Workshop on Spray Equipment Used in Desert Locust Control

Organized by the FAO Commission for

Controlling the Desert Locust in the Central Region

and the FAO EMPRES/CR Programme

23 – 25 September 2002

CAIRO, EGYPT

**FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS**

ACKNOWLEDGEMENTS

The organizers of the workshop wish to express their sincere appreciation to the Government of Egypt for agreeing to host the workshop, the Ministry of Agriculture and Land Reclamation for providing vehicles, equipment, labor and clearance assistance, the sprayer manufacturers for providing spray equipment and the staff of the FAO Near East Regional Office for their invaluable assistance during the workshop.

TABLE OF CONTENTS

INTRODUCTION

The Desert Locust (*Schistocerca gregaria*, Försk) 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 provided 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 However this pesticide has now been withdrawn from use because of its potential effects on the environment and has been replaced by less toxic, more environmentally benign pesticides.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.

A workshop was organised in August 1994 to demonstrate and evaluate hand-held, knapsack and vehicle-mounted sprayers commonly used in Desert Locust control. That workshop was organized by the FAO Near East Regional Office 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. Participants, methodology and findings from the workshop were presented in a report entitled Report of the Workshop on Evaluation of Spray Equipment Used in Desert Locust Control (FAO 1994) and the summary sprayer evaluation table is presented at Appendix 1.

One of the recommendations of that workshop was that a similar workshop be held within 3-5 years. After an interval of 8 years, a second workshop, the subject of this report, was held from 23 – 25 September 2002. Aims of this second workshop were broader than the first workshop and were to:

- Check progress on 1994 recommendations
- Review recent developments in locust sprayers
- Carry out a rapid field evaluation of currently available sprayers
- Develop the key design and performance criteria for Desert Locust ULV sprayers
- Develop practical field testing procedures for locust sprayers
- Make recommendations for the future of locust spraying equipment

Progress on 1994 recommendations

It was also recommended that the 1994 report be circulated as widely as possible to all interested parties. Copies were sent to participants, manufacturers, donors and it is available on the internet at http://www.fao.org/news/global/locusts/PDFs/Cairorep.pdf. It is likely that the existence of this report produced several benefits: donors had a reference document which provided both highly summarised, and more detailed critical evaluations of available equipment on which to base their purchasing decisions. Also, since 1994, two of the manufacturers whose equipment was judged as poor for locust control no longer offer their sprayers in the locust market. It was also clear that some manufactuers had addressed the shortcomings identified during the 1994 sprayer evaluations. All of these factors mean that locust staff are increasingly working with better ground-based ULV sprayers, and that the FAO initiative to test sprayers can take at least some of the credit for this.

The second recommendation was that further information be gathered on locust spraying machinery. Some work has been carried out in recent years through the EMPRES Western Region project on aspects of sprayer design which influence operator safety. There has also been some work carried out to begin development of minimum standards and testing protocols for locust sprayers through an MSc Thesis carried out by an MSc student at the University of Greenwich, UK, through funding from the FAO Central Region Commission. These draft standards and testing protocols were used as a basis for this workshop and developed further in consultation with the locust specialists present. However, there is still significant work to be done to develop workable minimum requirements, technical standards and practical methods of testing compliance.

MATERIALS AND METHODS

Sprayer manufacturers and sprayers

Representatives from those manufacturers known to FAO to provide sprayers for Desert Locust control operations were invited to attend the workshop. Some manufacturers present in 1994 are no longer producing locust sprayers or promoting their sprayers for locust control. Others declined to attend. Reasons for this may have been that their products have not changed significantly since then or that they did not feel the expense of sending their machinery or attending themselves was justified. Manufacturers who participated in the workshop and the spray models tested are listed in Appendix 2.

Sprayer evaluation panel

16 specialists in locust control and pesticide application (contact details at Appendix 3) were invited to the workshop in order to evaluate the performance of locust spray equipment in a fair and objective manner in the field.

Programme

The workshop consisted of one indoor day establishing objectives and testing criteria, then presentations by the manufacturers on developments in their products. This was followed by one day of testing at a field site near Cairo and concluded with a day of data analysis, discussion and drafting of ratings, conclusions and recommendations (see Appendix 4).

Field site and materials

The performance testing of the sprayers was undertaken at a field site (29°53'34.2" N / 31°05'04.1" 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. 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 from Cairo to Faiyum.

Diesel fuel was used for most of the testing and a blank ultra low volume formulation (no active ingredient) was used during the dynamic spray testing[1].

The evaluation process

The key performance criteria for locust sprayers were discussed and agreed upon during the first day, and the specific expectations under each main heading were established. A means of verifying each expectation was also suggested and a check list question developed for each expectation which would prompt evaluators to obtain the necessary information in the field. These factors, expectations, means of testing and questions were drawn up into a series of field evaluation sheets - see Appendix 5.

Performance criteria

In response to the question ‘what do we want from a ULV locust sprayer?’, the panel agreed on a list of key performance criteria as detailed below. Further detail is given in Appendix 5.

Efficacy

This is a critical criterion since the sprayer must kill locusts when it uses ULV insecticide formulations at the recommended dose. Efficacy is determined by the size of droplets produced since this influences the distribution of the spray downwind (small droplets are carried further), the losses as fall out (large droplets sediment onto the soil) and the impaction efficiency on locusts and vegetation (very small droplets impact less efficiently). There are two principal factors relating to droplet size which will affect efficacy:

Volume median diameter (VMD): There is an optimal droplet size for each locust control situation, and droplets larger or smaller than this size will be less biologically effective. Evidence suggests that droplets less than 50 um will either be dispersed beyond the target area or largely fail to impact, and that drops larger than 100 um 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. However, no commercial sprayer can produce uniformly sized droplets and the range of droplet sizes or spectrum can be characterised by a parameter called volume median diameter (VMD) which indicates the droplet size which has half of the

[1] EF 1325 ULV blank formulation for spray application work produced by DowElanco August 1994, Formulation code # EF XXX

spray volume contained in larger droplets and half of the spray volume contained in smaller droplets. It was agreed that locust sprayers must be able to produce a droplet spectrum which has a volume median diameter (VMD) of between 60 and 80 um at a typical locust control flow rate for that sprayer.

Spectrum width: Although there is always a range of droplet sizes from any sprayer, some sprayers produce a wide range, whereas locust spraying requires as narrow a range of droplet sizes as possible. Since laser data were requested from the manufacturers, it was decided to rate the droplet spectra according to the percentage of droplet volume falling within the size range 50 – 100 um. Best performance was considered to be when 80% or more of spray volume fell within that range, while worst performance was considered to be when less than 50% fell within the range.

Some other factors influenced overall rating of efficacy, such as ability to adjust droplet size and the likelihood of droplet size and spectrum varying during sprayer operation.

Efficiency

This was included since a sprayer must not only kill locusts, but it must do so at a reasonable cost. In the context of this workshop, efficiency is considered to cover a range of sprayer aspects such as work rate, purchase price, running costs, but especially flow rate aspects as described below:

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 0.5 l/ha and 2.0 l/ha so for example a vehicle mounted sprayer traveling 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. See Appendix 6 for a table of spray parameters and flow rates for the different ULV sprayer categories.

Other important features relating to flow rate were also considered, such as the reliability of flow rate (how much does it change when measured several times at the same setting) and security of flow rate (could the setting be accidentally changed in use).

Many of the aspects covered under efficiency also have a strong influence on environmental impact – if application is being done at recommended doses using the correct droplet sizes, the negative impact on the environment will be minimized.

Safety

This factor was included since it is not acceptable to control locusts effectively and efficiently, if operators or others are harmed in the process. Various elements of the sprayer and its performance were rated for the risk to the operator of pesticide contamination, mechanical injury or burning.

Ease of use

It was agreed that if essential sprayer tasks are easy to do, they are more likely to be done properly. These tasks include installing, filling, calibrating, operating, cleaning, servicing and repairing the sprayers.

Durability

With the factors above covering the capacity of a sprayer to kill locusts safely and efficiently, and for operators to be able to do this as easily as possible, the panel thought it important to include a factor which tested the sprayer's ability to keep on operating reliably under rough field conditions. This covered construction materials, design and some other factors such as presence of filters to prevent blockage. Assessments were somewhat subjective since firm conclusions would be difficult without long term, or destructive testing methods.

Field Evaluation of locust spray machinery

In order to evaluate the 8 sprayers brought to the workshop (see Appendix 2) in one day, rapid appraisal techniques were required. These involved various tests of the 5 main performance criteria identified earlier in the workshop, namely efficacy, efficiency, safety, ease of use and durability – some of them quantitative, others qualitative and subjective. Members of the evaluation team were divided into three groups so that work could continue on three sprayers simultaneously and each group was issued with part of the standard portable or vehicle sprayer evaluation form for each of the sprayers to be tested. See Appendix 7 for the schedule of testing. Various categories of test method were used as summarised in Table 1 below:

Table 1. Summary of methods used for testing sprayers

Test type	***Brief description***	***Example of use***
Visual check	Examine carefully by eye to check it	Is a full tool kit supplied with the sprayer
Manual check	Manipulate the component to check it	Can the filter bowl be removed without using tools
Measure	Use measuring equipment to record specific numerical values	How high is the atomiser above the vehicle floor?
Consult	Make enquiries from manufacturers or other source	What material are the pump seals made from?
Deduce	Work out from information available	Is the droplet spectrum likely to vary during spraying
Judge	Make a subjective assessment	Is the design durable?

Additional points relating to test methods

Although droplet spectrum was tested in the field in 1994, this was not done in 2002. The reason for this is that field results are not always a true representation of emitted droplet spectrum – larger droplets may already have fallen out of the spray cloud before collection and the smaller droplets may have been carried upwards or have evaporated (even from some ULV formulations). Even if the smaller droplets are present in the collection area, they may not impact on samplers since their impaction efficiency is low. Instead, manufacturers were requested to submit laser droplet analysis data as a more objective measurement of droplet spectrum and a summary of this data is presented in Appendix 8.

A dynamic spray test was also carried out. This served three purposes:

- to observe the sprayer in action
- to collect spray at intervals downwind in order to gain a rough estimate of swath width
- to assess subjectively the droplet spectrum

The rough estimate of swath width was achieved by mounting thin strips of oil sensitive paper vertically on 30 cm sticks at distances downwind of the spray pass. Distances used for portable sprayers were 0, 1, 2, 4, 7, 10, 15, 20, 30, 50, 75 and 100 m. Samplers were spaced out more for vehicle mounted sprayers due to the greater emission height at distances of 0, 1, 3, 7, 12, 20, 30, 40, 60, 80 and 100 m. A single spray pass was made at right angles to the wind and to the sampling line and the time, temperature and windspeed were recorded. Later, the number of droplets per cm2 was counted and a graph produced of number of droplets per cm2 against distance downwind (see Appendix 9)

This should 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 windspeeds. Also, if this sort of test is carried out several times, each graph will be slightly different due to variations in meteorological conditions from moment to moment. In addition, deposit has been assessed on the basis of number of drops per cm2. This does not give an accurate measure of volume of spray per cm2 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 and the large number of small droplets being carried large distances represent negligible 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.

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.

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 its performance.

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.

Analysing and summarising the findings

When data collection was complete, the sixteen members of the evaluation team met to discuss and summarise the findings. This was done through within-group discussions to establish a star rating (1 – 5) for each of the main performance criteria for each of the sprayers. The rating applies to each sprayer in relation to the other sprayers in its class (either vehicle-mounted or portable). The results and a key for the star ratings are shown in Appendix 10.

Participants (including manufactureres) felt that some of the performance criteria were more important than others and that, in fact, some were so critical that they should be treated as qualifiers for consideration. It was decided that efficacy and safety were so crucial that any score below 3 stars should eliminate the sprayer from further consideration. Also, in order to allow some other important criteria to carry extra weight in the overall star rating, some weighting of the scores was required before taking an average. These qualifiers and weightings are summarised in the table below and the summarised results are shown in Appendix 10.

Table 2 . ULV locust sprayer score weighting system

Factor	*Qualifier*	*Weight (1-3)*
Efficacy	***Must be 3 or above***	***3***
Efficiency		***2***
Safety	***Must be 3 or above***	***3***
Ease of filling		***1***
Ease of flow rate regulation		***1***
Ease of spraying		***1***
Ease of cleaning, maintenance and repair		***1***
Durability		***2***

At the foot of the table in Appendices 11 and 12 are the averages of the ratings for all criteria which give an overall rating for each sprayer. These are a combined assessment including all factors of efficacy, efficiency, safety, ease of use and durability. Any weighted average score which is over a ‘.5’ value has been rounded up to avoid the complication of decimal stars e.g. a score of 3.5 will be assigned 4 stars for the overall assessment.

Notes on individual sprayers

Notes were taken by the groups on particular aspects of each sprayer design which contributed to decisions on the ratings given and these are summarised below.

Curtis Dynafog L15 (overall rating ∗∗∗)

This is a new sprayer in the locust market, developed by a US manufacturer better known for its foggers.

Significant positive points	*Significant negative points*
• Radar control of flow rate to compensate for ground speed variations • two atomiser heights – upper one is higher than other sprayers • direct drive atomiser • separate flushing tank for cleaning fluids	• droplet spectrum is rather wide in relation to some of the other sprayers • narrow tank aperture (12 cm) • difficult to fill the tank due to the reinforced metal bars • impossible to empty tank – residual volume of 1.5 l and no drain pipe • some sharp edges • flow control needs allen key to fix the position • pipework (with many joints) looks vulnerable to leaks when sprayer is used over rough ground • atomizer supporting structure may be vulnerable to damage when used over rough ground, especially when the atomiser is in the upper position

Micron Ulvamast V3 M (overall rating ∗∗∗∗∗)

An earlier model of this sprayer was evaluated in 1994 and scored 4 stars. Since then there has been a radical redesign which addresses many of the shortcomings noted at the last evaluation. The model evaluated was the V3 M.

Significant positive points	*Significant negative points*
• direct drive atomiser (previous model had vulnerable rubber drive belts) • magnetic impeller pump which avoids ALL contact between pesticide and pump seals • separate flushing tank for cleaning fluids with easy valve system • V3E version has adjustable droplet size and adjustable flow rate via the control box in the cab. • multilingual manuals	• flow control needs an allen key to fix it in place • V3M version has no means of adusting droplet size (fixed atomiser speed).

Micronair AU8115 (overall rating ∗∗∗∗)

This air-assisted machine was designed some years ago for migratory pest control including locusts and uses a version of the atomiser used in most aerial spraying operations. An earlier model of this sprayer was also evaluated in 1994 and scored 3 stars. Since then there has been a major redesign with the sprayer frame now being common to the Micron Ulvamast.

Significant positive points	*Significant negative points*
• airblast can be angled upwards, level or downwards • magnetic impeller pump which avoids ALL contact between pesticide and pump seals • electronic version has adjustable flow rate via the control box in the cab. • robust atomiser head	• flow control valve has to be fixed with an allen key • spray head dripped more than 10 seconds after finishing spraying • some dismantling required to change droplet size (via blade angle and therefore rotational speed) • Difficult to collect engine oil during oil changes. • some risk of airtube damage when passing under tree branches

Chema Microjet K5 (overall rating: unclassified)

This is a cold fogger which was presented for the first time for evaluation as a locust sprayer. This sprayer was ruled out on safety grounds due to the fact that it requires an operator to sit beside it to switch it on and off at the start and end of spray passes. The manufacturer's do produce other models of cold fogger which have controls located in the vehicle cab, but the manufacturer was not aware of this requirement and did not demonstrate those models.

Significant positive points	*Significant negative points*
• simple design • robust atomiser head – no moving parts • any pesticide drum can be used as the pesticide tank, provided there is a leak-proof coupling to it – reduced risk of contamination during filling. • 'airflush' system of cleaning out sprayer pipework • multilingual manual	• on/off requires an operator to sit beside the sprayer. • droplet size appears to be very small • small tank inlet diameter (6.5 cm) • needle valve flow rate control which could be easily knocked to a different setting • could be spillage from the pesticide drum if there is no leak-proof coupling to it • difficult to change the oil

*Micron Ulva + (overall rating *****)*

This is a hand-held spinning disc sprayer which was tested in 1994 and rated 4 stars. The on/off switching system has changed since then and is now less likely to be mislaid.

Significant positive points	*Significant negative points*
• droplet spectrum is excellent • supplementary backpack tank available for longer operations in the field • multilingual manuals • 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 • 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 • restrictors can be replaced without removing the spray bottle	• need to break into the pesticide line to change the flow rate (via a range of restrictors)

Berthoud C5 (overall rating: unclassified)

This is a battery powered hand-held spinning disc sprayer which was tested in 1994. At that time it was thought that the rather large droplet sizes produced were the result of a poor motor contacts or other sprayer problem. However, large droplets were also seen on the oil sensitive paper in 2002 during the dynamic spray test. No laser data were available, but it was concluded that since the sprayer is principally aimed at the cotton market where track spacings are less than for locust spraying, these large droplet sizes are intentional, but unfortunately rule it out as a ULV locust sprayer.

Significant positive points	*Significant negative points*
• supplementary backpack tank available for longer operations in the field • restrictors can be replaced without removing the spray bottle • the quick coupling to the optional backpack tank is well thought out.	• droplet sizes appear large and number of batteries cannot be increased to try to solve this • droplet spectrum appears relatively wide • tank opening on the supplementary backpack tank is rather small (10 cm) • no indication of which way round to insert the batteries • it would be possible to switch the sprayer on accidentally • difficult to see the pesticide level through the walls of the bottle • battery life is reported to be lower than the other spinning disc sprayer tested

Micronair AU8000 (overall rating ∗∗∗∗)

This is a motorised knapsack mistblower with a rotary cage mounted in the airtube.

Significant positive points	*Significant negative points*
• atomiser appears robust • presence of a pesticide pump if the sprayer is being used with the atomiser held up high to direct the spray into bushes or low trees	• controls on the frame of the sprayer rather than on the airtube handle • changing droplet size requires some dismantling in order to change the angle of the atomiser blades. • changing flow rate means breaking into the pesticide line to swap restrictors • mistblower is quite loud and would require the use of ear defenders • rather large tank (17 l) which, with the motor and the atomisers, makes the whole sprayer rather heavy when full • No mesh on the sides of the filter and the filler aperture is rather narrow (9.5 cm) • flow rate calibration required detachment of the pesticide pipe from the atomiser. A quickly detachable union would make the process easier.

Curtis Dynafog Twister (overall rating unclassified)

This is a cold fogger mounted on a backpack frame which was being proposed for the first time as a locust sprayer. However, the laser droplet sizing data presented to the evaluation team showed that the droplet size was far too small for locust control with VMDs between 10 and 15 um depending on the flow rate.

Significant positive points	*Significant negative points*
• robust atomiser (no moving parts)	• droplet sizes are far too small for locust control (<15 um VMD) • no facility for changing the droplet size • need to break into the pesticide line to change flow rate via a series of restrictors. These were slippery and tricky to handle with gloves on • pesticide pipes do not appear to be resistant to all types of pesticide • tank opening rather small (5 cm) • some sharp components and some flat surfaces collect spray liquid • no filter in the tank opening • spark plug difficult to access

DISCUSSION AND CONCLUSIONS

This workshop brought together the major locust sprayer manufacturers and their equipment, and experts from FAO, locust affected countries and locust-related institutions. This unique gathering offered the opportunity to evaluate the strengths and weaknesses of current machinery, to agree on key design and performance criteria for good ULV locust sprayers and to develop some field testing methods to check compliance with the ideal. 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 (even those with 5 stars had some shortcoming as outlined above).

The most suitable ***type*** of sprayer will depend on the size and type of target, for example portable passive drift sprayers will be more suitable for small hopper bands and vehicle-mounted airblast sprayers for larger bands and in some instances small swarms. As a consequence, only sprayers of the same type should be compared.

It should be emphasised that this report does not recommend purchase of any sprayer, nor advise against purchase of any another. However, the summary evaluation tables (Appendix 11 and 12) represent 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.

Some of the sprayers were considered ‘unclassified’ because they were awarded a score of less than 3 for one of the ‘qualifier’ criteria (either safety or efficacy). Where the failing identified was safety, it is possible that those safety issues could be addressed easily by a simple modification, or that different models of sprayer from the same company might already meet the required safety standards. Where the failing was efficacy (droplet spectrum), it is possible that different settings of the sprayer might allow the sprayer to meet the required standards. However, the evaluation team had to assess the sprayers on the basis of laser droplet size data supplied by the manufacturers at the time of the workshop. Some manufacturers did not provide any laser analysed droplet spectrum data and it is not clear whether the sprayers in question would have qualified or not qualified on efficacy had such data been available. However, no manufacturer who did supply data is considered to be disadvantaged by having provided such data since the sprayers from the two companies who did not supply laser data were considered unclassified anyway. Some of these difficulties could be addressed in any future workshop by sending a more detailed brief to manufacturers on what would be expected of their equipment and what information and data they should provide.

The workshop also provided the opportunity for invited specialists to work in a participatory way to formulate firmer ideas on what design and performance features locust sprayers should have, and simple, practical methods to test those features. These ideas will form the basis for development of FAO Guidelines on minimum requirements and standards for ULV locust and grasshopper sprayers, and related procedures to test them.

RECOMMENDATIONS

1. As with the 1994 event, this 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, NGOs and manufacturers and it is **recommended** that this report be circulated to all these parties.. It should also be posted on the FAO web site to improve access for any other interested parties.

2. In order to allow manufacturers to respond to the critical feedback on sprayer shortcomings, it is **recommended** that this workshop be repeated within the next 3-5 years. As part of the invitations to any such workshop in future, manufacturers should be provided with details of what design and performance features their equipment will be expected to have, and also on what information and data they will be asked to supply along with the equipment.

3. However, to steer developments in the shorter term, it is **recommended** that FAO develop and publish a guideline on minimum requirements and standards, together with testing procedures for ULV locust sprayers within 12 months. This will allow manufacturers to test their machines against the standards or send machines to an accredited testing centre which can issue a certificate of compliance with the standards.

4. With this in mind, it is **recommended** that FAO should establish how the guideline on minimum standards and testing protocols will be developed and should identify possible testing centres in different parts of the world. [2]

[2] Development of the minimum requirements and standards for ULV locust and grasshopper sprayers, together with testing procedures is underway and these guidelines are expected to be available in April 2003.

APPENDICES

Appendix 1. Summary of ground sprayer evaluation (FAO, Cairo, 1994).

	VEHICLE - PASSIVE		VEHICLE - AIRBLAST				
	Micron	MAT Airbi	Francome	Berthoud	Micronair	Micronair	Tifa
Pesticide Efficiency	**MKII Ulvamast**	**Drift Air**	**MkII ENS (iv))**	**Puma**	**AU8110**	**AU7010**	**100 E**
droplet size (i)	****	**	***	****	***	****	*
spectrum width	*****	*	**	*	**	***	**
flow rate	*****	*****	*	*****	*****	*****	*****
calibration ease/safety	****	****	*	**	****	****	***
Sustainability							
filling/spraying/cleaning	****	****	**	**	**	***	*
durability/maintenance	***	***	***	*	**	**	*
Socio-economic merit							
safety (operator/environ.)	****	****	*	*	***	***	*
purchase 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. (iv) not tested – scores judged by panel.

Summary of evaluation of ground sprayers (continued)

	KNAPSACK		HANDHELD		
	Jacto	Micronair	Berthoud	Micron	Micron
Pesticide Efficiency	**PL 50**	**AU8000**	**C5**	**UlvaPlus**	**MicroUlva**
droplet size (i)	**	***	***	*****	****
spectrum width	**	**	****	****	*****
flow rate	****	****	*****	*****	*****
calibration ease/safety	****	***	*****	*****	****
Sustainability					
filling/spraying/cleaning	****	****	*****	*****	*****
durability/maintenance	****	****	****	*****	***
Socio-economic merit					
safety (operator/envrion.)	***	***	***	***	****
cost (ii)	***	**	*****	****	****
work rate (iii)	***	****	***	***	***
OVERALL RATING	***	***	****	****	****

KEY to star ratings	*****	****	***	**	*
Technical assessments	Excellent	Good	Average	Poor	Inappropriate
Cost (US$) - Vehicle	0 - 1,000	1,001 - 2,000	2,001 - 5,000	5,001 - 10,000	1,0001 - 2,5000
Cost (US$) - Portable	0 - 50	51 - 100	101 - 500	501 - 1,000	1,001 - 2,000

Appendix 2. Sprayers and manufacturers contact details

PLATFORM	TYPE	MANUFACTURER	MODEL
Portable	Passive drift	Micron	ULVA+
	Passive drift	Berthoud	C5
	Airblast	Micronair	AU8000
	Airblast	Curtis Dynafog	Twister
Vehicle-mounted	Passive drift	Curtis Dynafog	L15
	Passive drift	Micron	Ulvamast V3
	Airblast	Micronair	AU8115
	Airblast	Chema	Microjet K5

Berthoud Sprayers
EXEL Gsa –
BP 424 - 69653 VILLEFRANCHE s/s
Cedex, FRANCE
Tél : +33 (0)4 74 62 48 30
Fax : +33 (0)4 74 62 37 51
http://www.berthoud.fr/default_gb.htm

Chema Industries
26, 1st, Industries Zone
New Nubaria City, Behira
EGYPT
Tel: (045) 632801
Fax: (045) 632796
Email: chema@elisra.net
http://www.elisra.net

Curtis Dyna-fog Ltd
P.O. Box 297
17335 US 31 North
Westfield, IN 46074-0297
USA
Tel: 317/896-2561
Fax: 317/896-3788
E-Mail: dynafog@iquest.net

Micron Sprayers Ltd
Three Mills, Bromyard
Herefordshire, HR74HU
ENGLAND
Tel: +44 (0) 1885 482397
Fax: +44 (0) 1885 483043
Email: micron@micron.co.uk
http://www.micron.co.uk

Micronair (contact Micron Sprayers Ltd)
Three Mills, Bromyard
Herefordshire, HR74HU
ENGLAND
Tel: +44 (0) 1885 482397
Fax: +44 (0) 1885 483043
Email: micron@micron.co.uk
http://www.micron.co.uk

Appendix 3. Participant list
(and see Appendix 13 for contact details)

NAME	ORGANISATION AND COUNTRY
Mamoon Al Alawi	Natural ResourcesInstitute, United Kingdom, Omani MSc Student
Abdulaziz Mansour Al-Shanfari	Director General of Agriculture & Animal Affairs, Sultanate of Oman
Mohamed Abdel Aziz	Agriculture Research Institute, Egypt
Bob Aston	FAO Mauritania
Mahmood Attia	Local distributor for Micron Sprayers, Egypt
Wagdy Botros	Curtis Dynafog, Egypt
Munir Butrous	CRC Egypt
John Clayton	Micron Sprayers, UK
Hans Dobson	Workshop Coordinator Natural Resources Institute, United Kingdom
Mr. M. El-Shafei	Chema Industries
Theodor Friedrich	FAO HQ ROME
Mahmoud Harb	Agriculture Research Institute, Egypt
Mr. Adel Helmi	Chema Industries
Said Lagnaoui	Centre National de Lutte Antiacridienne, Morocco
Maatoug A. Munshi	Locust Research & Control Center, Saudi Arabia
Ibrahim Magzoob	Plant Protection Directorate, Sudan
Yassin M. Al Nakeeb	General Dept. for Plant Protection, Yemen
Christian Pantenius	EMPRES/CR Egypt
Graham Parker	Curtis Dynafog, USA
Tahar Rachadi	Cirad, France
Mohamed Abdel Rahman	Locust Affairs & Agro-Aviation, Egypt
Tim Sander	Micron Sprayers, UK
Johannes Wilps	GTZ/EMPRES/CR Egypt

Appendix 4. Workshop programme for sprayer testing workshop

DATE	TIME	SUBJECT	VENUE	NAME
Mon 23-Sep	09:00-09:15	Opening	FAO/RNE Conference Room (6th Floor)	Dr. M. Zehni (AGD a.i.)
	09:15-09:30	Registration	FAO/RNE Conference Room (6th Floor)	All
	09:30-10:00	Coffee Break	Cafeterai	
	10:00-11:00	Introduction	FAO/RNE Conference Room (6th Floor)	Han Dobson
	11:00-11:30	Coffee Break	Cafteria	
	11:30-13:30	Company Presentations	FAO/RNE Conference Room (6th Floor)	Micron, Curtis Dynafog, CHEMA Egypt
	13:30	Sprayers to be mounted on Vehicles, provided for the Workshop		
Tues 24-Sep	07:30 (Pick-up from Hotel)	Field Testing of Sprayers outside Cairo		
		Drinks & Snacks are prvided in the field		
Wed 25-Sep	09:00-11:00	Analysis & Results	FAO/RNE Conference Room (6th Floor)	Evaluation Team
	11:00-11:30	Coffee Break	Cafeteria	
	11:30-13:30	Analysis & Results	FAO/RNE Conference Room (6th Floor)	Evaluation Team
	13:30-14:00	Coffee Break	Cafeterai	
	14:00-16:00	Conclusion	FAO/RNE Conference Room (6th Floor)	All
	16:00	CLOSURE		

Appendix 5. Field evaluation sheets – portable ULV locust sprayers

FACTOR	EXPECTATION	MEANS OF VERIFYING	CHECK LIST QUESTION	ANSWERS
Efficacy				
Appropriate VMD	Capable of a VMD of 60 – 80 um	Laser data	Is the sprayer capable of producing a VMD of between 60 and 80 um at normal flow rates?	
Droplet spectrum	As narrow as possible. 80% of volume between 50 and 100 um (5 star), 70% (4 star), 60% (3 star), 50% (2 star), < 50% (1 star)	Laser data	At a VMD of 75 um, what is the percentage of spray volume within a size range of 50 – 100 um	
VMD adjustability	A mechanism to adjust VMD between 50 – 100 um	Manual check and laser data	Is the VMD adjustable – if so what is the range of VMDs at normal flow rates?	
Spectrum variability	Droplet spectrum should not vary during spraying	Deduce	Is the droplet spectrum likely to vary during spraying?	
Efficiency				
Flow rate range	Passive drift 0.008 – 0.27 l/min Airblast 0.017 – 0.33 l/min	Measure	What is the flow rate range?	
Security of flow rate	Positive setting system with markings or colour coding	Visual and manual check	How is the flow rate adjusted and set?	
Variability of flow rate over time	< 5% variation of a standard flow rate	Measure	How much does the flow rate vary between three identical measurements and after 10 minutes spraying (with diesel).	
Variabliity of flow rate depending on volume of spray liquid in the tank	< 5% variation of a standard flow rate	Measure	Does the flow rate vary according to whether the tank is ¼ full and completely full	
Adjustment for increased work rate (airblast sprayers)	Airblast can be angled upwards so that swath width (and therefore track spacing and work rate) can be maximised	Manual check	Can the airblast be directed upwards?	
Dynamic sprayer test	Sprayer operates normally and produces droplets which appear to be the correct size and range.	Judge	Does the sprayer appear to operate properly and produce a normal deposit on oil sensitive paper when operated over one spray pass.	
Purchase price	As low as possible	Consult manufacturers	What is the unit price?	
Running costs (specify how tested [battery type/cost, fuel type/cost])	As low as possible fuel or battery consumption	Consult manufacturers and deduce	What are the running costs?	

FACTOR	EXPECTATION	MEANS OF VERIFYING	CHECK LIST QUESTION	ANSWERS
Safety				
Operator exposure risk during filling	Tank opening (for MB sprayers and RA sprayers with knapsack tanks) should be 10 cm minimum	Measure	What is the tank opening diameter?	
Operator exposure risk after filling	There should be no concave surfaces (including tank lid) which might collect pesticide	Visual check	Are there any concave surfaces (including tank lid) which might collect pesticide.	
Residual volume in sprayer tank and pesticide line (including pipes and pump)	No more than 0.1% of total tank volume	Measure if possible, or judge	What is the residual volume in the tank and the residual volume in the pesticide lines?	
Operator exposure risk during flow rate changes	No operator contact with pesticide when adjusting flow rate	Visual check	How is the flow rate adjusted and set?	
Operator exposure risk during emptying	A drain pipe for emptying the tank	Visual check	Is there a sufficiently long drain pipe for draining off remaining pesticide from the tank?	
Operator (and other people) exposure risk during transit	There must a positive switch off position	Visual check	Is the on/off switch secure and unlikely to be switched on accidentally	
Mechanical injury risk to operator	No physical features (sharp edges, points, or unguarded moving parts) which might injure operator	Visual check	Are there any sharp components or unguarded moving parts which might injure the operator?	
Comfort for operator	Any carrying straps should be a minimum of 50 mm wide at the point where they go over the shoulder	Measure	If there are carrying straps, how wide are they at the point where they pass over the shoulders?	
Burn risk to operator	Any hot engine parts must be protected by a guard	Visual check	Are there any unguarded hot components which might burn the operator?	
Hearing risk to operator	Noise levels must be reasonable (international standard – 85 – check??)	Subjective aural check (low (can hear other things), moderate (cannot hear anything else), loud (painful))	How loud is the noise from the sprayer?	
Training of operators in safe use	Manufacturers should provide basic training in the safe and effective use of the equipment	Consult manufacturers	Does the manufacturer provide basic training in safe and efficient use of sprayer?	
Ease of filling				
Appropriate size of tank	Maximum tank volume of 15 l. This allows prolonged spraying without being excessive.	Consult	Is the sprayer tank big enough for prolonged spraying but not excessively big.	
Appropriate weight of sprayer	Maximum weight of full sprayer should not exceed 25 kg	Measure	Is the maximum weight of full sprayer less tha 25 kg	
Liquid flow speed through tank filter (for MB sprayers and RA sprayers with knapsack tank)	Should be deep with mesh on sides as well as bottom (specify a flow rate through filter??)	Visual check and manual check	Is the filter deep with mesh on the sides and the bottom, and does the liquid flow rapidly enough through it when filling?	
Ease of undoing and refitting tank lid	Secure closing system which is easy to operate with gloves on	Manual check	Is the lid easy to take off and refit securely with gloves on?	

FACTOR	EXPECTATION	MEANS OF VERIFYING	CHECK LIST QUESTION	ANSWERS
Ease of flow rate regulation				
Ease of flow rate measurement	Preferably possible to collect spray liquid directly	Manual check	Can spray liquid be collected directly during flow rate checks?	
Ease of flow rate adjustment	Flow rate can be adjusted without the need for special tools	Manual check	How is the flow rate adjusted?	
Ease of spraying				
Clarity of labels on controls	Well labelled controls with instructions to operator always to turn the atomizer on before the pump (except during flow rate calibration)	Visual check	Are the sprayer controls well labelled (with instructions to switch the atomizer on before the pump)?	
Ease of operation of controls	Accessible controls and positive positions for on an off (for MB sprayers they should be on the handle not the sprayer body)	Manual check	Are the sprayer controls accessible and easy to operate?	
Ease of knowing when pesticide tank needs refilling	Some sort of visual indication of pesticide level in the tank	Visual check with liquid in the tank	Can the liquid level be seen through the pesticide tank?	
Ease of changing droplet size	There should be a system to change droplet size without the need for tools or major dismantling	Manual check	How is the droplet size adjusted?	
Ease of cleaning, maintenance and repair				
Ease of learning about cleaning, maintenance and repair	There should be an Illustrated operator's manual in appropriate languages	Visual check and consult manufacturer	Is there an operator's manual and if so, is it illustrated well and does it give clear information? What languages is it available in?	
Ease of servicing, maintenance and repair	Easy access to engine oil, spark plug, pump, taps. Filters (air, fuel, pesticide) must be accessible and easily removable without tools	Visual and manual checks	Is it easy to reach engine oil filler, spark plugs, pump, taps? Can filters be reached and removed without the need for tools?	
Durability				
Durability of construction materials	Materials for tank, frame atomiser, etc are durable	Visual check and manual check	Do the materials for the major components appear durable?	
Resistance of construction materials to pesticides and their formulations	The materials for pipes, tank, atomizer, filters etc should be resistant to all kinds of pesticide formulations	Consult manufacturer	Are the materials for pipes, tank, atomizer, filters etc resistant to all kinds of pesticide formulations	
Durability of design	Sprayer design is likely to withstand tough conditions during storage, transportation and operation	Visual check	Does the sprayer design appear durable?	
risk of sprayer damage in transit	Should be a guard for the atomiser	Visual and manual check	Is there an atomiser guard?	
filters prevent blockages	Filters should be effective at preventing restrictor and atomizer blockages. Maximum 0.25 mm hole size	Visual check and consult	What are the filter mesh sizes?	
Efficacy				
Appropriate VMD	Capable of a VMD of 60 – 80 um	Laser data	Is the sprayer capable of producing a VMD of between 60 and 80 um at normal flow rates?	

FACTOR	EXPECTATION	MEANS OF VERIFYING	CHECK LIST QUESTION	ANSWERS
Droplet spectrum	As narrow as possible. 75% of volume between 50 and 100 um (5 star), 70% (4 star), 65% (3 star), 60% (2 star), < 50% (1 star)	Laser data	At a VMD of 75 um, what is the percentage of spray volume within a size range of 50 – 100 um	
VMD adjustability	A mechanism to adjust VMD between 50 – 100 um	Manual check and laser data	Is the VMD adjustable – if so what is the range of VMDs at normal flow rates?	
Spectrum variability	Droplet spectrum should not vary during spraying	Deduce	Is the droplet spectrum likely to vary during spraying?	
Efficiency				
Flow rate range	Passive drift 0.03 – 1.67 l/min Airblast 0.06 – 3.33 l/min	Measure	What is the flow rate range?	
Security of flow rate	Positive setting system with markings or colour coding (which doesn't require tools)	Visual and manual check	How is the flow rate adjusted and set?	
Variability of flow rate over time	< 5% variation of a standard flow rate	Measure	How much does the flow rate vary between three identical measurements and after 10 minutes spraying (with diesel).	
Variabliity of flow rate depending on volume in the spray tank	< 5% variation of a standard flow rate		Does the flow rate vary according to whether the tank is ¼ full and completely full	
Adjustment for increased work rate (passive drift sprayers)	Atomiser can be fixed high above the vehicle so that swath width (and therefore track spacing and work rate) can be maximised	Measure height	How high is the atomiser above the vehicle bed?	
Adjustment for increased work rate (airblast sprayers)	Airblast can be angled upwards so that swath width (and therefore track spacing and work rate) can be maximised	Manual check	Can the airblast be directed upwards?	
Swath width adjustable to cope with smaller targets	Atomiser height is adjustable to a lower height or airblast can be directed downwards to cope with smaller targets	Manual check	Can the atomiser be lowered, and if so to what height? For airblast sprayers, can the airblast angle be adjusted to point downwards?	
Dynamic sprayer test	Sprayer operates normally and produces droplets which appear to be the correct size and range.	Judge	Does the sprayer appear to operate properly and produce a normal deposit on oil sensitive paper when operated over one spray pass.	
Purchase price	As low as possible	Consult manufacturers	What is the unit price?	
Running costs	As low as possible fuel or battery consumption	Consult manufacturers and deduce	What are the running costs?	
Repair costs	As low as possible for main components*	Consult manufacturers	What are the prices for atomiser, pump, flow regulator + other frequently needed spares?	
Safety				
Operator exposure risk during filling	Tank opening should be 20 cm minimum	Measure	What is the tank opening diameter?	
Operator exposure risk after filling	There should be no concave surfaces (including tank lid) which might collect pesticide	Visual check	Are there any concave surfaces (including tank lid) which might collect pesticide.	
Operator risk when	Flow rate can be changed with	Manual check	Can flow rate be changed	

FACTOR	EXPECTATION	MEANS OF VERIFYING	CHECK LIST QUESTION	ANSWERS
chaning flow rate	gloves on		easily with gloves on?	
Residual volume in sprayer tank and pesticide line (including pipes and pump)	No more than 0.1% of total tank volume	Measure	What is the residual volume in the tank and the residual volume in the pesticide lines?	
Operator exposure risk during operation	Controls must be in cab	Visual check	Where are the sprayer controls?	
Operator exposure risk during flow rate changes	No operator contact with pesticide when adjusting flow rate	Visual check	How is the flow rate adjusted and set?	
Low exposure risk to operator when walking under spray head	No dripping from the atomiser 10 seconds after switching off	Visual check	Does the spray head drip 10 seconds after switching off?	
Operator exposure risk during emptying	A drain pipe for emptying the tank	Visual check	Is there a sufficiently long drain pipe for draining off remaining pesticide from the tank?	
Operator (and other people) exposure risk during transit	Cables should disconnect from control box during transit to avoid accidental operation	Visual check	Can the control box cables be disconnected easily during transit	
Mechanical injury risk to operator	No physical features (sharp edges, points, or unguarded moving parts) which might injure operator	Visual check	Are there any sharp components or unguarded moving parts which might injure the operator?	
Burn risk to operator	Any hot engine parts must be protected by a guard	Visual check	Are there any unguarded hot components which might burn the operator?	
Hearing risk to operator	Noise levels must be reasonable (international standard?)	Subjective aural check (low, moderate, loud)	How loud is the noise from the sprayer?	
Training of operators in safe use	Manufacturers should provide basic training in the safe and effective use of the equipment	Consult manufacturers	Does the manufacturer provide basic training in safe and efficient use of their equipment	
Ease of installation				
Mounting security on the spray vehicle	Bolting points should be provided on the sprayer frame	Visual check	Are there adequate bolt holes on the sprayer frame for firm mounting on the vehicle?	
Ease of electrical installation	Wires to control box in the cab must be sufficiently long and have a system to ensure that the positive and negative cannot be connected the wrong way round.	Visual check	Is the control box wire sufficiently long to reach the driver's cab on all possible vehicle platforms & is there a system to prevent the positive/ negative wires being connected the wrong way round?	
Ease of filling				
Appropriate size of tank	Minimum tank volume of 60 l and maximum of 110 l. This allows prolonged spraying without being excessive and is also a convenient size for filling from 25 and 50 litre drums	Consult	Is the sprayer tank big enough for prolonged spraying but not excessively big, and is the size appropriate to commonly available drum sizes.	
Liquid flow speed through filter	Should be > 20 cm deep with mesh on sides as well as bottom	Visual check and manual check	Is the filter deep with mesh on the sides and the bottom, and does the liquid flow rapidly enough through it when filling?	
Ease of undoing and	Secure closing system which	Manual check	Is the lid easy to take off and	

FACTOR	EXPECTATION	MEANS OF VERIFYING	CHECK LIST QUESTION	ANSWERS
refitting tank lid	is easy to operate with gloves on		refit securely with gloves on?	
Ease of flow rate regulation				
Ease of flow rate measurement	Should be possible to collect spray liquid directly	Manual check	Can spray liquid be collected directly during flow rate checks?	
Ease of flow rate adjustment	Flow rate can be adjusted without the need for special tools or the need for contact with the pesticide	Manual check	How is the flow rate adjusted?	
Ease of spraying				
Clarity of labels on controls	Well labelled controls with instructions to operator always to turn the atomizer on before pump (except during calibration)	Visual check	Are the sprayer controls well labelled (with instructions to switch the atomizer on before the pump)?	
Ease of operation of controls	Accessible controls and positive positions for on an off	Manual check	Are the sprayer controls accessible and easy to operate?	
Ease of sprayer operation for flow rate calibration	disc and pump can be operated independently (where applicable)	Manual check	Can the pump be operated independent of the atomiser for measuring flow rate?	
Ease for operator in the cab to tell which part of the sprayer is switched on	Controls have lights or other clear system to indicate when they are switched on	Visual check	Is it immediately obvious from the drivers cab which part of the sprayer is operating (engine, electric motor, pump)	
Ease of knowing when pesticide tank needs refilling	Some sort of visual indication of pesticide level in the tank	Visual check with liquid in the tank	Can the liquid level be seen through the pesticide tank?	
Ease of changing droplet size	There should be a system to change droplet size without the need for tools or major dismantling	Manual check	How is the droplet size adjusted?	
Ease of cleaning, maintenance and repair				
ease of flushing pipes with cleaning fluid	Extra tank for cleaning liquid (minimum 5l) provided with clearly labelled valves to allow flushing of pesticide line	Visual and manual check	Is there an extra tank for cleaning liquid and are the valves to draw liquid from it clearly marked and easy to operate?	
ease of emptying tank (subjective)	Drain pipe must be fitted at the low est point of the pesticide tank	Visual check	Does the drain pipe draw liquid from the lowest point in the pesticide tank?	
ease of emptying tank (quantitative)	Residual volume in the pesticide tank should be less than 0.1% of the tank volume	Measure	What volume of liquid remains in the tank after emptying?	
ease of emptying pipework	Residual volume in pipework should be less than ??	Measure	What volume of liquid remains in the sprayer pipes, pump, filters after emptying	
availability of tools	Tool kit supplied as standard equipment by sprayer manufacturer with all necessary tools for installation, adjustment and operation	Visual check	Is there a tool kit supplied with the sprayer which performs all necessary tasks?	
ease of learning about cleaning, maintenance and repair	There should be an Illustrated operator's manual in appropriate languages	Visual check and consult manufacturer	Is there an operator's manual and if so, is it illustrated well and does it give clear information? What languages is it available in?	

FACTOR	EXPECTATION	MEANS OF VERIFYING	CHECK LIST QUESTION	ANSWERS
ease of servicing, maintenance and repair	Easy access to engine oil, spark plug, pump, taps. Filters (air, fuel, pesticide) must be accessible and easily removable without tools	Visual and manual checks	Is it easy to reach engine oil filler, spark plugs, pump, taps? Can filters be reached and removed without the need for tools?	
availability of spares	A supply of commonly required spares should be supplied with new sprayer	Consult	Are all commonly required spares supplied with the new sprayer?	
Durability				
durability of construction materials	Materials for tank, frame atomiser, etc are durable	Visual check and manual check	Do the materials for the major components appear durable?	
resistance of construction materials to pesticides and their formulations	The materials for pipes, tank, atomizer, filters etc should be resistant to all kinds of pesticide formulations	Consult manufacturer	Are the materials for pipes, tank, atomizer, filters etc should be resistant to all kinds of pesticide formulations	
durability of design	Sprayer design is likely to withstand tough conditions during storage, transportation and operation	Visual check	Does the sprayer design appear durable?	
security on vehicle	Means of fixing securely to vehicle	Visual check	How is the sprayer fixed to the vehicle and is it secure?	
risk of sprayer damage in transit	Secure transport position and dust guard for atomiser if necessary	Visual and manual check	Is there a secure transport position for the sprayer mast and is there an atomiser dust guard?	
steady pesticide flow	Tank should have a non-return valve to allow air in, but not allow pesticide out	Visual check	Does the tank lid have a non-return valve?	
filters prevent blockages	Filters should have a maximum 1.0 holes size gauge in order that they are likely to be effective at preventing restrictor and atomizer blockages. Maximum 1.0 mm hole size.	Visual check and consult	What are the filter mesh sizes?	
risk of sprayer damage during spraying	A guard to protect the atomiser during spraying	Visual check	Is there a guard to prevent damage to the atomiser if it passes under low branches?	

Appendix 6. Flow rate ranges required for ground spray equipment

Platform	Type	Level	Track spacing (m)	Forward speed (km/hr)	Volume rate (l/ha)	Flow rate (l/min)
Vehicle	Passive drift	Minimum	12	3	0.5	0.03
		Maximum	50	10	2	1.67
	Airblast	Minimum	25	3	0.5	0.063
		Maximum	100	10	2	3.33
Portable	Passive drift	Minimum	5	2	0.5	0.0083
		Maximum	20	4	2	0.27
	Airblast	Minimum	10	2	0.5	0.017
		Maximum	25	4	2	0.33

Appendix 7. Field evaluation schedule

SEQUENCE	TIME	GROUP 1	GROUP 2	GROUP 3
Arrival and briefing	8.30			
1st	9.00	ULVA+	AU8115	L15
2nd	9.40	C5	Microjet K5	Ulvamast V3M
3rd	10.20	AU8000	ULVA+	AU8115
4th	11.00	Twister	C5	Microjet K5
5th	11.40	L15	AU8000	ULVA+
Lunch break	12.20			
6th	13.00	Ulvamast V3M	Twister	C5
7th	13.40	AU8115	L15	AU8000
8th	14.20	Microjet K5	Ulvamast V3M	Twister
Pack and depart	15.00			

Appendix 8. Summary of laser droplet sizing data from manufacturers

	Spray liquid	Speed setting	RPM	Flow (ml/min)	VMD (um)	Dv10 (um)	Dv90 (um)	Span
Micronair AU8115M	Blank ULV	-	8000	250	74.3	29.8	112.7	1.12
Micronair AU8000	Blank ULV	-	3500	250	78.3	28.1	127.5	1.27
Micron Ulvamast V3M	Oil/paraffin	-	7000	500	66.1	32.9	109.4	1.16
Micron Ulva+	Blank ULV	6 batts.	7200	60	71.2	56.4	94.1	0.53
Curtis Dynafog L15	Kerosene	2	-	200	47.8	19.4	93.4	1.55
Curtis Dynafog L15	Kerosene	2	-	1800	50.4	22.8	105.4	1.64
Curtis Dynafog Twister XL	Kerosene	-	-	45	11.37	2.87	24.0	1.86
Curtis Dynafog Twister XL	Kerosene	-	-	150	14.57	4.25	27.0	1.54

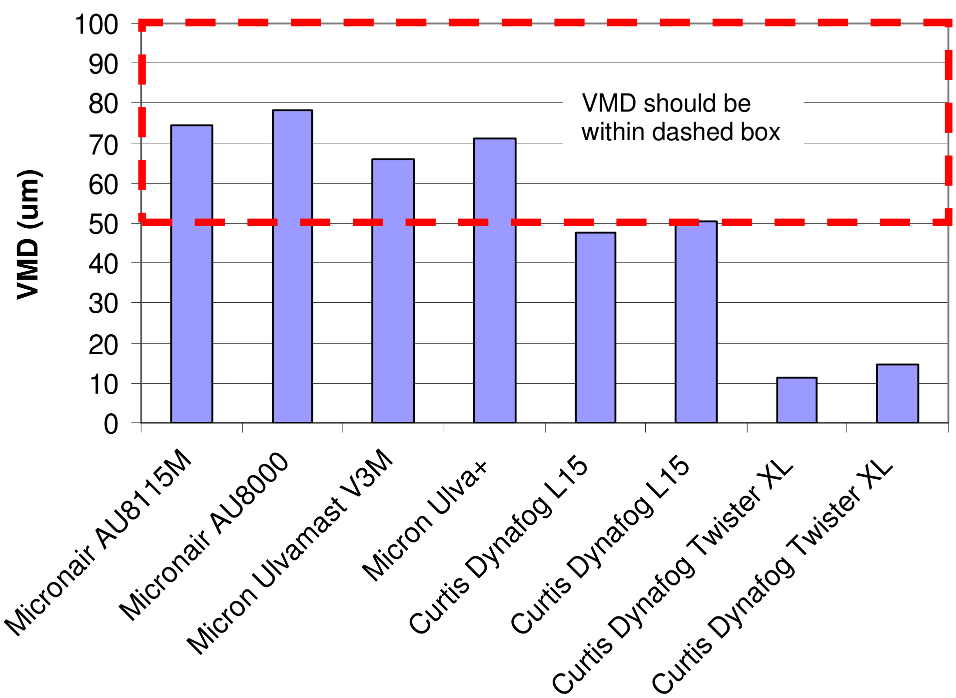
Notes

1. VMD = volume median diameter (diameter below which 50% of spray volume is distrubuted)
2. Dv10 = Diameter below which 10% of spray volume is distributed
3. Dv90 = Diameter below which 90% of spray volume is distributed
4. Span is a measure of the width of the droplet spectrum. It is calculated as follows:

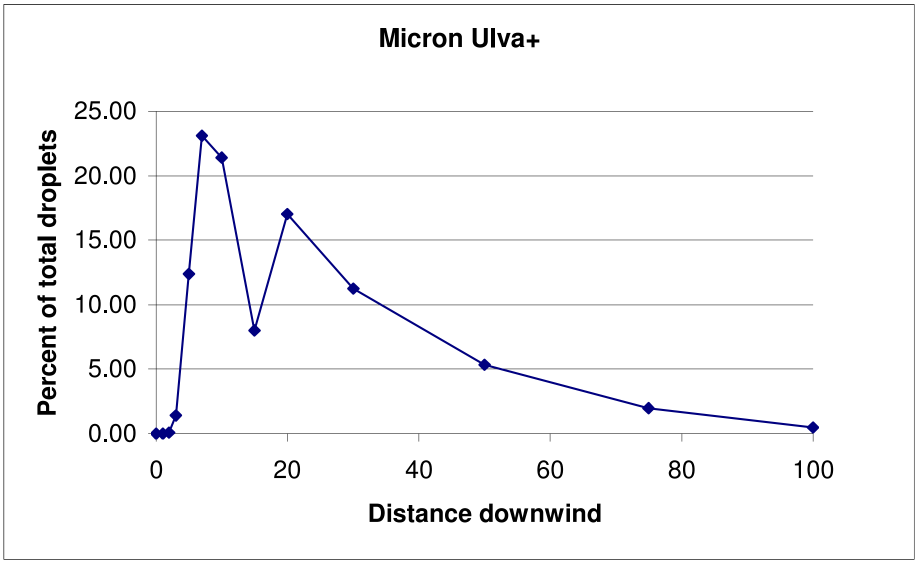
$$\frac{Dv90 - Dv10}{VMD}$$

5. Micron and Micronair spray spectra were analysed using a Malvern II Laser Particle Analyzer and the Curtis Dynafog machines were analysed using a Malvern, Insitec 'Spraytec' Model RTS 5414 laser particle analyser.

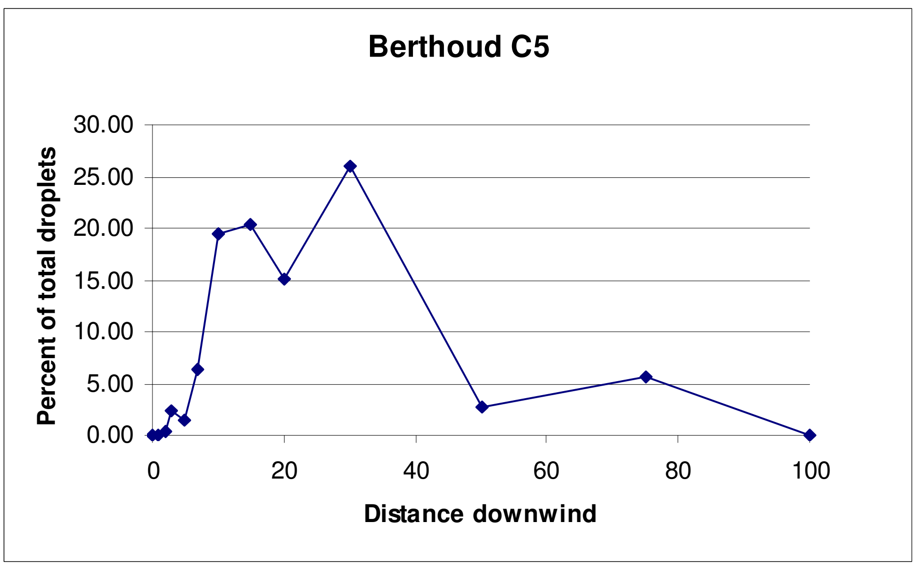
Graphical representation of VMD values (laser analysis data supplied by manufacturers)



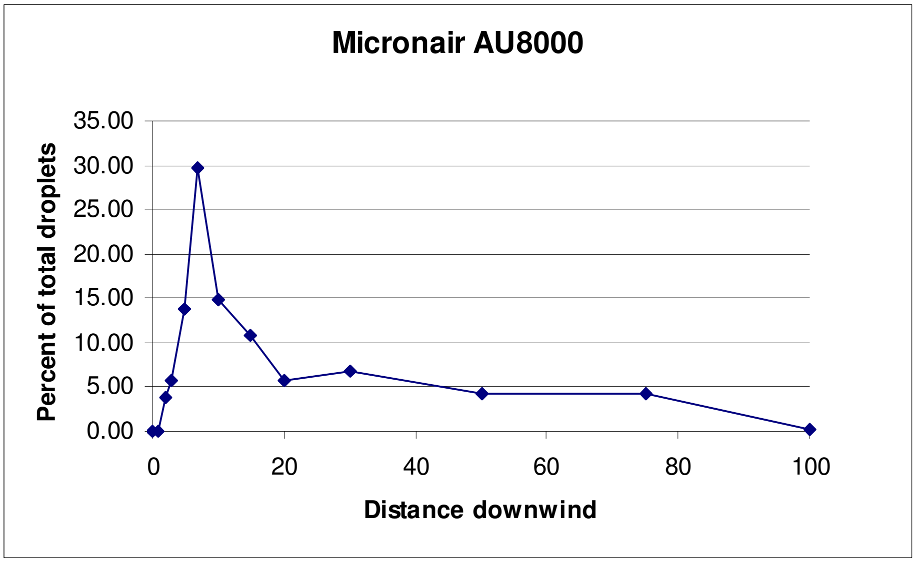
Appendix 9. Swath width results from dynamic spray test

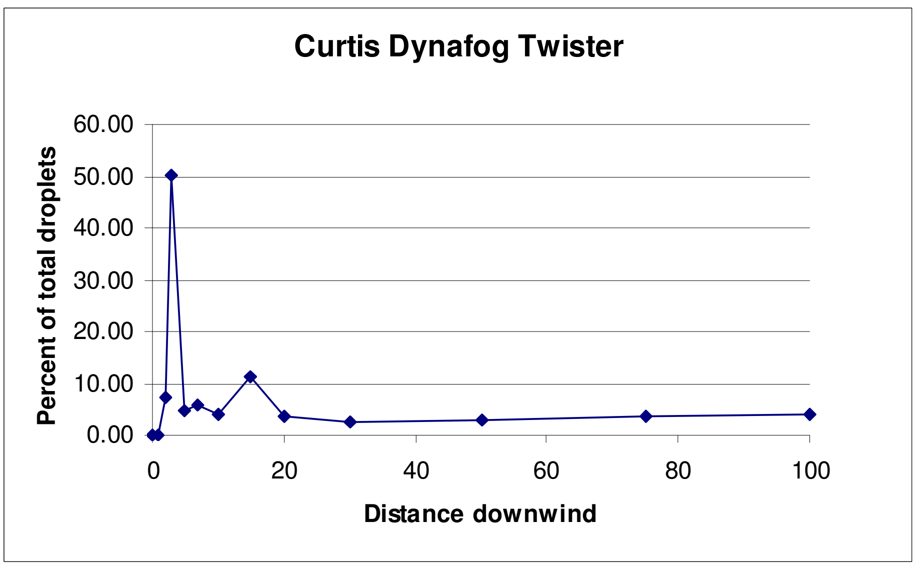


Note: results beyond 50m for the Micron Ulva+ are extrapolated due to no data

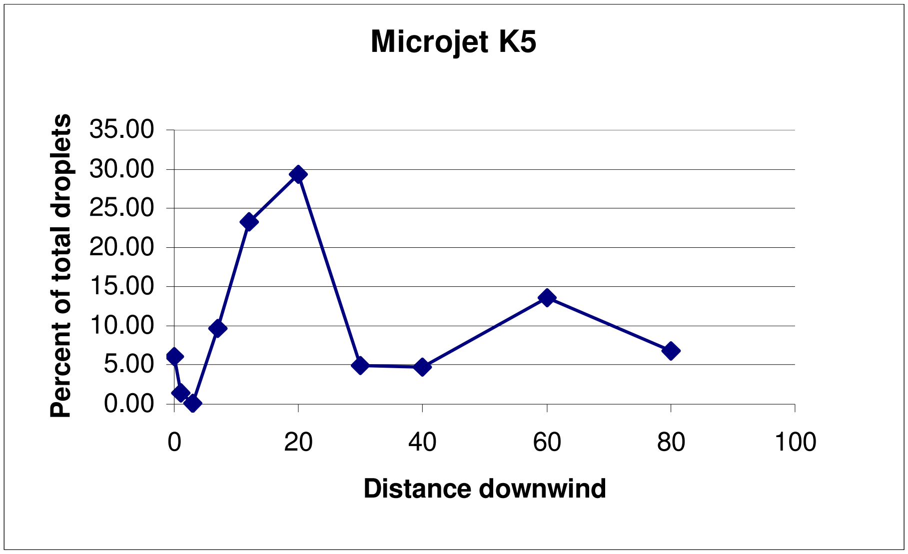


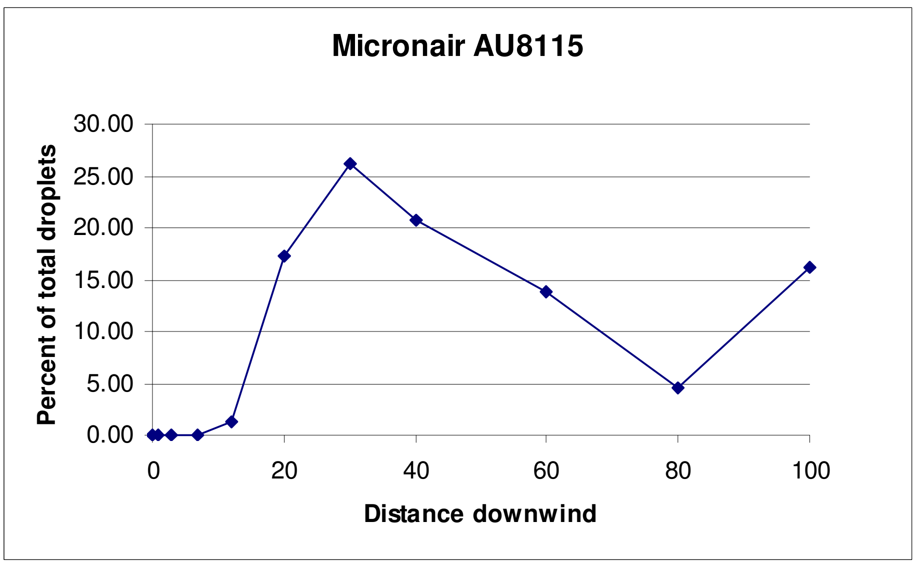
Appendix 9. Swath width results from dynamic spray test – contd



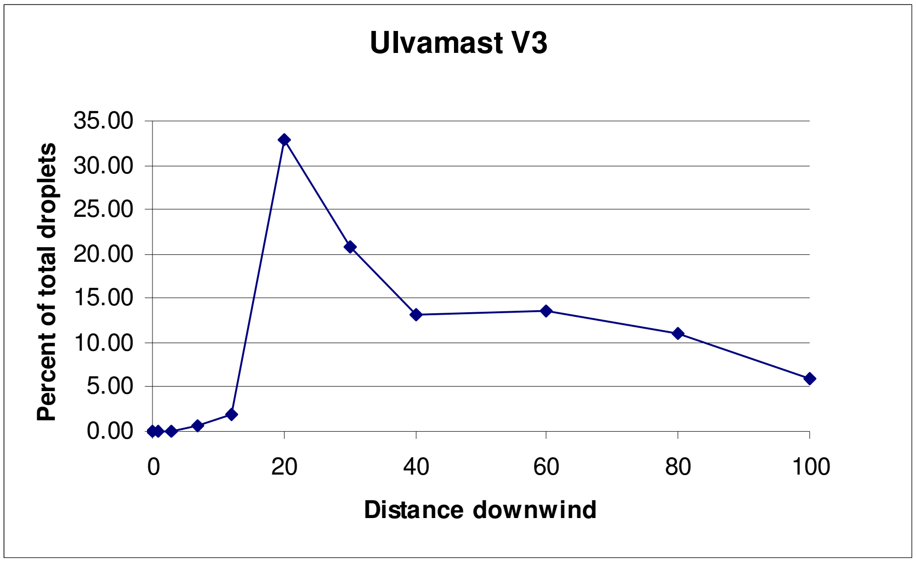


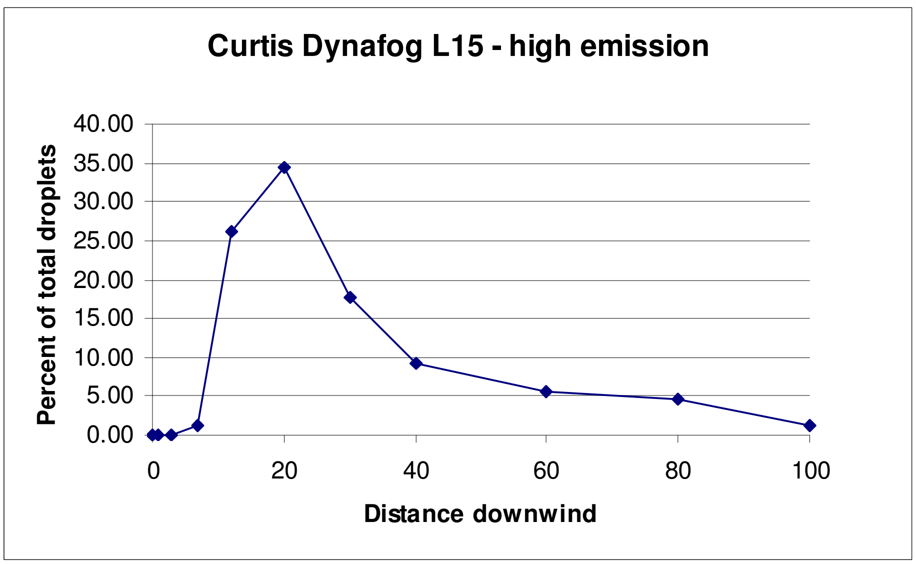
Appendix 9. Swath width results from dynamic spray test – contd



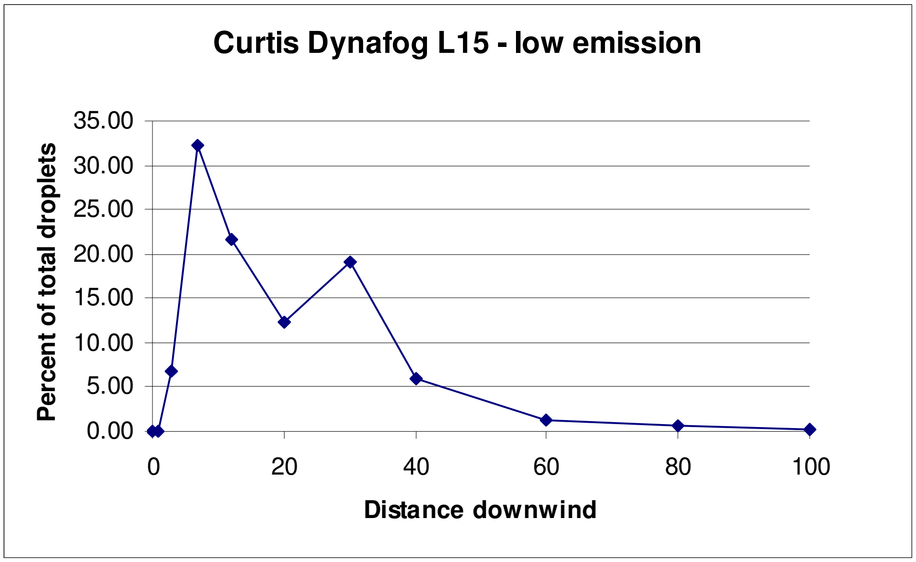


Appendix 9. Swath width results from dynamic spray test – contd





Appendix 9. Swath width results from dynamic spray test – contd



Appendix 10. Tables showing raw scores and weighted scores

A. Portable sprayers

Factor			Micron Ulva +		Berthoud C5		Micronair AU8000		Curtis Dynafog Twister	
	Weighting	Possible total	Raw score	Weighted score	Raw score	Weighted score	Raw score	Weighted score	Raw score	Weighted score
Efficacy	*3*	*15*	5	15	2	6	5	15	2	6
Efficiency	*2*	*10*	5	10	2	4	5	10	5	10
Safety	*3*	*15*	4	12	3	9	3	9	3	9
Ease of filling	*1*	*5*	4	4	4	4	4	4	3	3
Ease of flow rate regulation	*1*	*5*	4	4	4	4	4	4	2	2
Ease of spraying	*1*	*5*	5	5	4	4	4	4	4	4
Ease of cleaning, maintenance and repair	*1*	*5*	5	5	5	5	4	4	3	3
Durability	*2*	*10*	5	10	5	10	4	8	3	6
	Weighted average			**4.64**		**3.29**		**4.14**		**3.0**

B. Vehicle-mounted sprayers

Factor			Curtis Dynafog L15		Ulvamast V3 M/R		Micronair AU8115		Microjet K5	
	Weighting	Possible total	Raw score	Weighted score	Raw score	Weighted score	Raw score	Weighted score	Raw score	Weighted score
Efficacy	*3*	15	3	9	5	15	5	15	4	12
Efficiency	*2*	10	4	8	4	8	4	8	3	6
Safety	*3*	15	3	9	5	15	4	12	1	3
Ease of filling	*1*	5	2	2	5	5	5	5	3	3
Ease of flow rate regulation	*1*	5	5	5	3	3	3	3	2	2
Ease of spraying	*1*	5	4	4	5	5	5	5	2	2
Ease of cleaning, maintenance and repair	*1*	5	1	1	5	5	4	4	4	4
Durability	*2*	10	2	4	5	10	4	8	5	10
	Weighted average			**3.00**		**4.71**		**4.29**		**3.00**

[grey box] = a score which falls below a critical efficacy or safety threshold, resulting in the sprayer being judged as 'unclassified'

Appendix 11. Portable sprayer summary performance rating (1 – 5)

FACTOR	MICRON ULVA +	BERTHOUD C5	MICRONAIR AU8000	CURTIS DYNAFOG TWISTER
Efficacy	*****	**	*****	**
Efficiency	*****	** (a)	*****	*****
Safety	****	***	***	***
Ease of filling	****(b)	****(c)	****	***
Ease of flow rate regulation	****	****	****	**
Ease of spraying	*****	****	****	****
Ease of cleaning, maintenance and repair	*****	*****	****	***
Durability	*****	*****	****	***
Weighted overall score	*****	u/c d)	****	u/c d)

KEY to star ratings	*****	****	***	**	*
Technical assessments	Excellent	Good	Average	Poor	Inappropriate
Cost (US$) - Vehicle	500 - 2,000	2,001 - 5,000	5,001 - 8,000	8,001 - 12,000	>12000
Cost (US$) – Hand-held	10 - 50	51 - 100	101 - 500	501 - 1,000	>1,000
Cost (US$) – Knapsack	400 - 800	801 -1200	1201 - 1500	1501 - 2000	>2000

a) No regard to costs – no information available, but this would anyway not have affected the star rating
b) but a score of 5 for the backpack tank
c) but a score of 3 for the backpack tank
d) u/c = unclassified due to scoring less than 3 stars in one of the qualifier criteria (efficacy or safety)

Appendix 12. Vehicle-mounted sprayer summary performance rating (1 – 5)

FACTOR	CURTIS DYNAFOG L15	ULVAMAST V3 M	MICRONAIR AU8115	MICROJET K5
Efficacy	***	*****	*****	**** (a)
Efficiency	****	****	****	***
Safety	***	*****	****	*
Ease of filling	**	*****	*****	***
Ease of flow rate regulation	*****	*** (b)	*** (c)	**
Ease of spraying	****	*****	*****	**
Ease of cleaning, maintenance and repair	*	*****	****	****
Durability	**	*****	****	*****
Weighted overall score	***	*****	****	u/c d)

KEY to star ratings	*****	****	***	**	*
Technical assessments	Excellent	Good	Average	Poor	Inappropriate
Cost (US$) - Vehicle	500 - 2,000	2,001 - 5,000	5,001 - 8,000	8,001 - 12,000	>12000
Cost (US$) – Hand-held	10 - 50	51 - 100	101 - 500	501 - 1,000	>1,000
Cost (US$) – Knapsack	400 - 800	801 -1200	1201 - 1500	1501 - 2000	>2000

a) pending droplet spectrum data
b) electronic version (V3E) would have scored 5 stars, but was not tested, only demonstrated
c) electronic version also available for the AU8115
d) u/c = unclassified due to scoring less than 3 stars in one of the qualifier criteria (efficacy or safety)

Appendix 13. Contact details for participants

Mamoon Al Alawi
Natural Resources Institute
Chatham Martime, Kent , ME4 4TB
UK
01634 880088
01634 880077/66

Abdulaziz Mansour Al-Shanfari
Direc. Gen. of Agriculture & Animal Affairs
P.O.Box 1501 Code 211,
Technical Department, MOA, Oman
00 968 294 421
00 968 949 2264
00968 294 141
abdulaziz@taymur.com

Mohamed Abdel Aziz
Senior Locust Officer Locust Research Dept.
Locust Affairs & Agro-Aviation
c/o Mohamed Abdel Rahman Ministry of Agriculture, Dokki, Cairo, Egypt
00202 748 8974
00 202 749 3184
Said97@esic.claes.sci.eg

Robert Aston
Chief Technical Adviser
FAO Mauritania
B.P. 665-Nouakchott, Mauritania
0022 2 258 342
faonorim@toptechnology.mr

Mahmood Attia
Micron Sprayers - local distributor for Micron Sprayers
Cairo, Egypt

Wagdy Botros
Service and Trade International Distributor of Curtis Dynafog in Egypt
76 El Khalifa Al Maamoun Str. Roxy Heliopolis
00202 257 2768
0020 12 213 0116

Munir Butrous
Secretary of the Commission for Controlling the Desert Locust in the Central Region
FAO Near East Regional Office, 11 El Eslah El Zerai Str. P.O. Box 2223- Cairo, Egypt
00202 754 7569
0020 12 391 2541
00202 761 6804
munir.butrous@fao.org

John Clayton
Technical Director
Micron Sprayers UK
Bromyard Industrial Estate, Bromyard,
Herefordshire, UK
0044 1885 482 397
00 44 79 681 93241
0044 1885 483 043
john.clayton@micron.co.uk

Hans Dobson
Natural Resources Institute
Imperial College at Silwood Park, Ascot,
Berkshire, SL5 7PY, UK
0207 594 23 83
0207 594 2450
hans@dobsons.demon.co.uk

Mohamed El Shafai
Chema Industries
37 Victor Emmanuel Sq. Smouha, Alexandria 21615
Egypt
00203 424 1313
00203 429 2120
isra@dataxprs.com.eg

Theodor Friedrich
Senior Agricultural Engineer FAO
FAO HQ ROME
Viale Delle terme di Caracalla 00100 Rome, Italy
00 39 065 705 56 94
0039 065 705 67 98
theodor.friedrich@fao.org

Mahmoud Harb
Senior Locust Officer Locust Research Dept.
Locust Affairs & Agro-Aviation
P.O. Box 19 Dokki, Cairo
Egypt
525 0586 / 526 2891
harbmahmoud@37.com

Adel Helmi
Chema Industries
Manager Chema Industries
Nubaria City
00203 424 1313
00203 424 1313

Said Lagnaoui
Consultant
Centre National De Lutte Antiacridienne BP 125
Inezgane
Morocco
00212 48 24 1221
00 212 61 38 12 66
00212 48 24 1529
saidlagnoui@yahoo.fr

Maatoug A. Munshi
Locust Research & Control Center
Head of Locust Research
Mecca P.O. Box 9138
Saudi Arabia
5400 827 / 620 3000
0545 00 182
mphil-munshi@hotmail.com

Ibrahim Magzoob
Desert Locust Officer
Plant Protection Directorate
P.O. Box 14 Khartoum North,
Sudan
00249 13 33 74 37
00249 13 337 495

Yassin M. Al Nakeeb
Officer
General Dept. for Plant Protection
c/o Fuad Bahakim
FAO Representation Office, P.O. box 1867-
Sana'a
Yemen
00967 1 230 500
00967 1 250 980
empr-fao-ye@y.net.ye

Christian Pantenius
EMPRES/CR Coordinator
EMPRES
FAO Near East Regional Office, 11 El Eslah El
Zerai Str. P.O. Box 2223- Cairo
Egypt
00202 337 4543
0020 12 391 2540
00202 761 6804
christian.pantenius@fao.org

Graham Parker
Curtis Dynafog
17335 U.S. 31 North P.O. Box 297 Westfield
USA
United Kingdom P.O.Box 67
Liskeard PL 14 5YN England
USA tel 001 317 896 2561
UK tel 0044 1579 348796
UK mobile 0777 168 2466
USA fax 001 579 321 276
UK fax 0044 1579 348796
dynagof@igest.net
gparker.gandn@virgin.net

Tahar Rachadi
Locust Control Specialist
CIRAD
TA 40/D Campus International de Baillarguet 34398
Montpellier, Cedex 5
France
0033 467 593936
0033 467 593873
tahar.rachadi@cirad.fr

Mohamed Abdel Rahman
Director of Locust Affairs & Agroaviation,
Locust Affairs & Agro-Aviation, Egypt
Ministry of Agriculture, Dokki, Cairo,
Egypt
00202 748 8974
00 202 749 3184
Said97@esic.claes.sci.eg

Timothy Sander
Technical Manager
Micron Sprayers UK
Bromyard Industrial Estate, Bromyard,
Herefordshire
UK.
0044 1885 482397
0044 7768 686049
0044 1885 483043
tsander@micronair.co.uk

Johannes Wilps
GTZ
FAO Near East Regional Office, 11 El Eslah El
Zerai Str. P.O. Box 2223- Cairo-
Egypt
00202 335 2432
0020 12 391 2539
00202 761 6804
hans.wilps@fao.org