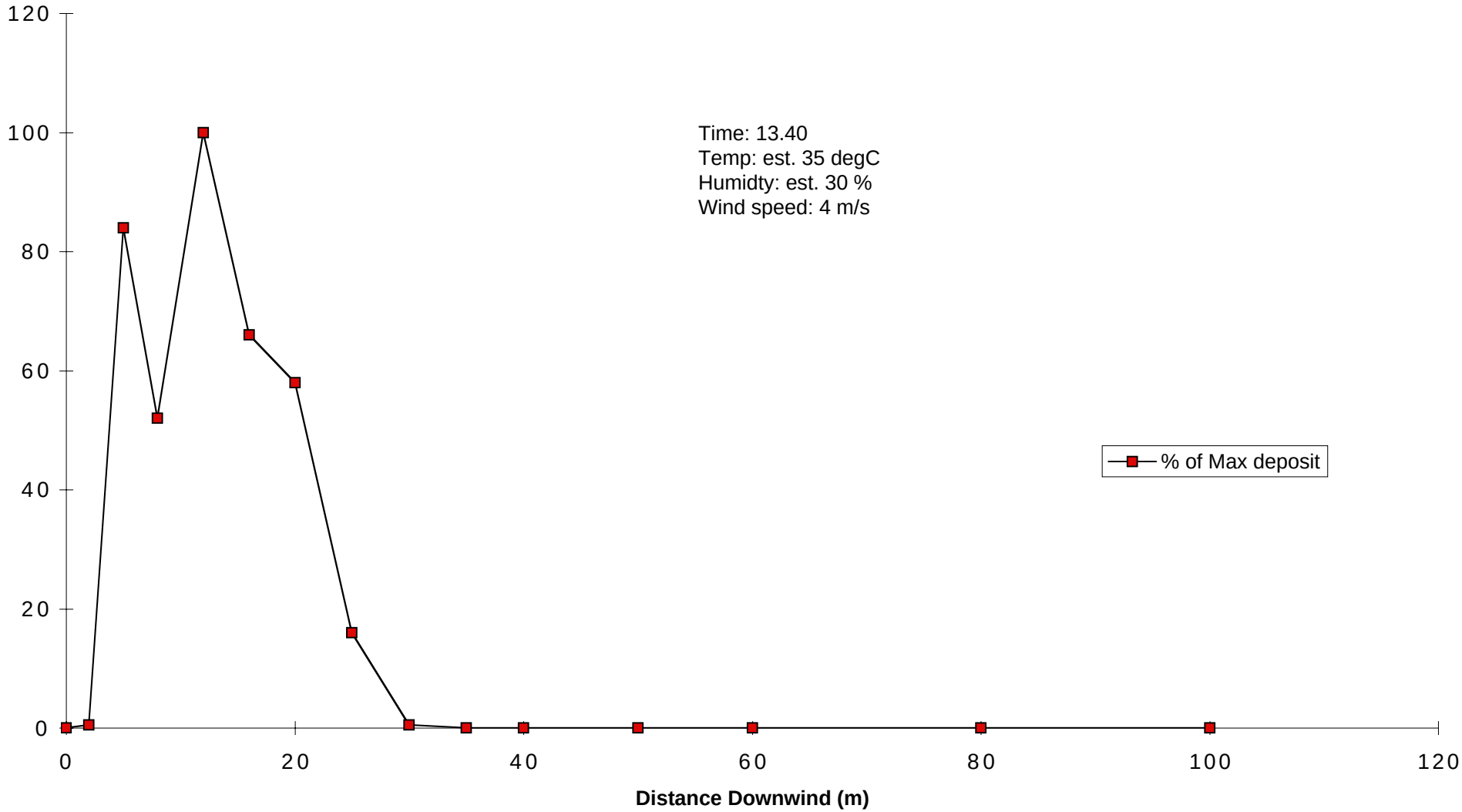
Annex 10e. Micronair AU7110



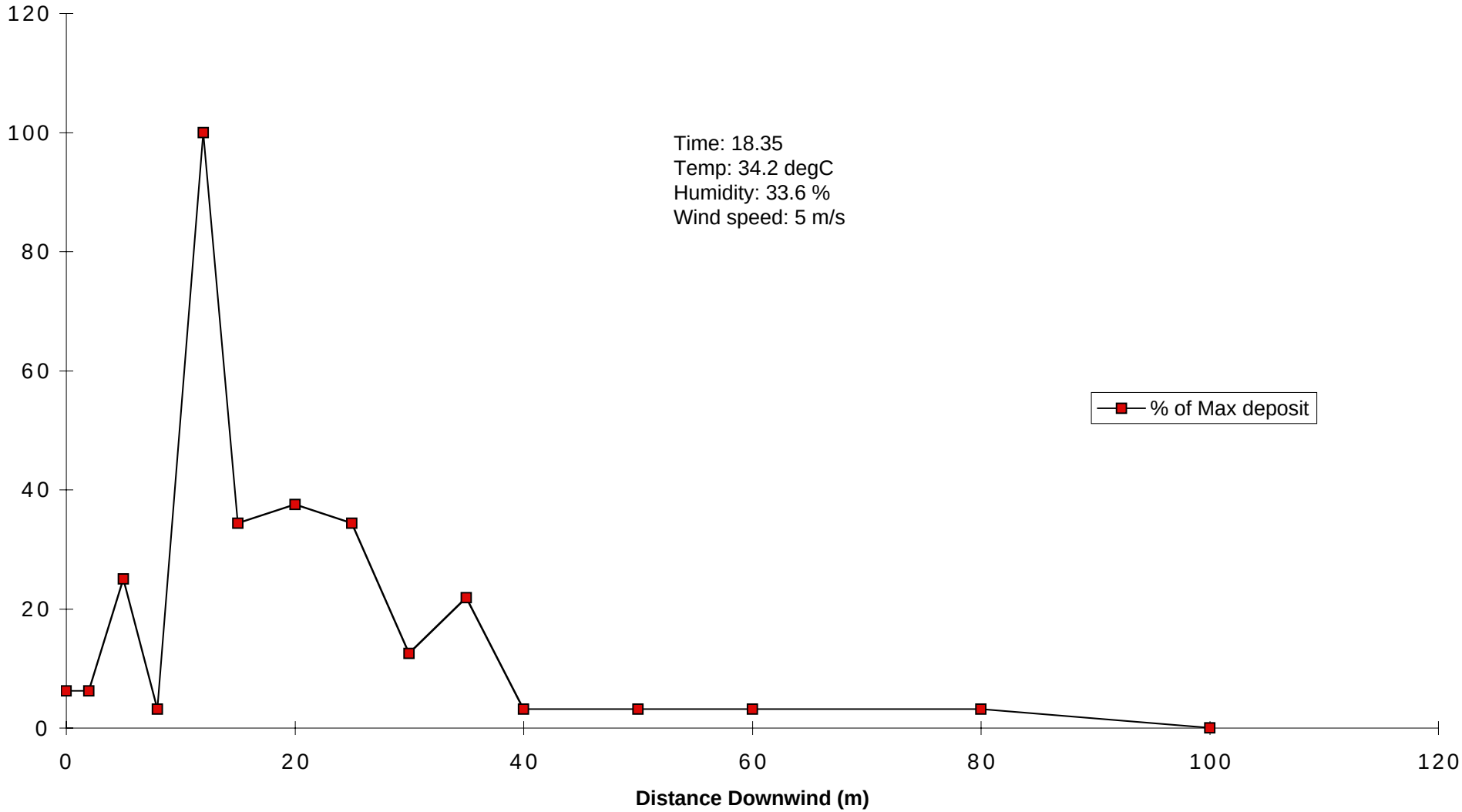
Annex 10f. TIFA 100E



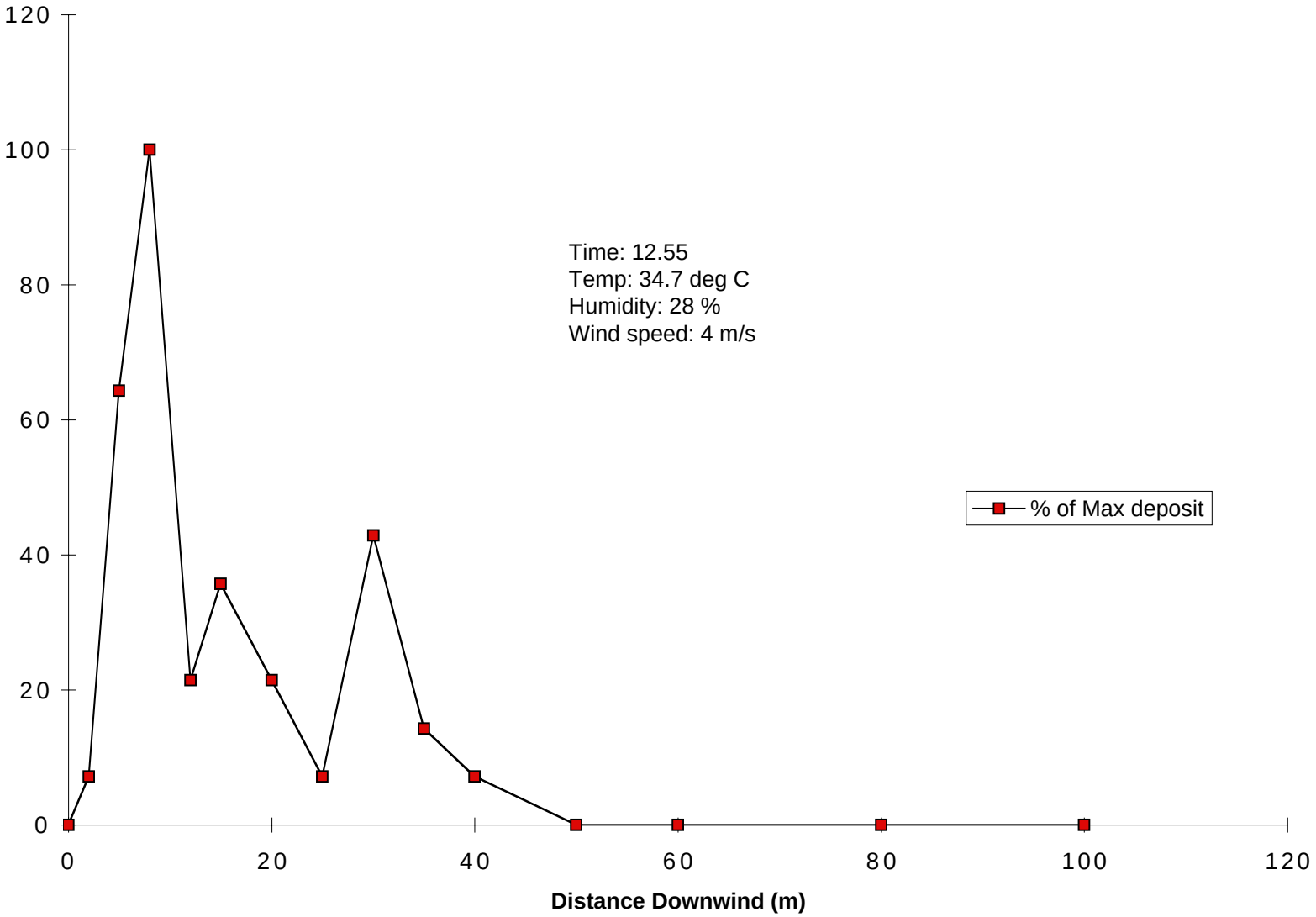
Annex 10g. Jacto PL50



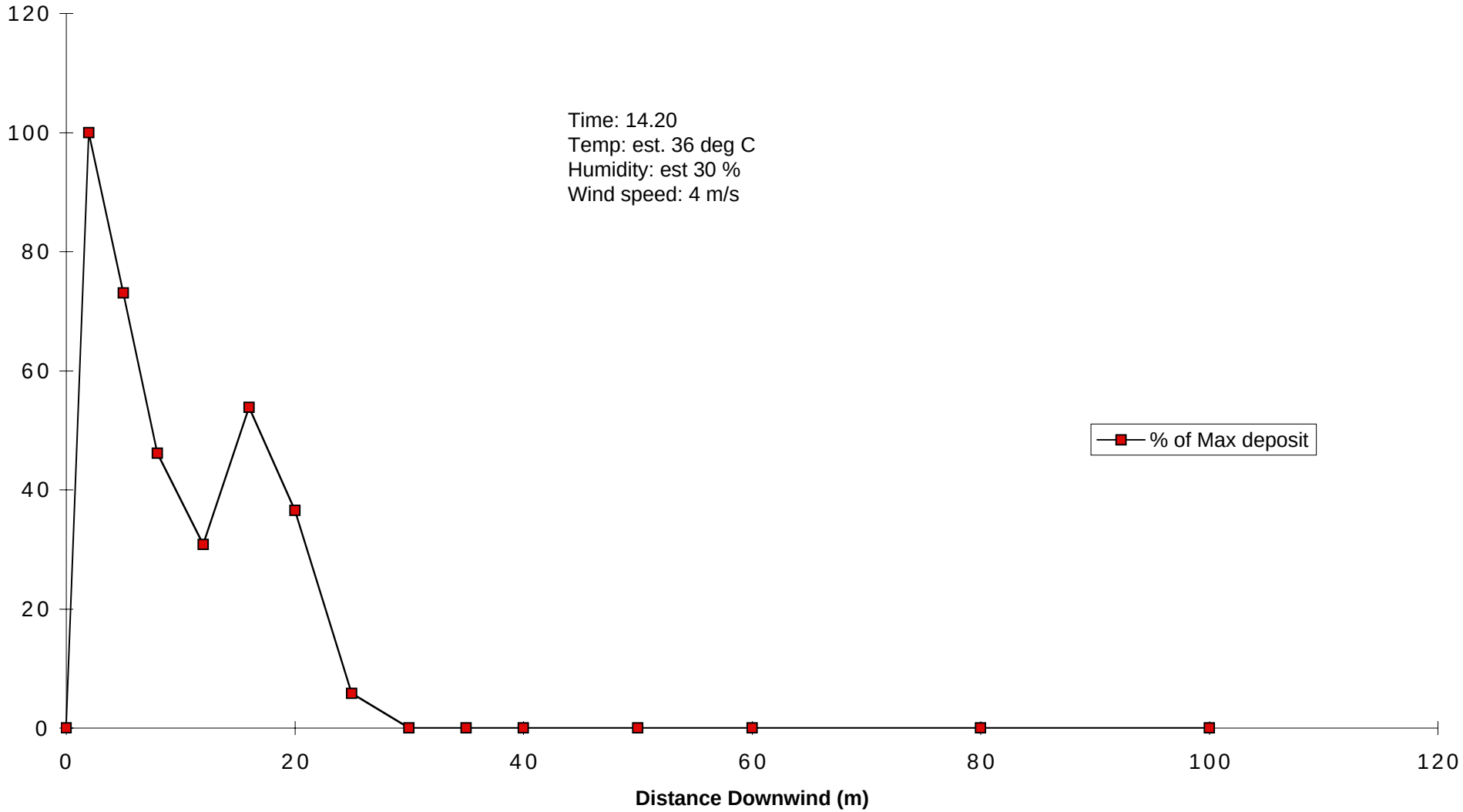
Annex 10h. Micronair AU8000



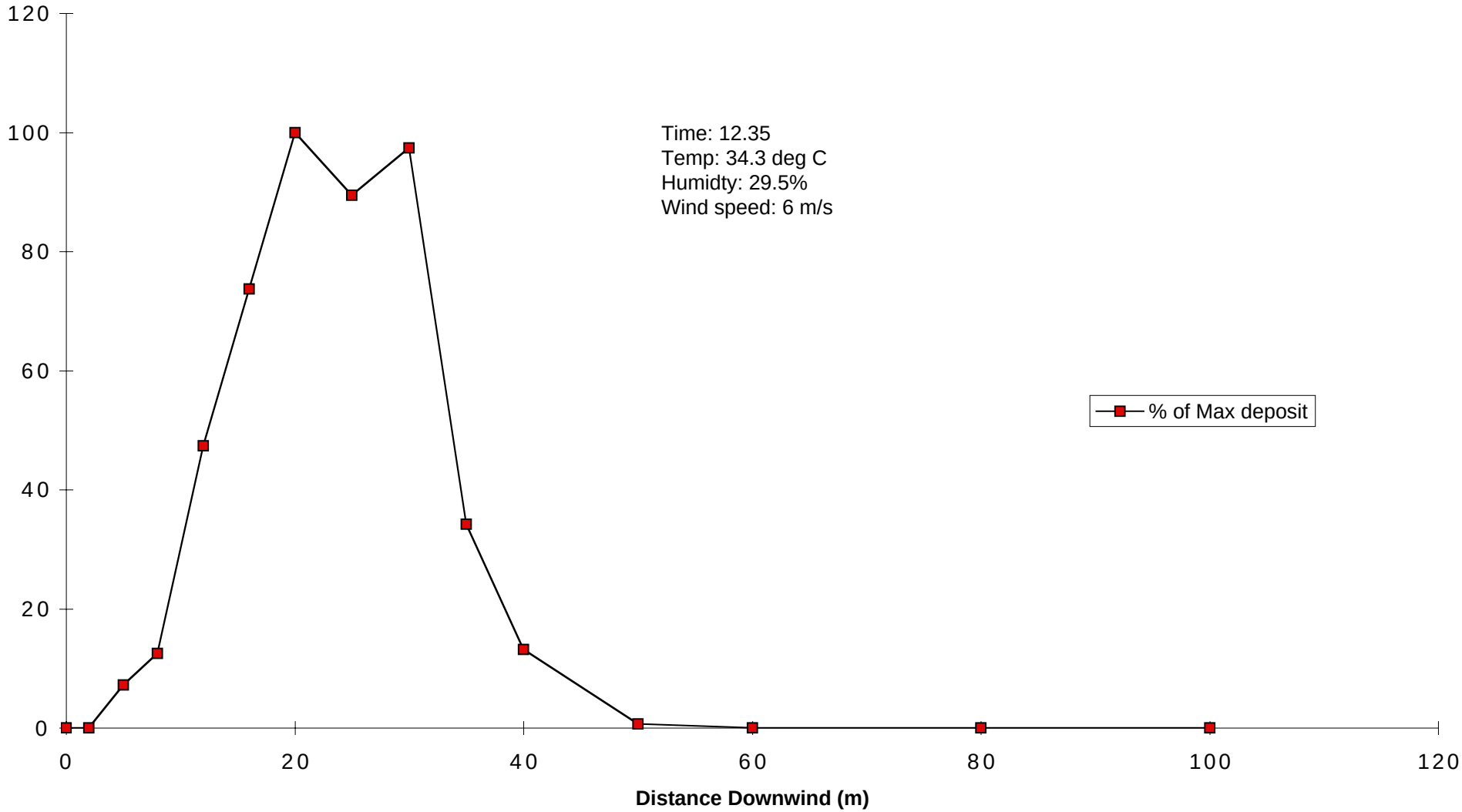
Annex 10i. Berthoud C5



Annex 10j. Micron Ulva



Annex 10k. Micron Ulva+



Annex 11. Summary of evaluation of sprayers

	VEHICLE MOUNTED							BACKPACK		HANDHELD		
	Francome	**Berthoud**	**MAT Airbi**	**Micron**	**Micronair**	**Micronair**	**Tifa**	**Jacto**	**Micronair**	**Berthoud**	**Micron**	**Micron**
Pesticide Efficiency	MkII ENS (not tested)	Puma	Drift Air	MKII Ulvamast	AU8110	AU7010	100 E	PL 50	AU8000	C5	UlvaPlus	MicroUlva
droplet size (i)	◆◆◆	◆◆◆◆	◆◆	◆◆◆◆	◆◆◆	◆◆◆◆	◆	◆◆	◆◆◆	◆◆◆	◆◆◆◆◆	◆◆◆◆
spectrum width	◆◆	◆	◆	◆◆◆◆◆	◆◆	◆◆◆	◆◆	◆◆	◆◆	◆◆◆◆	◆◆◆◆	◆◆◆◆◆
flow rate	◆	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆	◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆
ease/security of calibration	◆	◆◆	◆◆◆◆	◆◆◆◆	◆◆◆◆	◆◆◆◆	◆◆◆	◆◆◆◆	◆◆◆	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆
Sustainability												
ease of filling/spraying/cleaning	◆◆	◆◆	◆◆◆◆	◆◆◆◆	◆◆	◆◆◆	◆	◆◆◆◆	◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆
durability/maintenance	◆◆◆	◆	◆◆◆	◆◆◆	◆◆	◆◆	◆	◆◆◆◆	◆◆◆◆	◆◆◆◆	◆◆◆◆◆	◆◆◆
Socio-economic merit												
safety (operator/environment)	◆	◆	◆◆◆◆	◆◆◆◆	◆◆◆	◆◆◆	◆	◆◆◆	◆◆◆	◆◆◆	◆◆◆	◆◆◆◆
cost (ii)	◆◆◆◆	◆◆◆	◆◆◆	◆◆◆◆	◆◆	◆◆◆◆	◆	◆◆◆	◆◆	◆◆◆◆◆	◆◆◆◆	◆◆◆◆
work rate (iii)	◆◆◆◆	◆◆◆	◆◆◆	◆◆◆	◆◆◆◆	◆◆◆	◆◆◆◆	◆◆◆	◆◆◆◆	◆◆◆	◆◆◆	◆◆◆
OVERALL RATING	◆◆	◆◆	◆◆◆	◆◆◆◆	◆◆◆	◆◆◆	◆◆	◆◆◆	◆◆◆	◆◆◆◆	◆◆◆◆	◆◆◆◆

(i) as measured at the workshop

(ii) based on suggested manufacture's retail cost; categories differ for vehicle mounted and portable sprayers

(iii) based on assumed track spacing and forward speed; vehicle mounted and portable sprayers assessed separately

	Assessment
◆◆◆◆◆	excellent
◆◆◆◆	good
◆◆◆	average
◆◆	poor
◆	inappropriate

	Cost (US$)	
	Vehicle	**Portable**
◆◆◆◆◆	0 - 1,000	0 - 50
◆◆◆◆	1,000 - 2,000	50 - 100
◆◆◆	2,000 - 5,000	100 - 500
◆◆	5,000 - 10,000	500 - 1,000
◆	10,000 - 25,000	1,000 - 2,000