Workshop on Spray Equipment Used in Desert Locust Control

Organized by
the FAO Commission for Controlling the Desert Locust in the Central Region &
the FAO Commission for controlling the Desert Locust in the Western Region

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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 2003 - 2005.

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 insecticide 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. The total amount of assistance provided by the international community during the last major upsurge from 2003-2005 was about 400 million US Dollars where about 13 million litres of pesticides were used to treat 13 million hectare in 11 countries.

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 persistence and relatively easy method of application. It was commonly applied as barriers on vegetation in locust infested areas – a method not requiring great spatial or temporal accuracy. However this pesticide has now been withdrawn from use because of its potential effects on the environment and no equivalent barrier spray product has been identified. The only alternatives are less persistent, more environmentally benign pesticides that must be 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 portable 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).

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 was held from 23 – 25 September 2002. The 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

This produced in a report entitled 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, also available in Arabic and English online at: www.crc-empres.org

During this workshop, a series of technical and performance expectations were developed and a team of specialists from locust-affected countries evaluated a range of equipment against them.

Around the same time as that workshop, FAO began developing a series of quality expectations relating to more mainstream agricultural spray machinery. These included documents setting out the technical expectations for lever operated knapsack sprayers, knapsack mistblowers, tractor mounted boom and nozzle sprayers, and orchard airblast sprayers. There were two levels of documents developed; at a basic level were the 'Minimum Requirements' comprising a sort of check list that could be used to evaluate spray machinery relatively rapidly in the field. At a higher level were the 'Standards' where the machinery was tested to a higher level of rigour, requiring more time and needing more sophisticated laboratory facilities.

One of the recommendations of the 2002 locust sprayer workshop was that FAO develop and publish a guideline on minimum requirements and standards, together with testing procedures for ULV locust sprayers. As a result this became the focus of an MSc study at Greenwich University through funding from the FAO Central Region Commission, and part of a PhD study at Imperial College London. The Guidelines on Minimum Requirements for Ground-Based Locust and Grasshopper Sprayers were published by FAO in 2004 And are available in Arabic and English at: www.crc-empres.org

Another of the recommendations of the 2002 workshop was that the workshop be held again in 3-5 years. In the event, it was 7 years later that a third workshop was held – the subject of this report.

Since 1994 it has been clear that the existence of an objective system for evaluating locust sprayers has had several benefits. Part of the motivation for the third workshop was the demand from FAO procurement for up to date information on available locust and grasshopper spraying equipment – they have used the 2002 report extensively but needed a more recent review of options and performance to have confidence in 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 taken steps to address the shortcomings identified during the 1994 and 2002 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 objectives of the 2009 workshop were:

- Constructive dialogue between industry, funders and users of locust sprayers
- Common understanding of key performance criteria and practical ways to evaluate them
- Review of any recent advances in technology since previous workshop
- Systematic evaluation of available spraying equipment using new 'minimum requirements'

- Field testing of the minimum requirements to iron out any inconsistencies, duplications or omissions, possibly leading to a second edition.
- This should lead to better sprayers, more cost-effective use of public funds and improved locust control.

MATERIALS AND METHODS

Sprayer manufacturers and sprayers

Representatives from manufacturers of sprayers, personal protective equipment (PPE) and camping equipment that could be used for Desert Locust control operations were invited to attend the workshop – see Appendix 1. for list of invited companies. In the event, the response was very small from manufacturers of PPE and camping equipment, so the workshop confined itself to an assessment of ground-based spraying equipment. Invitations were also sent to all member countries of the Central Region (CRC), the Eastern Region (SWAC) and the Western Region (CLCPRO) with the request that they invite any manufacturers of locust spraying equipment in their countries. Manufacturers who responded and participated in the workshop and the spray models tested are listed in Appendix 2.

Sprayer evaluation panel

Eleven specialists in locust control and pesticide application from the Desert Locust front-line countries participated in the workshop in order to evaluate the performance of locust spray equipment in a fair and objective manner in the field. These were joined by specialists from FAO and the Natural Resources Institute (NRI) and representatives from 3 sprayer manufacturers – see participant list at Appendix 3 and full contact details at Appendix 11)

Programme

The workshop programme (see Appendix 4) consisted of two indoor days establishing objectives and developing the testing methodology, together with presentations by the manufacturers on their products. This was followed by two days of testing at a field site near Ismailia and concluded with a day of data analysis, discussion and drafting of assessment, conclusions and recommendations.

Initial information gathering

In the invitation, the manufacturers were asked to bring with them a range of different types of information. The status of this information was gathered by the evaluation panel, and the results shown in Appendix 5.

Field site and materials

The performance testing of the sprayers was undertaken at a field site approximately 10 km south west of Ismailia (N30 37 52 E032 11 15). The site was a flat 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 in the working area. The weather was sunny and cloudless with low relative humidity; temperature was 26 - 29°C and winds were 4-6 m/s. Temperature and wind conditions

as well as site characteristics were similar to conditions encountered during some actual locust control operations.

Water was used for most of the basic sprayer manipulations and flow rate testing and a blank ultra low volume formulation[1] (no active ingredient) was used during the dynamic spray testing and swath width measurement.

The evaluation process

The structure of the minimum requirements models the components and functional structure of a sprayer – see Figure 1.

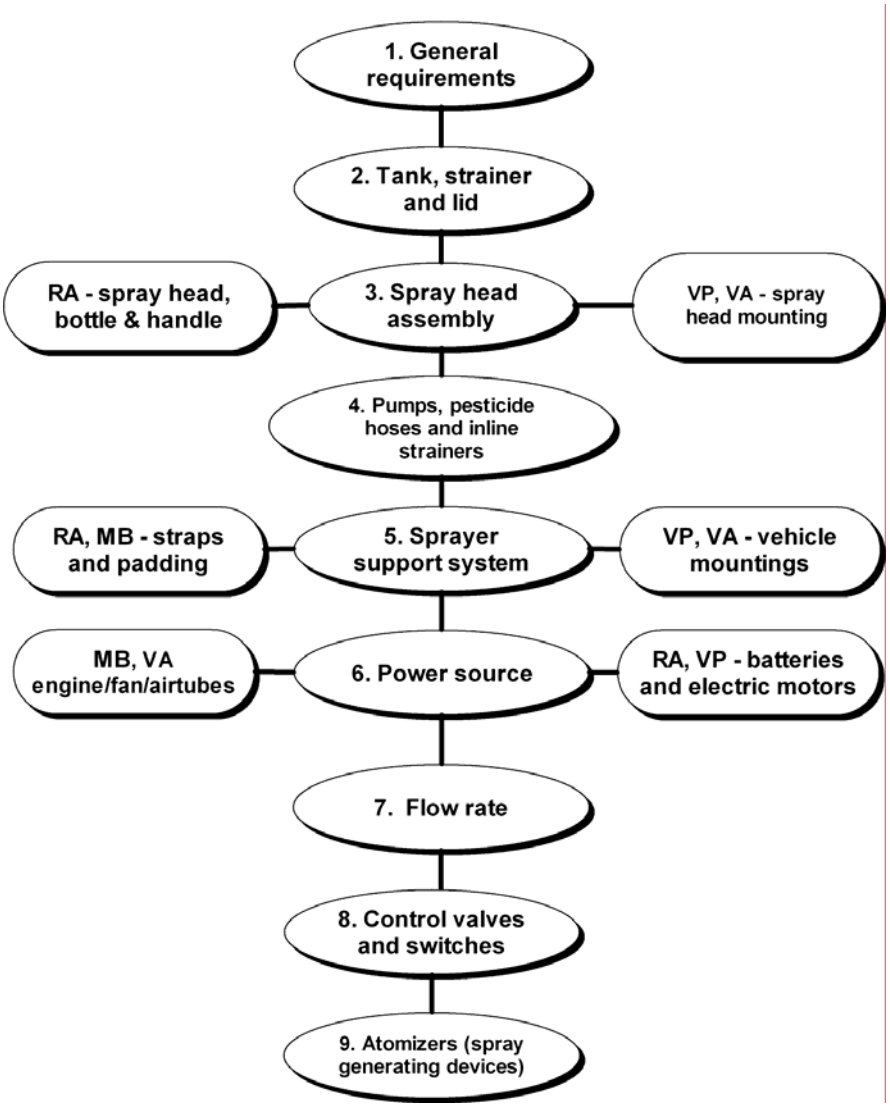


Figure 1. Modules of the Minimum Requirements, based on sprayer form and function

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

Therefore, in contrast to the two previous workshops which grouped factors for evaluation into a series of performance categories such as efficacy, safety and ease of use, this workshop structured its evaluations on the 9 modules of the minimum requirements.

At the beginning of this workshop, a cross referencing exercise was carried out to be sure that the minimum requirements were not missing any crucial sprayer performance factors from previous workshops, and some edits made to the document for the purposes of the workshop. As the minimum requirements were used in earnest in the field exercises, it became clear that some further changes were necessary, so that by the end of the workshop a revised version of the minimum requirements had been developed – see Appendix 9. Some of the texts have been modified and some of the requirements are highlighted grey, indicating that they are for removal from the requirements due to duplication or irrelevance. This modified set of requirements will be submitted to FAO with a recommendation that they be used in a second edition of the Guidelines on Minimum Requirements for Ground-Based Locust and Grasshopper Sprayers

Also, at the beginning of the workshop, the general method of evaluating a sprayer against each requirement was decided, and participants worked in groups to develop the detail of their approach to the testing using the following questions to guide them:

1. Do you understand the requirement?
2. How will you test it?
3. What equipment will you need to test it?
4. What information will you report against each requirement?
5. Are there any problems with the requirement e.g. duplication, irrelevance?

The general categories of evaluation were as follows:

Test type	*Brief description*	*Example of use*
Visual check	Examine carefully by eye to check it	Is a tool kit supplied with the sprayer
Manual check	Manipulate the component to check it	Can the filter bowl be removed without using special tools
Measure	Use measuring equipment to record specific numerical values	What is the diameter of the tank filler opening?
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?

In order to make the assessments as quantitative and definitive as possible, the evaluation panel was asked to judge whether a sprayer passed or failed against each of

the requirements, rather than allowing any grey areas in between. In this way the total number of passes and fails of different sprayers could be compared.

However, some of the requirements were considered to be more important than others, and a small number of requirements was judged to be critical, and would represent 'qualifying' criteria for consideration as a locust sprayer. In order to make the overall judgement therefore, weightings were applied to the assessments as follows:

1. Minor issues – e.g. ease of access to a filter. Carries a weight of 1
2. Major - e.g. construction materials. Carries a weight of 3
3. Critical e.g. droplet spectrum, key safety issues. Any fail disqualifies the sprayer from consideration.

The justifications and the weightings are shown in Appendix 6 .

Although cost is an important consideration, it was considered by the panel to be primarily a concern for those individuals, organizations or authorities purchasing the equipment. Therefore, unlike in previous workshops, the equipment was not judged by the panel on the basis of cost. Moreover, it was not considered appropriate to ask for exact quotes on price – manufacturers have different pricing structures depending on country, volumes and exchange rates, and any quotes would quickly be out of date too. In order to give an approximate idea of price, manufacturers were asked to assign their equipment to one of a range of price bands – see Appendix 5 for this information.

Field evaluation of locust spray machinery

In order to evaluate the 9 sprayers brought to the workshop, members of the evaluation team were divided into four groups so that everyone could work simultaneously on different sprayers. See Appendix 7 for the schedule of testing.

Additional points relating to test methods

Although droplet spectrum was tested in the field in 1994, this was not done in 2002 nor during this workshop in 2009. The reason for this is that droplet samples in the field 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 this data is also shown in Appendix 5.

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 and horizontally on 30 cm sticks at distances downwind of the spray pass. Distances used for portable and vehicle-mounted sprayers were 0, 1, 2, 3, 4, 6, 8, 11, 15, 20, 25, 30, 40, 60, 80, 100 metres. A single spray pass was made at roughly right angles to the wind and to the sampling line and the time, temperature and windspeed 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 (see Appendix 8)

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 cm^2. This does not give an accurate measure of volume of spray per cm^2 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.

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 their performance.

Analysing and summarising the findings

When data collection was complete, the 13 members of the evaluation team (11 experts from the countries, the NRI consultant and the Secretary of CRC) met to compile the passes and fails (with justifications) for each sprayer. Extensive use was made of photographs to record particular design features, and these were very useful to refer to during the discussions to recall or clarify particular issues.

A feedback session was held with manufacturers to go through the evaluations and allow a right to reply.

At the end of the workshop, some questions were unresolved due to lack of information e.g. some droplet spectrum data was not available yet, and information on whether some components are resistant to ULV formulations. There were also some requirements which involved manufacturers giving written assurance e.g. that they would guarantee that all spare parts would be available for sale for a period of 5 years after the workshop. Manufacturers were given a period of one month to provide the necessary information and assurances to the CRC, otherwise the relevant evaluation of the requirement would be recorded as a fail due to lack of information.

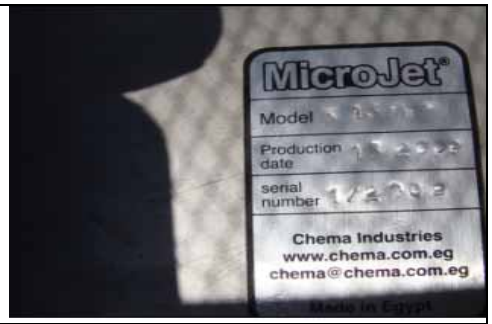
RESULTS

For the complete table of passes and fails, see Appendix 9. While there are many good features of all of the sprayers, this section will concentrate on the points where each

sprayer failed the requirements. Wherever possible, the fail point is accompanied by a photograph to support and illustrate the judgement. Where there were fails or missing information, manufacturers were given a period of one month after the workshop to rectify things and provide evidence of designs or materials modifications. Photos are also included in some of these cases, and a green tick symbol is used to indicate where fails have become passes as a result of additional information or design modification.

Chema K13 – fail points

Reqirement	Initial	Final	Requirement	Comment	Photos
1.5	✗	✗	When filled to the manufacturers recommended maximum capacity, the vehicle mounted sprayer should not leak either when upright or when tilted 45 degrees from the vertical in all directions.	Fail – will leak through vent. Update 20/6/ - unclear how air is to get in through new convex tank lid. If a simple vent, then tank will still leak.	
1.6	✗	✗	The sprayer should be easy to clean both inside and out. Rough surfaces and awkward recesses should be avoided	Fail – cage impedes access and many recesses. Update 20/6/09 – cage removed but still many recesses.	
1.7	✗	✓	There should be easy access to service components such as engine oil, spark plug, pump, taps. Filters (air, fuel, pesticide) must be accessible and easily removable without tools.	Fail – cage prevents access. Update 20/6/09 – cage removed so PASS	
1.8	✗	✓	The outer surfaces of the sprayer should not trap or retain spray liquid, including the spray tank lid.	Fail – tank lid is concave. Update on 20/6/09 – tank lid has been renewed and is now convex - PASS	
1.9	✗	✓	There should be no sharp edges, abrasive areas or unnecessary projections, which could injure the operator.	Fail – cage and filter have sharp edges. Update on 20/6/09. Cage removed and filter replaced - PASS	

1.12	✗	✗	To facilitate the accurate identification of replacement parts, the sprayer should be clearly and durably marked to indicate the manufacturer's name and address and the sprayer name and model.	Fail – no address given	
1.17	✗	✓	All sprayer components that come into constant direct contact with ULV pesticide should be resistant to deterioration from contact with ULV pesticide formulations. The manufacturer should provide written assurance of this with the sprayer instruction manual. It should also provide information on the materials used in pipes, pump seals, tanks, valves and any other component that comes into direct contact with ULV pesticide.	Fail – the material in some of the components are not resistant to ULV pesticide formulations (Note – the manufacturer has stated they will rectify this in the future). Update 20 June 09 – pictures of stainless steel coated Teflon pipes to carry pesticide to spray head. Also undertaking sent on 25 May 09 that pump, other pipework, filter seals etc are resistant. Presumed PASS	
1.18	✗	✗	The manufacturer should supply with the sprayer, a clear, simple, illustrated, instruction manual in English, French and Arabic. (See ***Appendix 1 of the Guidelines on Mimimum Requirements for Agricultural Pesticide Application Equipment Volume Four*** for detail on what the instruction manual should cover).	Fail – no French manual. Update 20/6/09 – French manual provided, but translation poor and does not contain all required information as set out in Appendix 1 of the Mimimum Requirements.	

1.19	✗	✗	Sprayer construction materials and design should be able to withstand the tough conditions during storage, transportation and operation typical of locust control.	Fail – cage is weak. Atomizer mast is unstable. No dedicated place for middle section of mast to be stored for transport. Update 20/6/09 – mast stays installed, but still considered not durable over rough terrain.	
2.1	✗	✗	Operator reach distances to the tank opening should not exceed 1.0 m vertically from the sprayer platform and there should be no obstructions around the filling area.	Fail – height is OK but the cage door gets in the way of safe filling. Update 20/6/09 – cage has been removed, but not clear whether this removes the safe filling problem	
2.7	✗	✗	The strainer should be easy to remove and fit with gloved hands.	Fail – filter is not easy to remove, gets stuck due to mesh being attached on the outside of the filter Update 20/6/09 – filter replaced but mesh still looks to be attached to outside of filter cylinder.	
2.9	✗	✗	The strainer mesh should be securely fitted to, or form part of, the strainer body.	Fail – mesh coming loose due to spot welding rather than welding all round. Update 20/06/09 – still attached with spot welds.	See photo above

2.17	✗	✓	The spray tank should incorporate a safe and convenient system to enable unused spray liquid to be discharged and collected safely. Any drain pipe should be fitted at the lowest point on the pesticide tank.	Fail – not fitted at the lowest point of the tank. No valve, and outlet is facing the vehicle cabin. Update 20/6/09 – outlet moved to base of tank and dedicated drain valve and pipe added. PASS	
2.19	✗	✓	It should be possible to drain the tank to leave a total residual volume in the sprayer (including tank, pipes, etc) of less than 0.5% of total tank volume.	Fail – likely to be over 1 litre of residual volume. See above - PASS	See photo above
5.8	✗	✗	The sprayer should have a transport position to ensure the atomizer head or its supporting structure is not damaged in transit, unless the atomizer head is well supported with a structure that can withstand rough roads.	Fail – no special box or retaining system for extension tubes	

6.16	✗	✗	The engine should still run after being exposed to heavy rain.	Fail – battery is unprotected and will short out in rain	
7.1	✗	✗	Flow rate should be controlled by a system of interchangeable or indexed restrictors (not a continuously adjustable valve) or by pre-calibrated flow settings set by an electronic control box.	Fail – it has a continuously adjustable valve	
7.8	✗	✗	Variation in flow rate should be no more than 10% regardless of terrain, speed of movement, volume of pesticide in the tank or height of emission.	Fail Static 0.393 l/min Dynamic 0.496 (>10% variation)	
9.1	✗	✓	The sprayer should be capable of at least 50 hours of 'continuous' operation (5 hours per day for 10 consecutive days) at normal operating speed without loss of performance or needing maintenance. The manufacturer should provide written assurance of this together with the sprayer instruction manual (see Section 1.18).	Pending written assurance from the manufacturer. Update 4/6/09 – undertaking sent by manufacturer. PASS	

9.2	✗	✗	The sprayer must be capable of producing a consistent droplet spectrum with VMD between 60 and 80 um when spraying UL formulations or equivalent blank formulations, as determined by laser droplet analysis. The manufacturer should provide data and written assurance of this together with the sprayer instruction manual (see Section 1.18).	Pending evidence of droplet spectrum. Update 20/6/09 - FAIL. No evidence presented.	
9.3	✗	✗	The sprayer must be capable of producing a consistent droplet spectrum with at least 50% of the spray volume in the size range 50 –100 um when spraying UL formulations or equivalent blank formulations, as determined by laser droplet analysis. The manufacturer should provide data and written assurance of this together with the sprayer instruction manual (see Section 1.18).	Pending evidence of droplet spectrum. Update 20/6/09 - FAIL. No evidence presented.	

Micron Ulva + (without backpack tank) – fail points

None			

Micron Ulva + with backpack option – fail points

Reqirement	Initial	Final	Requirement	Comment	Photos
1.4	✗	✓	When filled to the manufacturers recommended maximum capacity, the backpack/shoulder-slung sprayer/tank should not leak in such a way that the operator could be contaminated, either when the sprayer is upright or when tilted forward 90 degrees from the vertical (laid down on the straps).	Fail (leaks from the lid vent). Update 12/6/09 air bleed valve has been plugged in the 5 litre backpack tank. Filling the 1 litre bottle requires a small procedural change to the manual. PASS	

2.6	✗	✓	The tank should include a strainer, located in the fill opening to filter the pesticide as it enters the tank.	Fail. Update 12/6/09 the manufacturer accepted the point that funnels with integral strainer are rarely available for filling the 1 litre bottle directly. They have added a strainer between the bottle and the restrictor. Pass	
5.5	✗	✓	Straps fitted to a backpack sprayer or tank should be easily adjustable without assistance when the sprayer is full and in the working position on the operator's back.	Pass (but suggest longer straps be provided). Update 12/6/09 manufacturer will supply longer straps on request. Pass	

Micronair AU8000 - – fail points

Reqirement	Initial	Final	Requirement	Comment	Photos
1.1	✗	✓	Total mass when filled should not exceed 25 kg	Pass pending confirmation that manufacturer will mark the spray tank with instructions not to fill more than 10 litres. Confirmed 12/6/09. Pass	
1.8	✗	✗	The outer surfaces of the sprayer should not trap or retain spray liquid, including the spray tank lid.	Fail (lid retains liquid)	
1.18	✗	✓	The manufacturer should supply with the sprayer, a clear, simple, illustrated, instruction manual in English, French and Arabic. (See Appendix 1 for	Fail (no Arabic). Update 12/6/09 – Arabic manual provided. PASS	

			detail on what the instruction manual should cover).		
3.2	✗	✓	The length of the air tube from the on/off lever to the air outlet should be no less than 400 mm.	Fail (only 300 mm). Update 6/6/09 – in discussions with FAO, this requirement was considered arbitrary for mistblowers and has been removed from the requirements given that the pesticide is projected away from the operator by the airblast. PASS	
4.8	✗	✓	Hoses should be positioned so that, in the event of leakage or bursting, the risk of operator contamination is minimized. On vehicle-mounted sprayers, they should not pass through the vehicle cab.	Pass (but some problems with the pipe passing through the filter). Update 12/6/09 – the modification to increase the diameter of the centre hole by 1 mm has now been made.	
5.1	✗	✗	Straps, padding and fixings should be strong, durable and made of non-absorbent material which retains a minimal volume of pesticide	Fail (retain liquid)	
6.5	✗	✗	The fuel tank and the fuel on/off valve should be positioned to minimise the risk of fuel spilling onto the engine.	Fail (no fuel tap)	
6.6	✗	✗	The fuel on/off valve should be close to the fuel tank outlet and easily accessible to the operator when the sprayer is in the working position.	Fail (no fuel tap)	See photo above

6.7	✗	✗	An easily serviceable fuel filter should be located in the line between the fuel tank and the carburettor.	Fail (present but not easily serviceable)	
7.5	✗	✓	The sprayer should be capable of producing a flow rate range of 0.06 – 0.2 l/min	Fail (0.075 is the minimum). Max is OK. Update 12/6/09 – minimum flowrate with Brown no 1 restrictor and ULV blank formulation is 0.045l/min. PASS	

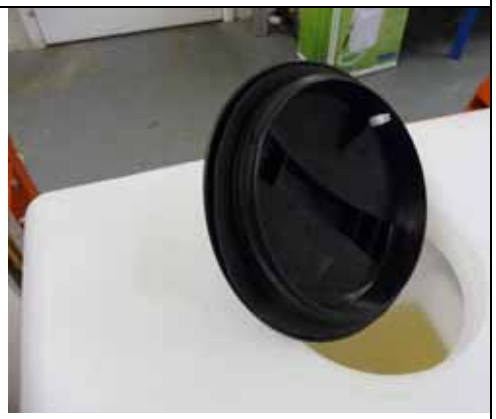
Fontan Portastar – fail points

Reqirement	Initial	Final	Requirement	Comment	Photos
1.17	✗	✓	All sprayer components that come into constant direct contact with ULV pesticide should be resistant to deterioration from contact with ULV pesticide formulations. The manufacturer should provide written assurance of this with the sprayer instruction manual. It should also provide information on the materials used in pipes, pump seals, tanks, valves and any other component that comes into direct contact with ULV pesticide.	Fail – no written assurance provided. Update 08/6/09 – written assurance privided. PASS	
1.18	✗	✓	The manufacturer should supply with the sprayer, a clear, simple, illustrated, instruction manual in English, French and Arabic. (See Appendix 1 for detail on what the instruction manual should cover).	Fail – no Arabic manual provided Pass – Arabic manual provided later.	
3.2	✗	✓	The length of the air tube from the on/off lever to the air outlet should be no less than 400 mm.	Fail (less than 200 mm). Update 6/6/09 – in discussions with FAO, this	3.2

				requirement was considered arbitrary for mistblowers and has been removed from the requirements given that the pesticide is projected away from the operator by the airblast.	
6.7	✗	✗	An easily serviceable fuel filter should be located in the line between the fuel tank and the carburettor.	Fail (difficult to reach the fuel filter)	
7.8	✗	✗	Variation in flow rate should be no more than 10% regardless of terrain, speed of movement, volume of pesticide in the tank or height of emission.	Fail for smallest restrictor Full tank-Vertical 24 ml/min Full tank-Horizontal 44 ml/min	
9.1	✗	✓	The sprayer should be capable of at least 50 hours of 'continuous' operation (5 hours per day for 10 consecutive days) at normal operating speed without loss of performance or needing maintenance. The manufacturer should provide written assurance of this together with the sprayer instruction manual (see Section 1.18).	Fail – no written assurance provided. Update 08/6/09 – written assurance privided. PASS	
9.2	✗	✓	The sprayer must be capable of producing a consistent droplet spectrum with VMD between 60 and 80 um when spraying UL formulations or equivalent blank formulations, as determined by laser droplet analysis. The manufacturer should provide data and written assurance of this together with the sprayer instruction manual (see Section 1.18).	Fail – no data supplied. Update 08/6/09 – provided confirmation that the sprayer is capable to generate a droplet spectrum with VMD between 60-80 microns. PASS	

9.3	✗	✗	The sprayer must be capable of producing a consistent droplet spectrum with at least 50% of the spray volume in the size range 50 –100 um when spraying UL formulations or equivalent blank formulations, as determined by laser droplet analysis. The manufacturer should provide data and written assurance of this together with the sprayer instruction manual (see Section 1.18).	Fail – no data supplied. Update 08/6/09 – FAIL- do NOT comply with the requirement to have over 50% of the spray volume in the size range 50 – 100 um when using UL formulations or equivalent blanks.The sprayer produced a maximum of 43%.	

Micron Ulvamast V4 – fail points

Reqirement	Initial	Final	Requirement	Comment	Photos
1.5	✗	✓	When filled to the manufacturers recommended maximum capacity, the vehicle mounted sprayer should not leak either when upright or when tilted 45 degrees from the vertical in all directions.	Fail (leaked at about 30 degrees). Update 12/6/09 - The manufactuerers have made modifications. The tank lid is now fitted with a gasket seal to prevent liquid leaking from between the tank face and lid. The labyrinth air vent is replaced with a a flexible nylon pipe (400mm length) with spring kink relief and upstand to ensure pipe remains vertical. At its base under the tank lid there is a non return ball valve tube . This also provides an anti surge facility. PASS	

					
3.6	✗	✓	If the atomizer is exposed, a durable shield or cover should be supplied with the sprayer to protect it from physical damage in transit and in storage.	Fail (no cover supplied). Update 12/6/09 – a protective cover with hard liner will now be supplied with all units. PASS	
7.6	✗	✓	The sprayer should be capable of producing a flow rate range of 0.06 – 0.9 l/min	Fail Manual 0.15 to 1.55 Electronic 0.22 to 1.95 Update 12/6/09. Manufacturer has installed a by pass with adjustable needle valve to obtain lower flow rates. PASS	

Micronair AU8115 – fail points

Reqirement	Initial	Final	Requirement	Comment	Photos
1.5	✗	✓	When filled to the manufacturers recommended maximum capacity, the vehicle mounted sprayer should not leak either when upright or when tilted 45 degrees from the vertical in all directions.	Fail (leaks at around 30 degrees inclination. Update 12/6/09 - The manufactuerers have made modifications. The tank lid is now fitted with a gasket seal to prevent liquid leaking from between the tank face and lid. The labyrinth air vent is replaced with a a flexible nylon pipe (400mm length) with spring kink relief and upstand to ensure pipe remains vertical. At its base under the tank lid there is a non return ball valve tube . This also provides an anti surge facility. PASS	 

3.6	✗	✓	If the atomizer is exposed, a durable shield or cover should be supplied with the sprayer to protect it from physical damage in transit and in storage.	Fail (no protection in transit and storage). Update 12/6/09 – a protective cover with hard liner will now be supplied with all units. PASS	
7.7	✗	✓	The sprayer should be capable of producing a flow rate range of 0.18 – 1.7 l/min	Pending – not measured. Update 12/6/09. Manufacturer has installed a by pass with adjustable needle valve to obtain lower flow rates. PASS	

Fontan Mobilstar – fail points

Reqirement	Initial	Final	Requirement	Comment	Photos
1.6	✗	✗	The sprayer should be easy to clean both inside and out. Rough surfaces and awkward recesses should be avoided.	Fail (perforated engine shield, recesses, compartments etc)	
1.7	✗	✗	There should be easy access to service components such as engine oil, spark plug, pump, taps. Filters (air, fuel, pesticide) must be accessible and easily removable without tools.	Fail (need to remove tank to access pesticide filter, pump etc)	
1.8	✗	✓	The outer surfaces of the sprayer should not trap or retain spray liquid, including the spray tank lid.	Fail on stainless steel tank – concave lid traps liquid. But pass when polyethylene tank is considered.	

1.13	✗	✓	There should be a practical system in place to assist in the provision of replacement parts for a minimum of five years after the date of manufacture. The manufacturer should provide written assurance of this with the sprayer instruction manual (see Section 1.18).	Fail – no written assurance provided. Update 08/6/09 – written assurance privided. PASS	
1.17	✗	✓	All sprayer components that come into constant direct contact with ULV pesticide should be resistant to deterioration from contact with ULV pesticide formulations. The manufacturer should provide written assurance of this with the sprayer instruction manual. It should also provide information on the materials used in pipes, pump seals, tanks, valves and any other component that comes into direct contact with ULV pesticide.	Fail – no written assurance provided. Update 08/6/09 – written assurance privided. PASS	
1.18	✗	✓	The manufacturer should supply with the sprayer, a clear, simple, illustrated, instruction manual in English, French and Arabic. (See Appendix 1 for detail on what the instruction manual should cover).	Fail – no Arabic manual provided. Pass – Arabic manual provided later	
1.19	✗	✗	Sprayer construction materials and design should be able to withstand the tough conditions during storage, transportation and operation typical of locust control.	Fail - concern about the stability of the spray head supports. However tight the screw fastening, it is still possible to pull the heads out of position. This means the heads will flop up and down during spraying or transit over rough terrain.	

2.3	✗	✓	The tank should be clearly and durably marked with: the manufacturer's recommended maximum filling level, which should be equivalent to no more than 95% of the total volume of the tank; appropriate intermediate filling levels.	Fail with stainless steel tank (markings are on a sticker – easily detached once pesticide has been on it). But pass when polyethylene tank is considered (has stainless steel gauge)	 
2.11	✗	✓	The strainer should be close fitting and permit safe, easy filling from a non- profiled container (i.e. one without a lip or spout) without overflowing, splashing or lifting from its seat. Tank opening diameter should not be less than 150 mm.	Fail with stainless steel tank (filler is only 50 mm diameter), but pass with polyethylene tank.	

2.17	✗	✗	The spray tank should incorporate a safe and convenient system to enable unused spray liquid to be discharged and collected safely. Any drain pipe should be fitted at the lowest point on the pesticide tank.	Fail (no system in place to drain the main tank safely). Similar for plastic tank.	
2.19	✗	✗	It should be possible to drain the tank to leave a total residual volume in the sprayer (including tank, pipes, etc) of less than 0.5% of total tank volume.	Not measured but judged Fail	See photo above
4.6	✗	✗	In-line strainers should be readily accessible for cleaning and maintenance.	Fail (pesticide tank needs to be moved to access the strainer)	
9.1	✗	✓	The sprayer should be capable of at least 50 hours of 'continuous' operation (5 hours per day for 10 consecutive days) at normal operating speed without loss of performance or needing maintenance. The manufacturer should provide written assurance of this together with the sprayer instruction manual (see Section 1.18).	Fail – no written assurance received. Update 08/6/09 – written assurance privided. PASS	
9.2	✗	✓	The sprayer must be capable of producing a consistent droplet spectrum with VMD between 60 and 80 um when spraying UL formulations or equivalent blank formulations, as determined by laser droplet analysis. The manufacturer should provide data and written assurance of this	Fail – no laser data supplied. Update 08/6/09 – provided confirmation that the sprayer is capable to generate a droplet spectrum with VMD between 60-80 microns.	

			together with the sprayer instruction manual (see Section 1.18).	PASS	
9.3			The sprayer must be capable of producing a consistent droplet spectrum with at least 50% of the spray volume in the size range 50 –100 um when spraying UL formulations or equivalent blank formulations, as determined by laser droplet analysis. The manufacturer should provide data and written assurance of this together with the sprayer instruction manual (see Section 1.18).	Fail – no laser data supplied. Update 08/6/09 – FAIL- do NOT comply with the requirement to have over 50% of the spray volume in the size range 50 – 100 um when using UL formulations or equivalent blanks.The sprayer produced a maximum of 41%.	

These results are summarised in Table 1 which gives the overall percentage compliances based on the number of passes and weighting assigned to each requirement. This table also shows which sprayers failed one or more of the critical requirements.

TABLE 1. SUMMARY OF COMPLIANCE RESULTS FOR ALL SPRAYERS

Parameter number	Parameter	*Chema K13*	*Micron Ulva +*	*Micron Ulva + with back tank*	*Micronair AU8000*	*Fontan Portastar*	*Micron V4M/E*	*Micronair AU8115M/E*	*Fontan Mobilstar ER*
1	**Total requirements**	69	54	54	75	75	58	69	69
2	**Total weighted requirements**	117	85	85	113	113	103	117	117
3	**Not applicable (n/a)**	5	12	2	3	4	1	3	6
4	**Weighted n/a**	6	14	2	5	6	1	5	8
5	**Fails**	14	0	0	5	3	0	0	7
6	**Weighted fails**	19	0	0	9	2	0	0	7
7	**Critical fails**	3	0	0	0	1	0	0	2
8	**Total possible score**	111	71	83	108	107	102	112	109
9	**Total score**	92	71	83	99	105	102	112	102
10	**Percent compliance**	83	100	100	92	98	100	100	94
11	**Appropriate for ULV locust and grasshopper spraying?**	No	Yes	Yes	Design modifications required	No	Yes	Yes	No

Key:

	Full compliance with FAO Guidelines on Minimum Requirements for Ground-Based Locust and Grasshopper Sprayers. Considered appropriate for ULV locust and grasshopper spraying.
	Incomplete compliance with FAO Guidelines on Minimum Requirements for Ground-Based Locust and Grasshopper Sprayers with one or more non-critical requirements failed. Some design modifications are needed to satisfy these requirements before it can be considered appropriate for ULV locust and grasshopper spraying
	Incomplete compliance with FAO Guidelines on Minimum Requirements for Ground-Based Locust and Grasshopper Sprayers with one or more critical requirements failed relating to safety, durability or efficacy. Not considered appropriate for ULV locust and grasshopper spraying.

The way the percent compliance is calculated.

The table above divides the sprayers into three categories with different colours – see key above for explanation.

The actual figures in Parameter 10 show how close to 100% compliant each sprayer was, so that manufacturers and potential purchasers can see how much design modification might be required to gain compliance in the future. A refinement in the compliance calculations is the weighting that each requirement is given – some were considered more important than others - as set out in Appendix 6. A complication in the calculations is the fact that not all requirements are applicable for all sprayers of a particular type, for a range of reasons - see Appendix 10. The two factors of weighting and applicability of requirements are taken into account in the way the percent compliance is calculated as follows:

Parameter 1. This is the total number of requirements relevant to each sprayer – see cells with ticks in the RA, MB, VP and VA columns in Appendix 9.
Parameter 2. Not all requirements carry the same 'weighting' – some of the requirements that are not applicable have a weighting of 1 and some have a weighting of 3 - see Appendix 6. Paramter 2 is the total for of all the requirements relevant to each sprayer once each of them has been multiplied by its weighting
Parameter 3. For each sprayer, there are a number of requirements that are relevant to that type of sprayer but for one reason or another are not applicable (n/a) to that particular sprayer. Parameter 3 gives this number of n/a requirements – see Appendix 10.
Parameter 4. Parameter 4 gives the total score for all of the n/a requirements once each of them has been multiplied by its weighting.
Parameter 5. This is the number of requirements that each sprayer failed to achieve (shown for interest)
Parameter 6. This is the score for the total score for all of the failed requirements once each of them has been multiplied by its weighting
Paremeter 7. This is the number of critical requirements that each sprayer failed to achieve. If any of these are failed, the sprayer is not considered appropriate for ULV locust and grasshopper spraying.
Parameter 8. This is the total possible score - the total of all weighted requirements (Parameter 2), minus the weighted n/a requirements (Parameter 4).
Parameter 9. This is the total score for all weighted requirements achieved – see Appendix 9.
Parameter 10. This is the percent compliance - the total score achieved (Parameter 8) as a percentage of the total possible score (Parameter 7).
Parameter 11. This gives the overall assessment of whether a sprayer is considered appropriate for ULV locust and grasshopper spraying. If a sprayer passes all requirements it is considered appropriate. If a sprayer fails one or more non-critical requirements, it is judged to need design modifications before it can be considered appropriate. If a sprayer fails one or more critical requirements, it is not considered appropriate due to the need for major redesign relating to the droplet spectrum it produces or other factors of safety or durability.

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 productive gathering offered the opportunity to evaluate the strengths and weaknesses of current machinery, against recently developed 'standards' for locust and grasshopper sprayers. 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.

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.

Some sprayers had useful refinements e.g. the automatic adjustment of flow rate according to forward speed on the Fontan Mobilstar, and the electronic flow control on the Micron Ulvamast. These exceeded the FAO requirements but it was decided not to evaluate them and make subjective judgements on their utility at the moment, although if proven to have significant advantages in field use, they may be included as requirements in future revisions of the FAO Guidelines on Minimum Requirements for Ground-Based Locust and Grasshopper Sprayers.

It should be emphasised that this report does not recommend purchase of any sprayer. However, the summary evaluation in Table 1 represents an independent assessment of the appropriateness for locust and grasshopper 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 inappropriate because they failed a critical requirement (either safety durability or efficacy). One manufacturer did not provide laser droplet spectrum data and felt that the time allowed to provide this was not sufficient. However, the panel felt that any manufacturer serious about promoting its sprayers in the market for locust sprayers should already have this data, given the specialist nature of the application task. The panel also felt that it was unlikely that any sprayer not fitted with a rotary atomizer would be able to comply with critical requirement 9.3. Other mechanisms of atomization do not have the precision to control droplet sizes as well as rotary devices. Other sprayers failed non-critical requirements and it is possible that design modifications in future might rectify these.

The workshop provided the opportunity for invited specialists and manufacturers to work in a participatory way to revise and refine the FAO Guidelines on minimum requirements and standards for ULV locust and grasshopper sprayers, and the related procedures to test machinery against them.

RECOMMENDATIONS

1. As with the 2002 event, this workshop provided the opportunity for rapid technical assessment of the current range of locust and grasshopper 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 information and data they will be asked to supply along with the equipment.

3. A very small number of the minimum requirements require specialist equipment to evaluate them. In particular, it is **recommended** that FAO CRC purchase a decibel meter so that noise levels at the operators ear can be measured accurately. It is also recommended that FAO CRC purchase one or more units of portable multimeters so that the electrical power consumption of sprayer can be measured easily.

4. The field testing of the minimum requirements generated useful feedback on the utility and practicality of each of the requirements. It also helped to identify some duplications, redundancies and logical inconsistencies. It is **recommended** that a second edition of the Guidelines on Minimum Requirements for Ground-Based Locust and Grasshopper be published in hard copy and online based on the modified version of the requirements shown at Appendix 9.

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, the Department for Locusts and Agro-aviation Affairs and in particular the Locust Control Base at Ismailia for providing vehicles, equipment, labor and clearance assistance, the sprayer manufacturers for providing representatives and spray equipment and the staff of the FAO Central Region Commission and the FAO Western Region Commission for their valuable assistance during the workshop. Grateful thanks are also due to all participants who contributed their unique expertise and experience.

APPENDIX 1. LIST OF INVITED COMPANIES

For protective clothing:

Toltecna Group	Malta
Andikona	Spain
Greenham Export	United Kingdom
Du Pont	United States
Dräger	Germany
Lakeland Industries Inc.	United States
Ansell Healthcare	United States
Kappler	United Kingdom

For camping equipment

Abinitio Overseas Inc.	India
Aipacs OAC	United Kingdom
Al Farooq Enterprises	Pakistan
Al Farooq Enterprises (Europe)	Italy
Al Mawsim Tents Industry LLC	United Arab Emirates
Al-Babar Imran Tentage	Pakistan
Alpinter	Belgium
Arvin Diba Co. Ltd	Iran
Best In-Tents Ltd	Kenya
BIAB International	Sweden
Canvas and Tent	South Africa
CICCI	Denmark
Elite Tools	Kenya
Global Relief Solutions Fzco	United Arab Emirates
HSNDS	Pakistan
NRS International	United Arab Emirates
ORT	Russia
ORT (South Africa)	South Africa
Universal Trading Corp.	Pakistan

For spray equipment

Berthoud – EXEL GSA sprayers	France
Curtis Dynafog	USA
Jacto	USA
Micron Sprayers	UK
Solo	USA
Stihl	USA
Swingtec	Canada
Swingtec	Germany (through their Agent in Sudan)
Pulsefog	USA
Chema	Egypt
China East Wuyi Electric Machinery	China
Jetstream,	Australia
Ledebuhr Industries, Inc,	USA
Seshin Enterprise Co.,	Korea
Spectrum	USA

APPENDIX 2. SPRAYERS AND MANUFACTURERS CONTACT DETAILS

Chema Industries
Head office: 303 Horeya Str, Sporting, Alexandria, Egypt.
Tel: 002 03 424 1313 / 425 0062
Fax: 002 03 429 2120
Email: chema@chema.com.eg
info@chema.com.eg
Factory : 26, 1st, Industrial Zone
New Nubaria City, Behira, Egypt
Tel: 002 (0)45 2632801
Fax:002(0)45 263 2796
Email: http://www.chema.com.eg/
http://www.chema.com.eg

Micron Sprayers Ltd
Bromyard Industrial Estate
Bromyard, Herefordshire
HR7 4HS, UK
Tel: +44 (0) 1885 482397
Fax: +44 (0) 1885 483043
Email: micron@micron.co.uk
http://www.micron.co.uk

Swingtec GmbH
Postfach 1322, 88307 Isny, Germany,
Tel. +49 (0) 7562 708-0,
Fax +49 (0) 7562 708-111,
e-mail: info@swingtec.de
www.swingtec.de

PLATFORM	TYPE	MANUFACTURER	MODEL
Portable	Passive drift	Micron	ULVA+
	Passive drift	Micron	ULV + with backpack
	Airblast	Micronair	AU8000
	Airblast	Swingtec GmbH	Fontan Portastar
Vehicle-mounted	Passive drift	Micron	Ulvamast V4
	Airblast	Chema	K13
	Airblast	Micronair	AU8115
	Airblast	Swingtec GmbH	Fontan Mobilstar

APPENDIX 3. PARTICIPANT LIST (SEE APPENDIX 10 FOR FULL CONTACT DETAILS)

NAME	ORGANISATION AND COUNTRY
Evaluation Panel	
Mohamed M. Abdel Rahman	Ministry of Agriculture & Land Reclamation ***Egypt***
Mohamed Abdel Aziz Hendy	Research Institute, Ministry of Agriculture & Land Reclamation**, *Egypt***
Ragab Bakri	General Department for Locust & Agro-Aviation Affairs, **, *Egypt***
Mamoon Al Alawi	Director of Plant Protection Department, Ministry of Agriculture**, *Oman***
Belai Fisehaye	Professional Mechanic, Ministry of Agriculture, ***Eritrea***
Kassahun Yitafgrn	Animal & Plant Health Regulation Directorate, ***Ethiopia***
Ali Hussin Al Janabi	Locust Research & Control Center, ***Saudi Arabia***
Abdulrahman F. AlSaegh	Locust Research & Control Center, ***Saudi Arabia***
Rabie A. Khalil	Plant Protection Directorate, ***Sudan***
Yassin M. Al Nakeeb	General Dept. for Plant Protection, ***Yemen***
Said Lagnaoui	Centre National de Lutte Antiacridienne, ***Morocco***
Munir Butrous	CRC ***Egypt***
Hans Dobson (Workshop Coordinator)	Natural Resources Institute, ***United Kingdom***
Manufacturers representatives	
Dietrich, Bernd-Ludwig	Managing Director, Swingtec GmbH, ***Germany***
Hosni Mohamed Shafik	Division Manager, Stachem Industrial Chemical. Public Health, ***Egypt***
Mohamed Abdel Salam El Shafei	- General Manager, Chema Industries, ***Egypt***
Ehsan Mohamed Mohamed	Chema Industries, ***Egypt***
Timothy Sander	Micron Sprayers, ***United Kingdom***
Anthony Outlaw	Micronair Sprayers, ***United Kingdom***

APPENDIX 4. PROGRAMME FOR SPRAYER TESTING WORKSHOP

Programme for Desert Locust Sprayer Testing Workshop, Ismailia (140 km east from Cairo along the Suez Canal) 10 – 14 May 2009

Day/Date May	Time	Activity	Who	Location
Sunday 10th	09.00	Registration and opening	Munir Butrous	Conference Room Ismailia Locust Control Base
	10.00	Introduction and outline of the workshop process	Hans Dobson	
	11.00	Coffee/tea break		
	11.30	Company presentations	Companies	
	13.00	Lunch break		
	14.00	Review of all available data and literature from companies	Evaluation team	
End of day one	16.00			
Monday 11th	09.00	Review of the FAO locust sprayer minimum requirements	Hans Dobson	Conference Room Ismailia Locust Control Base
	11.00	Coffee/tea break		
	11.30	Finalization of the testing procedures	Evaluation team	
	13.00	Lunch break		
	14.00	Preparation of sprayers and testing equipment	Evaluation team and companies	
End of day two	16.00			
Tuesday 12th	07.00	Field testing of sprayers – whole day	Evaluation team and companies	Field testing site at Ismailia
	Coffee/tea and lunch breaks will be served in the field			
Wednesday 13th	07.00	Field testing of sprayers – whole day	Evaluation team and companies	Field testing site at Ismailia
	Coffee/tea and lunch breaks will be served in the field			
Thursday 14th	09.00	Analysis of testing data	Evaluation team	Conference Room Ismailia Locust Control Base
	11.00	Coffee/tea break		
	11.30	Presentation of findings	Hans Dobson	
	13.00	Lunch break		
	14.00	Response by companies and evaluation of workshop	Companies, evaluation team	
	16.00	Workshop close	Munir Butrous	

APPENDIX 5. INFORMATION SUPPLIED BY MANUFACTURERS

Information	Chema K13	Micron Ulva +	Micron AU8000	Micron AU8115M	Micron AU8115E	Micron V4M	Micron V4E	Swingtec Fontan Mobilstar	Swingtec Fontan PortastarER
Evidence of droplet size spectrum	Not provided	See data (VMD = 71.1 µm % Vol 50 – 100 µm = 94.5)	See data (VMD = 78.3 µm % Vol 50 – 100 µm = 54.5)	See data (VMD = 74.2 µm % Vol 50 – 100 µm = 66.6)	Same as AU8115M	See data (VMD = 69.0 µm % Vol 50 – 100 µm = 74.6)	Same as V4M	VMD in required range but percentage of volume in size range 50 – 100 um is < 41%*	VMD in required range but percentage of volume in size range 50 – 100 um is < 43%*
Flow rate calibrations with ULV products;	0.5 – 2 l/min.	Colour coded feed nozzles (set of 3 for ULV)	Manually operated variable restrictor valve (5 positions)	Interchan-geable restrictor discs or variable restrictor valve (10 positions)	Electronic flow control (10 positions)	Interchan-geable restrictor discs or variable restrictor valve (10 positions)	Electronic flow control (10 positions)	83 ml/min upto 1.6 L/min LV mode	Interchang-able nozzle 17 ml/min upto 100ml/min
Price of the sprayer and main spare parts; (see key below)	Band 4	2 Portable	5 Portable	4 Vehicle	4 Vehicle	3 Vehicle	3 Vehicle	5 Vehicle	5 Portable
Operating and maintenance manuals;	2 manuals Eng./Arab.	Yes – list of languages - Arabic, English & French	Yes – list of languages - Arabic, English & French	Yes – list of languages - Arabic, English & French	Yes – list of languages - Arabic, English & French	Yes – list of languages - Arabic, English & French	Yes – list of languages - Arabic, English & French	Yes – list of languages - Arabic, English & French	Yes – list of languages - Arabic, English & French
Any spare parts or additional accessories e.g. calibration jugs, that are normally supplied with the sprayer	supplied	Feed nozzles (set of 3), disc cover	Basic tool kit, fuel mixing bottle, calibration tube	Full tool kit; restrictor discs; filter O-rings, cable ties, PTFE tape mounting bolts	Same as AU8115M	Full tool kit; restrictor discs; filter O-rings, cable ties, PTFE tape, mounting bolts, vibratak	Same as V4M	Tool kit + gasket, funnel with strainers and ear protection	supplied
The current distribution of their sprayers in locust affected countries;	No	Most	Approx 75%	Approx 50%	Few (new product)	New product (V3M in most)	New product (V3E in about 25%)	No	No
Any reports of operational use in above countries;	No	Yes – reference workshop participants	Yes – reference workshop participants	Yes – reference workshop participants	Yes – reference workshop participants	Yes – reference workshop participants	Yes – reference workshop participants	No	No
Any other reference materials.	2002 report & tool kit list	Yes -- see attached list	Yes -- see attached list	Yes -- see attached list	Yes -- see attached list	Yes -- see attached list	Yes -- see attached list	No	No

* Sprayers were sent after the workshop to the International Pesticide Application Research Centre at Imperial College London, Silwood Park for droplet measuring.

Price bands for locust sprayers

Price Band	***1***	***2***	***3***	***4***	***5***
Cost (US$) - Vehicle	0 - 1,000	1,000 - 2,000	2,000 - 5,000	5,000 - 10,000	10,000 – 25,000
Cost (US$) - Portable	0 - 50	50 - 100	100 - 500	500 - 1,000	1,000 - 2,000

APPENDIX 6. JUSTIFICATION FOR WEIGHTINGS

There were 6 requirements considered critical under three headings:

Safety requirements

1.4 relates to leaks from portable sprayers – clearly an important issue when the sprayer is in direct contact with the operator
1.14 relates to sprayer controls being clearly marked and within easy reach. This is also critical to prevent the sprayer being operated in the wrong way or switched on when it should be switched off.
8.4 is similar to 1.14 but is more specific in that it requires that vehicle mounted sprayer controls are located in the cab to prevent an operator having to sit in the back of the pickup vehicle, as has been seen in the past.

Durability

Given that long term destructive testing methods were not an option in this short workshop, 1.19 is a value judgement on whether the design and construction materials are likely to withstand the tough test of operating reliably in typical locust control conditions. This includes sometimes long trips to reach an infestation, as well as long periods actually spraying. Sprayers mounted on vehicles often have to travel over rocky or sandy terrain, steep inclines, corrugated roads, and continue working in hot, dusty conditions. Points that might lead to a fail are loose components, spray heads a long way from the roll and pitch axes of vehicle rotation (unless very well supported), spray tanks resting on sharp edges, vulnerable components too exposed, component parts not sufficiently strong.

Efficacy

Droplet size and spectrum are critical requirements since the sprayer must kill locusts when it uses ULV insecticide formulations at the recommended dose. Efficacy is determined by the size and range of sizes 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:

9.2 relates to 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 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. Requirement 9.3 states that the sprayer must be capable of producing a consistent droplet spectrum with at least 50% of the spray volume in the size range 50 –100 um when spraying UL formulations or equivalent blank formulations, as determined by laser droplet analysis. In fact in the previous workshop the best performance was considered to be when more than 80% of the spray volume is in this size range, but the minimum requirement point is currently set at 50%..

Weightings

	RA	MB	VP	VA	Results
1.1	✓	✓			Minor
1.2					Requirement removed
1.3					Requirement removed
1.4	✓	✓			Critical
1.5			✓	✓	Major
1.6	✓	✓	✓	✓	Minor
1.7	✓	✓	✓	✓	Minor
1.8	✓	✓	✓	✓	Major
1.9	✓	✓	✓	✓	Major
1.10	✓	✓			Minor
1.11	✓	✓	✓	✓	Minor
1.12	✓	✓	✓	✓	Minor
1.13	✓	✓	✓	✓	Minor
1.14	✓	✓	✓	✓	Critical
1.15			✓	✓	Minor
1.16		✓	✓	✓	Minor
1.17	✓	✓	✓	✓	Major
1.18	✓	✓	✓	✓	Major
1.19	✓	✓	✓	✓	Critical
2.1			✓	✓	Major
2.2	✓	✓	✓	✓	Major
2.3	✓	✓	✓	✓	Minor
2.4	✓	✓	✓	✓	Minor
2.5	✓	✓	✓	✓	Minor
2.6	✓	✓	✓	✓	Major
2.7	✓	✓	✓	✓	Minor

	RA	MB	VP	VA	Results
2.8	✔	✔	✔	✔	Minor
2.9	✔	✔	✔	✔	Minor
2.10	✔	✔			Minor
2.11			✔	✔	Minor
2.12	✔	✔	✔	✔	Major
2.13					Requirement removed
2.14	✔	✔	✔	✔	Major
2.15			✔	✔	Major
2.16			✔	✔	Minor
2.17			✔	✔	Major
2.18	✔	✔			Minor
2.19			✔	✔	Minor
3.1	✔				Major
3.2					Requirement removed
3.3					Requirement removed
3.4		✔			Minor
3.5		✔			Major
3.6	✔	✔	✔	✔	Major
3.7					Requirement removed
3.8	✔				Minor
4.1	✔	✔	✔	✔	Minor
4.2					Requirement removed
4.3	✔	✔	✔	✔	Major
4.4			✔	✔	Major
4.5			✔	✔	Minor
4.6		✔	✔	✔	Minor
4.7		✔	✔	✔	Major
4.8	✔	✔	✔	✔	Major
4.9	✔	✔	✔	✔	Minor
4.10	✔	✔	✔	✔	Minor
4.11		✔			Major
5.1	✔	✔			Major
5.2	✔	✔			Minor
5.3	✔	✔			Minor

	RA	MB	VP	VA	Results
5.4	✔	✔			Minor
5.5	✔	✔			Minor
5.6	✔	✔			Minor
5.7	✔	✔			Minor
5.8			✔	✔	Minor
5.9				✔	Major
5.10			✔	✔	Major
5.11					Requirement removed
6.1		✔		✔	Minor
6.2		✔			Major
6.3		✔			Minor
6.4		✔			Minor
6.5		✔			Minor
6.6		✔			Minor
6.7		✔		✔	Minor
6.8		✔		✔	Minor
6.9					Requirement removed
6.10		✔		✔	Major
6.11		✔		✔	Minor
6.12		✔		✔	Minor
6.13		✔		✔	Major
6.14		✔			Minor
6.15		✔		✔	Minor
6.16		✔		✔	Minor
6.17	✔				Minor
7.1	✔	✔	✔	✔	Major
7.2	✔	✔	✔	✔	Minor
7.3	✔	✔	✔	✔	Minor
7.4	✔				Major
7.5		✔			Major
7.6			✔		Major
7.7				✔	Major
7.8	✔	✔	✔	✔	Minor
7.9	✔	✔	✔	✔	Major

	RA	MB	VP	VA	Results
7.10	✔	✔	✔	✔	Minor
7.11	✔	✔	✔	✔	Minor
8.1		✔		✔	Minor
8.2		✔			Minor
8.3		✔			Minor
8.4			✔	✔	Critical
8.5	✔	✔	✔	✔	Major
8.6					Requirement removed
8.7			✔	✔	Minor
8.8			✔	✔	Major
8.9			✔	✔	Major
9.1	✔	✔	✔	✔	Major
9.2	✔	✔	✔	✔	Critical
9.3	✔	✔	✔	✔	Critical
9.4					Requirement removed

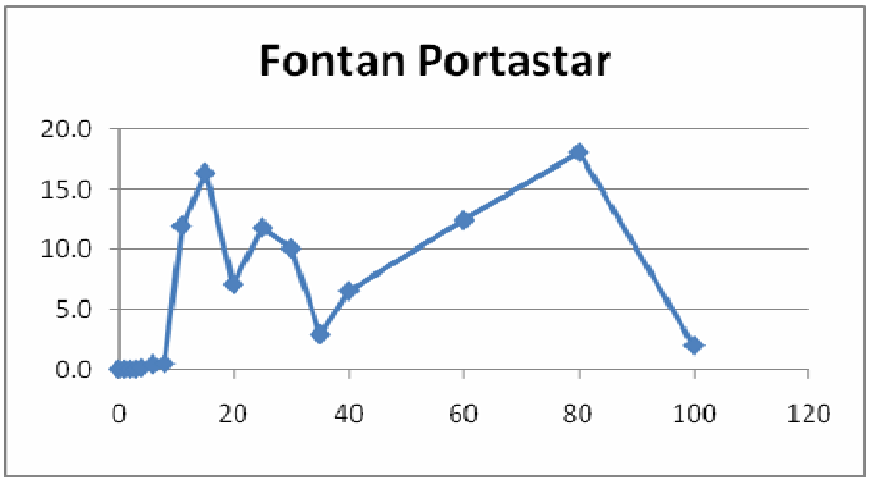
APPENDIX 7. TIMETABLE AND MODULES/GROUPS – 12 MAY 2009

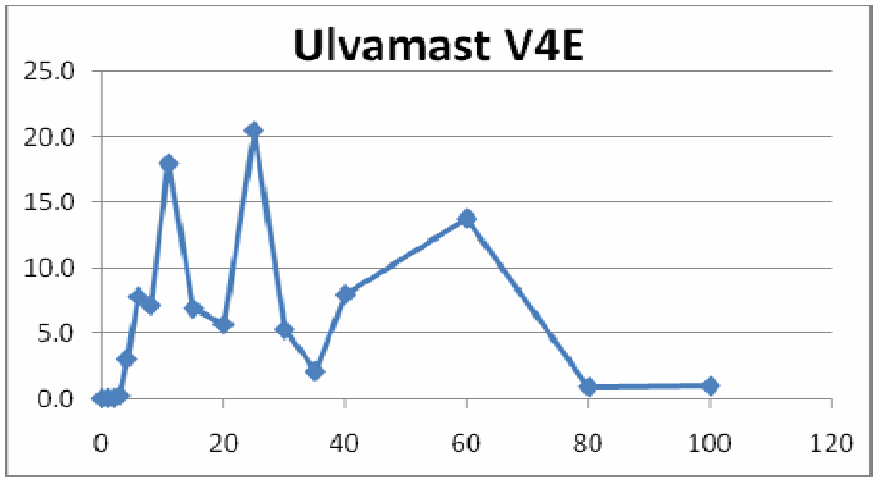
		Chema	***Micron***	***Micron***	***Swingtec***
Tues 12 May	***Modules***	***K13***	***Ulva +***	***AU8000***	***Fontan Portastar***
Time		***Group***	***Group***	***Group***	***Group***
08.00	1. General requirements	1	2	3	4
09.00	2. Tank, strainer and lid	2	3	4	1
09.30	3. Spray head assembly	2	3	4	1
10.00	4. Pumps, pesticide hoses and inline strainers	3	4	1	2
10.30	5. Sprayer support system	3	4	1	2
10.45	6. Power source	3	4	1	2
11.00	Break				
11.30	7. Flow rate	4	1	2	3
12.30	8. Control valves and switches	4	1	2	3
13.00	9. Atomizers (spray generating devices)	4	1	2	3

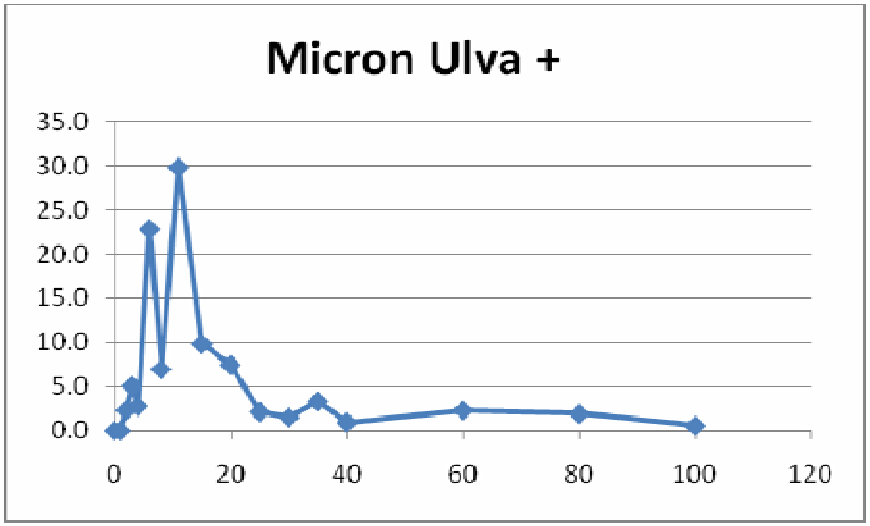
		Micron	***Micron***	***Micron***	***Swingtec***
		V4M/E	***AU8115M***	***AU8115E***	***Fontan Mobilstar ER***
		Group	***Group***	***Group***	***Group***
14.00	1. General requirements	1	2	3	4
15.00	2. Tank, strainer and lid	2	3	4	1
15.30	3. Spray head assembly	2	3	4	1
16.00	4. Pumps, pesticide hoses and inline strainers	3	4	1	2
16.30	5. Sprayer support system	3	4	1	2
16.45	6. Power source	3	4	1	2
17.00	7. Flow rate	4	1	2	3
18.00	8. Control valves and switches	4	1	2	3
18.30	9. Atomizers (spray generating devices)	4	1	2	3

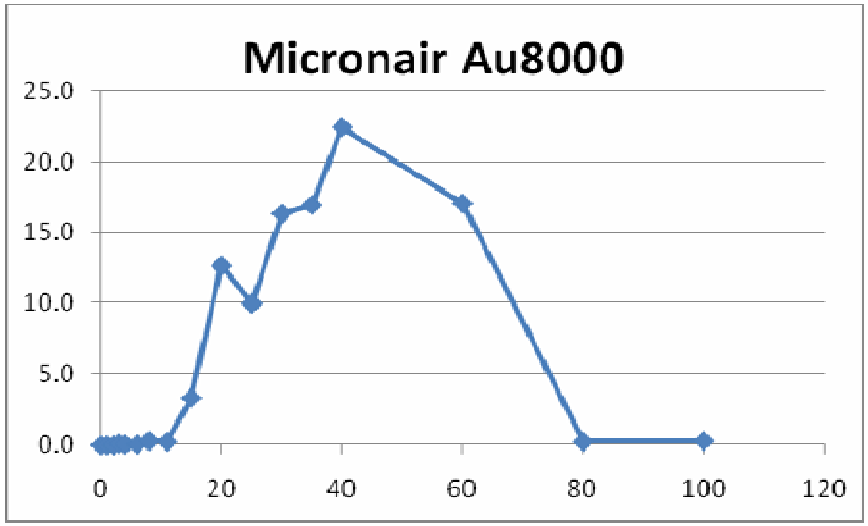
APPENDIX 8. GRAPHS OF DOWNWIND DROPLET COUNTS DURING DYNAMIC SPRAY TEST

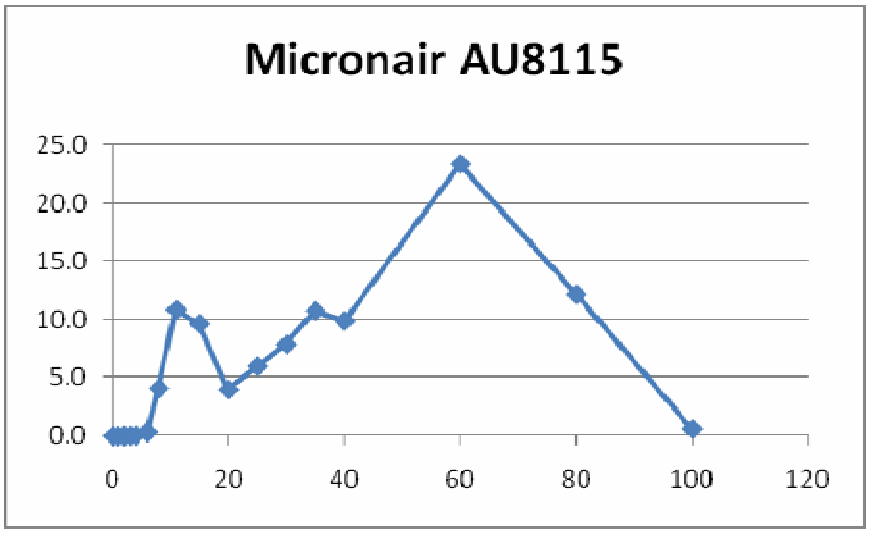
Note: X axis is percentage of total number of droplets counted and Y axis is distance downwind from emission point in metres

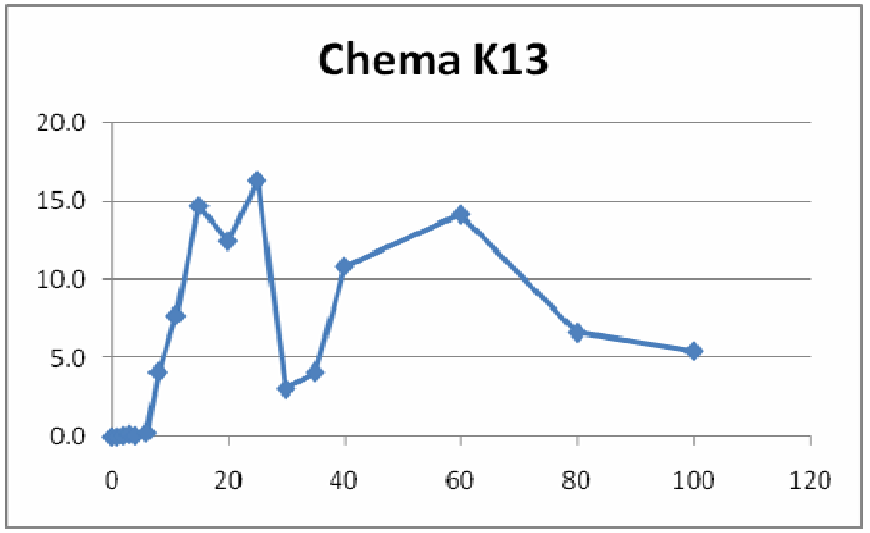


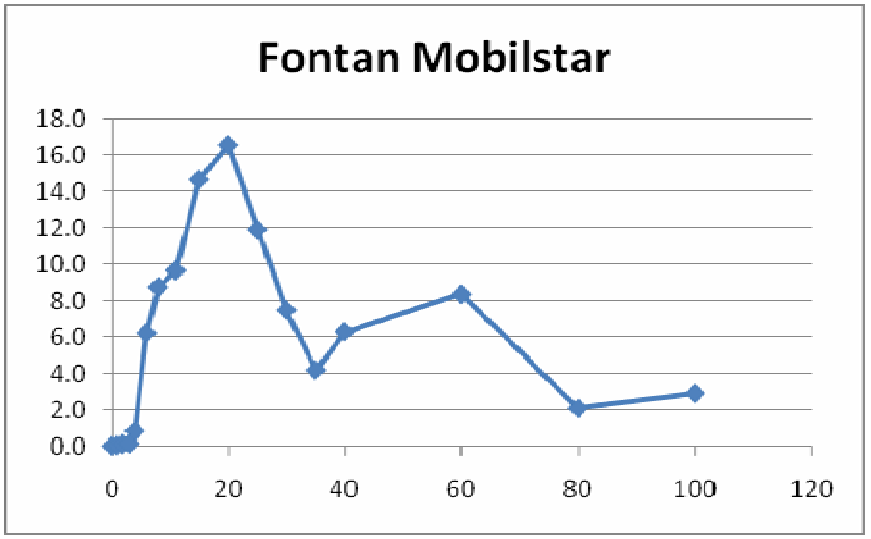







Micronair AU8115
25.0
20.0
15.0
10.0
5.0
0.0
0
20
40
60
80
100
120


Chema K13
20.0
15.0
10.0
5.0
0.0
0
20
40
60
80
100
120


Fontan Mobilstar
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
20
40
60
80
100
120

APPENDIX 9. MODIFIED LIST OF REQUIREMENTS WITH PASSES AND FAILS

Notes

a) Requirements that are highlighted in grey were excluded from the evaluations and are to be removed from future revisions of the Guidelines on Minimum Requirements for Ground-Based Locust and Grasshopper Sprayers due to duplication, redundancy or inconsistency.

b) The assessments and accompanying text below were based on interim judgements, and in some cases changed before the final assessment due to subsequent clarification, data provision or design modifications by the manufacturers. For the definitive list of failed requirements, see pages 11 – 29 in the main report.

	Module 1. General requirements	RA	MB	VP	VA	*Chema K13*	*Micron Ulva +*	*Micron Ulva + with back tank*	*Micronair AU8000*	*Fontan Portastar*	*Micron V4M/E*	*Micronair AU8115M/E*	*Fontan Mobilstar ER*
11.	Total mass for RA and MB sprayers when filled to the manufacturer's recommended maximum capacity should not exceed 25 kg. For RA sprayers, the following are acceptable guidelines for the division of the total mass: ■ 20 kg maximum for a backpack (or shoulder-slung) tank and battery power source carried on a waist belt, or on a shoulder strap. ■ 5 kg for a lance / battery case, spray head, spray bottle and a hand-carried tank, where present.	✔	✔				Pass	Pass	Pass pending confirmation that manufacturer will mark the spray tank with instructions not to fill more than 10 litres. Confirmed 12/6/09	Pass			
12.	The sprayer unit should be securely attached to the vehicle system.			✔	✔								

13.	The filling system for the spray tank(s) should permit safe, easy filling without overflowing or splashing (see later specific requirements for tank, strainer and lid).	✔	✔	✔	✔								
14.	When filled to the manufacturers recommended maximum capacity, the backpack/shoulder-slung sprayer/tank should not leak in such a way that the operator could be contaminated, either when the sprayer is upright or when tilted forward 90 degrees from the vertical (laid down on the straps). Over a 60 second test the following limits apply 0 degrees – 0 ml 45 degrees – 0.5ml Horizontal – 5.0 ml	✔	✔				Pass	Fail (leaks from the lid vent). Design modified - pass	Pass	Pass			
15.	When filled to the manufacturers recommended maximum capacity, the vehicle mounted sprayer should not leak either when upright or when tilted 45 degrees from the vertical in all directions.			✔	✔	Fail – will leak through vent				Pass	Fail (leaked at about 30 degrees)	Fail (leaks at around 30 degrees inclination	Pass
16.	The sprayer should be easy to clean both inside and out. Rough surfaces and awkward recesses should be avoided.	✔	✔	✔	✔	Fail – cage impedes access and many recesses	Pass	Pass	Pass	Pass	Pass	Pass	Fail (perforated engine shield, recesses, compartments etc)

17.	There should be easy access to service components such as engine oil, spark plug, pump, taps. Filters (air, fuel, pesticide) must be accessible and easily removable without tools.	✔	✔	✔	✔	Fail – cage prevents access Design corrected - pass	Pass	Pass	Pass	Pass	Pass	Pass	Fail (need to remove tank to access pesticide filter, pump etc).
18.	The outer surfaces of the sprayer should not trap or retain spray liquid, including the spray tank lid.	✔	✔	✔	✔	Fail – tank lid is concave. Design corrected - pass	Pass	Pass	Fail (lid retains liquid)	Pass	Pass	Pass	Pass on PE tank, Fail on stainless steel tank
19.	There should be no sharp edges, abrasive areas or unnecessary projections, which could injure the operator.	✔	✔	✔	✔	Fail – cage and filter have sharp edges. Design corrected - pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
110.	The backpack/shoulder slung sprayer/tank should be stable and stand upright on slopes up to 15% (1 in 7), irrespective of the amount of liquid in the tank, or the direction of the slope.	✔	✔				n/a	Pass	Pass	Pass			
111.	Servicing, maintenance, adjustment and cleaning of all sprayer components should be easily accomplished without needing special tools (i.e. tools specifically designed for the sprayer).	✔	✔	✔	✔	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

1.12	To facilitate the accurate identification of replacement parts, the sprayer should be clearly and durably marked to indicate the manufacturer's name and address and the sprayer name and model.	✔	✔	✔	✔	Fail – just website given	Pass	Pass	Pass	Pass	Pass	Pass	Pass
1.13	There should be a practical system in place to assist in the provision of replacement parts for a minimum of five years after the date of manufacture. The manufacturer should provide written assurance of this with the sprayer instruction manual (see Section 1.18).	✔	✔	✔	✔	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pending written assurance from manufacturer
1.14	All operational spray controls should be clearly marked and within easy reach of the operator from the normal driving/spraying position.	✔	✔	✔	✔	Pass	Pass	Pass	Pass	Pass	Pass (pending proper Arabic translation)	Pass	Pass
1.15	A supply of commonly required spares (i.e. any seals and gaskets that need regular replacement) should be supplied free of charge with a new sprayer			✔	✔	Pass	n/a	n/a	n/a		Pass	Pass	Pass
1.16	There should be a tool kit supplied as standard equipment by sprayer manufacturer with all necessary tools for installation, adjustment and operation.		✔	✔	✔	Pass	n/a	n/a	Pass	Pass	Pass	Pass	Pass

117.	All sprayer components that come into constant direct contact with ULV pesticide should be resistant to deterioration from contact with ULV pesticide formulations. The manufacturer should provide written assurance of this with the sprayer instruction manual. It should also provide information on the materials used in pipes, pump seals, tanks, valves and any other component that comes into direct contact with ULV pesticide.	✔	✔	✔	✔	Fail – the material in some of the components are not resistant to ULV pesticide formulations. Design corrected – presumed pass	Pass	Pass	Pass	Pass	Pass	Pass	Pending written assurance
118.	The manufacturer should supply with the sprayer, a clear, simple, illustrated, instruction manual in English, French and Arabic. (See Appendix 1 for detail on what the instruction manual should cover).	✔	✔	✔	✔	Fail – French manual not clear and not compliant	Pass	Pass	Fail (no Arabic)	Pass pending French and Arabic manuals to be sent to CRC	Pass	Pass	Pass pending French and Arabic being sent to CRC
119.	Sprayer construction materials and design should be able to withstand the tough conditions during storage, transportation and operation typical of locust control.	✔	✔	✔	✔	Fail – cage is weak. Atomizer mast is unstable. No dedicated place for middle section of mast to be stored for transport	Pass	Pass	Pass	Pass	Pass	Pass	Fail - concern about the stability of the spray head supports

	Module 2. Tank, strainer and lid	RA	MB	VP	VA	*Chema K13*	*Micron Ulva +*	*Micron Ulva + with back tank*	*Micronair AU8000*	*Fontan Portastar*	*Micro n V4M/E*	*Micronair AU8115M/E*	*Fontan Mobilstar ER*
	Note: For RA in this module, the tank refers to any separate container that is hand-held, carried on straps on the operator's back or slung on a strap over a shoulder, which is used to contain the spray liquid to be applied through a rotary atomizer. It does not refer to the smaller reservoir bottle attached to the spray head.												
2.1	Operator reach distances to the tank opening should not exceed 1.0 m vertically from the sprayer platform and there should be no obstructions around the filling area.			✔	✔	Fail – height is OK but the cage door gets in the way of safe filling					Pass	Pass	Pass
2.2	Sprayer tanks should be mechanically durable and fixed in such a way that rugged field operations will not puncture them.	✔	✔	✔	✔	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

2.3 The tank should be clearly and durably marked with: ■ the manufacturer's recommended maximum filling level, which should be equivalent to no more than 95% of the total volume of the tank; ■ appropriate intermediate filling levels.	✔	✔	✔	✔	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass with PE tank Fail with stainless steel tank (markings are on a sticker – easily detached once pesticide has been on it)
2.4 Further to Section 2.3, during spraying, the level of liquid in the tank should be clearly visible as it approaches empty.	✔	✔	✔	✔	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
2.5 Further to Section 2.3, during filling, even with any strainer fitted, the level of liquid in the tank should be clearly visible as it approaches the nominal maximum filling level.	✔	✔	✔	✔	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
2.6 The tank should include a strainer, located in the fill opening to filter the pesticide as it enters the tank.	✔	✔	✔	✔	Pass	Fail	Pass	Pass	Pass	Pass	Pass	Pass

2.7	The strainer should be easy to remove and fit with gloved hands.	✔	✔	✔	✔	Fail – filter is not easy to remove, gets stuck due to mesh being attached on the outside of the filter	n/a	Pass	Pass	Pass	Pass	Pass	Pass
2.8	For sprayers with no additional strainers, the tank opening strainer should have a mesh aperture size no greater than the smallest restrictor orifice recommended by the manufacturer.	✔	✔	✔	✔	Pass	n/a	Pass	Pass	Pass	Pass	Pass	Pass
2.9	The strainer mesh should be securely fitted to, or form part of, the strainer body.	✔	✔	✔	✔	Fail – mesh coming loose due to spot welding rather than welding all round	n/a	Pass	Pass	Pass	Pass	Pass	Pass
2.10	The tank strainer should be close fitting and permit safe, easy filling from a non-profiled container (i.e. one without a lip or spout) at a rate of 25 litres per minute without overflowing, splashing or lifting from its seat. Opening diameter should not be less than 100 mm across.	✔	✔				n/a	Pass	Pass	Pass		Pass	

2.11 The strainer should be close fitting and permit safe, easy filling from a non- profiled container (i.e. one without a lip or spout) without overflowing, splashing or lifting from its seat. Tank opening diameter should not be less than 150 mm.			✔	✔	Pass (but diameter is 170 mm so it passes due to modification to requirement)			Pass		Pass	Pass	Pass with PE tank Fail with stainless steel tank (filler is only 50 mm diameter)
2.12 The tank fill opening should be sealed with a lid that can be opened and securely closed with gloved hands and without tools.	✔	✔	✔	✔	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
2.13 When closed, the lid should not collect spray liquid.	✔	✔	✔	✔	Fail – the lid is concave	Pass	Pass	Fail (lid can collect spray liquid)	Pass	Pass	Pass	Pass
2.14 For all non-pressurised tanks, there should be a vent that allows air in.	✔	✔	✔	✔	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
2.15 There should be a separate flushing tank for cleaning fluid which can be switched into the spray line by use of clearly marked valves so that hoses, pumps, strainers and atomizers can be cleaned safely and easily.			✔	✔	Pass					Pass	Pass	Pass

2.16	Volume of the sprayer tank should be a minimum of 60 l and a 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.			✔	✔	Pass					Pass	Pass	Pass
2.17	The spray tank should incorporate a safe and convenient system to enable unused spray liquid to be discharged and collected safely. Any drain pipe should be fitted at the lowest point on the pesticide tank.			✔	✔	Fail – not fitted at the lowest point of the tank. No valve, and outlet is facing the vehicle cabin. Design modified - pass					Pass	Pass	Pass with PE tank. Fail with steel tank (no system in place to drain the main tank safely)
2.18	It should be possible to drain the tank to leave a total residual volume in the sprayer (including tank, pipes, etc) of less than 1% of total tank volume.	✔	✔				Pass	Pass	Pass	Pass			
2.19	It should be possible to drain the tank to leave a total residual volume in the sprayer (including tank, pipes, etc) of less than 0.5% of total tank volume.			✔	✔	Fail – likely to be over 1 litre of residual volume. Design modified - pass					Pass	Pass	Not measured but judged Fail

	Module 3. Spray head assembly	RA	MB	VP	VA	*Chema K13*	*Micron Ulva +*	*Micron Ulva + with back tank*	*Micronair AU8000*	*Fontan Portastar*	*Micron V4M/E*	*Micronair AU8115M/E*	*Fontan Mobilstar ER*
3.1	In all recommended working positions, the spray head should be a minimum of 500 mm from all parts of the operator's body to ensure that there is no direct contamination of the operator from the spray droplets.	✔					Pass						
3.2	The length of the air tube from the on/off lever to the air outlet should be no less than 400 mm.		✔						Fail (only 300 mm)	Fail (less than 200 mm)			
3.3	The sprayer should incorporate a robust "parking system" to secure the air tube when it is not in use.		✔										
3.4	The airtube should be fitted with a handle.		✔						Pass	Pass			
3.5	The liquid supply line to the nozzle should incorporate an on/off valve.		✔						Pass	Pass			

3.6	If the atomizer is exposed, a durable shield or cover should be supplied with the sprayer to protect it from physical damage in transit and in storage.	✔	✔	✔	✔	Pass	Pass		Pass	n/a	Fail (no cover supplied)	Fail (no protection in transit and storage)	n/a
3.7	If the atomizer is exposed, there should be a device to protect the atomizer from damage by low hanging branches or other obstacle.			✔	✔	Pass					Fail (no device to protect)	Pass	n/a
3.8	When the spray liquid to the atomizer is supplied solely from the bottle on the spray head (i.e. not re-filled from a back pack tank), it should be possible to fill the bottle via a funnel with an integral strainer, without spilling or splashing, at a rate of 5 litres per minute.	✔					Pass						

	Module 4. Pumps, pesticide hoses and inline strainers	RA	MB	VP	VA	*Chema K13*	*Micron Ulva +*	*Micron Ulva + with back tank*	*Micronair AU8000*	*Fontan Portastar*	*Micro n V4M/E*	*Micronair AU8115M/E*	*Fontan Mobilstar ER*
4.1	Spray hoses, when bent through 180 degrees at temperatures up to 40°C, should not kink (flatten) permanently.	✔	✔	✔	✔	Pass		pass	Pass	Pass	Pass	Pass	Pass
4.2	Hose connections should be easily adjustable and removable with gloved hands and should not leak when reconnected.	✔	✔	✔	✔								
4.3	Spray hoses should be of sufficient length to allow free movement and appropriate positioning of the spray head for spraying.	✔	✔	✔	✔	Pass		Pass	Pass	Pass	Pass	Pass	Pass
4.4	It should be possible to remove the pump without draining the tank.			✔	✔	Pass					Pass	Pass	Pass
4.5	There should be a strainer on the suction side of the pump with a maximum mesh aperture size of 0.5 mm.			✔	✔	Pass					Pass	Pass	Pass
4.6	In-line strainers should be readily accessible for cleaning and maintenance.		✔	✔	✔	Pass			Pass	Pass	Pass	Pass	Fail (pesticide tank needs to be moved to access the strainer)

4.7	It should be possible to clean the in-line strainers without needing to empty the sprayer tank(s).		✔	✔	✔	Pass			Pass	Pass	Pass	Pass	Pass
4.8	Hoses should be positioned so that, in the event of leakage or bursting, the risk of operator contamination is minimized. On vehicle-mounted sprayers, they should not pass through the vehicle cab.	✔	✔	✔	✔	Pass		Pass	Pass (but some problems with the pipe passing through the filter)	Pass	Pass	Pass	Pass
4.9	Hoses should be fitted to the sprayer so that they are not bent sharply (kinked), which could reduce the effective internal diameter of the hose.	✔	✔	✔	✔	Pass		Pass	Pass	Pass	Pass	Pass	Pass
4.10	Hose connections should be easy to disconnect and reconnect using gloved hands without needing special tools (i.e. tools specifically designed for the sprayer) and should not leak when reconnected.	✔	✔	✔	✔	Pass		Pass	Pass	Pass	Pass	Pass	Pass

4.11 The sprayer should have a partially pressurised tank (3-5 psi) or be fitted with a pesticide pump resistant to ULV formulations, or other active means of conveying the pesticide to the nozzle (other than gravity) to ensure reliable flow to the spray head even when it is being directed upwards.		✔						Pass	Pass			

Module 5. Sprayer supporting systems	RA	MB	VP	VA	*Chema K13*	*Micron Ulva +*	*Micron Ulva + with back tank*	*Micronair AU8000*	*Fontan Portastar*	*Micron V4M/E*	*Micronair AU8115M/E*	*Fontan Mobilstar ER*
RA and MB straps and padding. Note: For RA in this module, the straps and padding refers to any separate container that is hand-held, carried on straps on the operator's back or slung on a strap over a shoulder, which is used to contain the spray liquid to be applied through a rotary atomizer.												
5.1 Straps, padding and fixings should be strong, durable and made of non-absorbent material which retains a minimal volume of pesticide	✔	✔					Pass	Fail (retain liquid)	Pass			
5.2 Straps and padding should resist undue deterioration from contact with ULV pesticide formulations. The manufacturer should provide written assurance of this with the sprayer instruction manual (see Section 1.18).	✔	✔					Pass	Pass	Pass (pending written confirmation from manufacturer			

5.3 The load-bearing part of shoulder straps should be a minimum of 50 mm wide, except in the case of those RA sprayers that have a pesticide tank with less than 10 litres capacity, in which case the straps should be a minimum of 30 mm wide.	✔	✔					Pass	Pass	Pass			
5.4 When adjustable shoulder pads are included, they should remain firmly in place in their adjusted positions when the sprayer is in use.	✔	✔				n/a		n/a	Pass			
5.5 Straps fitted to a backpack sprayer or tank should be easily adjustable without assistance when the sprayer is full and in the working position on the operator's back.	✔	✔					Pass (but suggest longer straps be provided)	Pass	Pass			
5.6 Straps should be equipped with quick release catches that function efficiently when the tank is full and in the working position on the operator's back.	✔	✔					Pass	pass	Pass			
5.7 Backpack tanks when in the working position should be designed to be comfortable for the operator, either through the shape of the tank or through the provision of a back-frame.	✔	✔					Pass	Pass	Pass			

	VP and VA mountings and supports											
5.8	The sprayer should have a transport position to ensure the atomizer head or its supporting structure is not damaged in transit, unless the atomizer head is well supported with a structure that can withstand rough roads.			✔	✔	Fail – no special box or retaining system for extension tubes					Pass	Pass	n/a
5.9	The sprayer should be able to direct the spray upwards and downwards by a minimum of 45 degrees in order to take advantage of light winds or to improve targeting in windier conditions.				✔	Pass						Pass	Pass
5.10	The sprayer should have at least four boltholes in the base of the frame so that it can be bolted to the bed of the vehicle.			✔	✔	Pass					Pass	Pass	Pass
5.11	It is an advantage if the height of the atomizer can be varied to cope with different wind conditions.			✔									

Module 6. Power source	RA	MB	VP	VA	*Chema K13*	*Micron Ulva +*	*Micron Ulva + with back tank*	*Micronair AU8000*	*Fontan Portastar*	*Micron V4M/E*	*Micronair AU8115M/E*	*Fontan Mobilstar ER*
6.1 The engine should have a safe, robust starting mechanism.		✔		✔	Pass			Pass	Pass		Pass	Pass
6.2 The exhaust should be: ■ directed away from the operator's body; ■ positioned on the opposite side of the sprayer to the controls; ■ well-shielded to prevent burning the operator or a third party.		✔						Pass	Pass			
6.3 The engine should be isolated from the carrying frame by anti-vibration mountings.		✔						Pass	Pass			
6.4 The engine should be robustly protected against accidental physical damage.		✔						Pass	Pass			
6.5 The fuel tank and the fuel on/off valve should be positioned to minimise the risk of fuel spilling onto the engine.		✔						Fail (no fuel tap)	Pass			

6.6	The fuel on/off valve should be close to the fuel tank outlet and easily accessible to the operator when the sprayer is in the working position.		✔						Fail (no fuel tap)	Pass			
6.7	An easily serviceable fuel filter should be located in the line between the fuel tank and the carburettor.		✔		✔	Pass			Fail (present but not easily serviceable)	Fail (difficult to reach the fuel filter)		Pass	Pass
6.8	An easily replaceable air filter should be located directly on the carburettor intake.		✔		✔	Pass			Pass	Pass		Pass	Pass
6.9	Carburettor adjusting screws should be readily accessible without needing to remove parts or use special tools (i.e. tools specifically designed for the sprayer).		✔										
6.10	The noise level at the ear of the operator should not exceed 85 dB.		✔		✔	Cannot measure			Not measured (but very noisy and high pitched whine)	Not measured but judged a Pass		Not measured, but sounds loud	Pass (pending written assurance from manufacturer)
6.11	The fuel tank should have sufficient capacity for a minimum of one hour of continuous operation.		✔		✔	Pass			Pass	Pass		Pass	Pass
6.12	When a two-stroke engine is present, the fuel tank should be durably marked with the required fuel/oil ratio.		✔		✔	n/a			Pass	Pass		n/a	

6.13 All moving parts (including pumps driven by gears or pulleys) should be well shielded to prevent injury.		✔		✔	Pass			Pass	Pass		Pass	Pass
6.14 The fan should be protected by a casing measuring no more than 45 cm. in diameter.		✔						Pass	n/a			
6.15 The inlet to the fan should be equipped with a guard with a mesh-aperture size of between 5 mm and 10 mm.		✔		✔				Pass	n/a		Pass	n/a
6.16 The engine should still run after being exposed to heavy rain.		✔		✔	Fail – battery is unprotected and will short out in rain			Not tested but judged a pass due to spark plug covered in rubber boot and encapsulated electronic ignition	Pass		Not measured, but presumed OK, electronic ignition + rubber gaiter over spark plug	Not tested but presumed Pass – electronoic ignition and covered spark plug
6.17 The power consumption of the atomizer electric motor should not exceed 4 watts when loaded.	✔					Pass	Pass		n/a			

Module 7. Flow rate	RA	MB	VP	VA	*Chema K13*	*Micron Ulva +*	*Micron Ulva + with back tank*	*Micronair AU8000*	*Fontan Portastar*	*Micron V4M/E*	*Micronair AU8115M/E*	*Fontan Mobilstar ER*
7.1 Flow rate should be controlled by a system of interchangeable or indexed restrictors (not a continuously adjustable valve) or by pre-calibrated flow settings set by an electronic control box.	✔	✔	✔	✔	Fail – it has a continuou-sly adjustable valve	Pass		Pass	Pass	Pass	Pass	Pass
7.2 Where the is controlled by system of interchangeable or indexed restrictors, these should be clearly marked or colour coded and it should be possible to change them without special tools (i.e. without tools developed specifically for the sprayer).	✔	✔	✔	✔	n/a	Pass		Pass	Pass	Pass	Pass	n/a
7.3 Flow rate from restrictors with the same identity code and/or colour, i.e. which claim to have the same characteristics, should not differ by more than ± 5% from the nominal output. POSSIBLY INCREASE TO 10% - REVIEW IN THE FIELD	✔	✔	✔	✔	n/a	Pass		Not tested (no identical restrictors available)	Not measured (no identical restrictors available)	Not measur-ed	Not tested – no identical restricotrs available	N/a

7.4	The sprayer should be capable of producing a flow rate range of 0.02 – 0.14 l/min	✔					Pass with blank ulv oil (minimum is 0.20 l/min)	Pass with blank ulv oil (minimum is 0.20 l/min)					
7.5	The sprayer should be capable of producing a flow rate range of 0.06 – 0.2 l/min		✔						Fail (0.075 is the minimum). Max is OK.	Pass (minimum is 0.017 l/min) upper limit is OK at 0.32 l/min.			
7.6	The sprayer should be capable of producing a flow rate range of 0.06 – 0.9 l/min			✔							Fail Manual 0.15 to 1.55 Electro-nic 0.22 to 1.95		
7.7	The sprayer should be capable of producing a flow rate range of 0.18 – 1.7 l/min				✔	Pass (minimum 0.095, maximum OK)						Pass, pending assurance that can go low enough with blank ULV. Max is OK	Pass

7.8	Variation in flow rate should be no more than 10% regardless of terrain, speed of movement, volume of pesticide in the tank or height of emission.	✔	✔	✔	✔	Fail Static 0.393 l/min Dynamic 0.496	Pass		Pass ¼ tank low 1150 ml/min ¼ tank high 1060 ml/min Full tank low 1240 ml/min Full tank high 1140	Fail for smallest restrictor Full tank - Vertical 24 ml/min Full tank - Horizontal 44 ml/min Pass for biggest restrictor Horizontal 190 ml/min Vertical 170 ml/min	Pass Dynamic 0.392 l/min Static 0.415 l/min	Pass Static 0.45 l/min Dynamic 0.462 l/min	Pass Static: 0.4 l/min Dynamic: 0.4 l/min
7.9	It should be possible to collect pesticide directly during flow rate measurement (rather than using a 'loss' technique involving assessing the volume missing from the tank after a given time).	✔	✔	✔	✔	Pass	Pass		Pass	Pass	Pass	Pass	Pass
7.10	There should be minimal operator contact with pesticide when adjusting flow rate.	✔	✔	✔	✔	Pass	Pass		Pass	Pass	Pass	Pass	Pass
7.11	There should be no dripping from the atomizer after a period of 10 seconds after switching off or otherwise stopping the pesticide flow.	✔	✔	✔	✔	Pass	Pass		Pass	Pass	Pass	Pass	Pass

	Module 8. Control valves and switches	RA	MB	VP	VA	*Chema K13*	*Micron Ulva +*	*Micron Ulva + with back tank*	*Micronair AU8000*	*Fontan Portastar*	*Micron V4M/E*	*Micronair AU8115M/E*	*Fontan Mobilstar ER*
8.1	The engine throttle lever must remain firmly fixed in any pre-set position during operation.		✔		✔	Pass			Pass	Pass		Pass	
8.2	The engine should have an instant “cut out” mechanism that is readily accessible to the operator when the sprayer is in use.		✔						Pass	Pass		Pass	Pass
8.3	The pesticide flow controls should be on the air tube handle, not on the body of the sprayer.		✔						Pass	Pass			
8.4	Vehicle mounted sprayer controls (pump and atomizer) should be located in the vehicle cab, not on the body of the sprayer, and be durably and clearly labelled with on and off.			✔	✔	Pass					Pass	Pass	Pass
8.5	There should be a separate means of switching the pesticide flow and the atomizer on and off.	✔	✔	✔	✔	Pass	Pass		Pass	Pass	Pass	Pass	Pass

8.6	There should be well labelled controls with instructions to operator always to turn the atomizer on before the pump (except during flow rate calibration).			✔	✔	n/a							
8.7	It should be possible to isolate the controls so that atomizer and pump are not accidentally switched on in transit.			✔	✔	Pass					Pass	Pass	Pass
8.8	Controls should have lights or other clear system to indicate when they are switched on.			✔	✔	Pass					Pass	Pass	Pass
8.9	Any sprayer with electrically powered or controlled components should have a clear system to ensure that the positive and negative wires cannot be connected the wrong way round.			✔	✔	Pass					Pass	Pass	Pass

	Module 9. Atomizers (spray generating devices)	RA	MB	VP	VA	*Chema K13*	*Micron Ulva +*	*Micron Ulva + with back tank*	*Micron air AU8000*	*Fontan Portastar*	*Micro n V4M/E*	*Micronair AU8115M/E*	*Fontan Mobilstar ER*
91.	The sprayer should be capable of at least 50 hours of 'continuous' operation (5 hours per day for 10 consecutive days) at normal operating speed without loss of performance or needing maintenance. The manufacturer should provide written assurance of this together with the sprayer instruction manual (see Section 1.18).	✔	✔	✔	✔	Pass	Pass		Pass	Pending written assurance from company	Pass	Pass	Pending written assurance by manuf.
92.	The sprayer must be capable of producing a consistent droplet spectrum with VMD between 60 and 80 um when spraying UL formulations or equivalent blank formulations, as determined by laser droplet analysis. The manufacturer should provide data and written assurance of this together with the sprayer instruction manual (see Section 1.18).	✔	✔	✔	✔	Pending evidence of droplet spectrum	Pass		Pass	Pending evidence of droplet spectrum	Pass	Pass	Pending laser analysis and written assurance by manuf.
93.	The sprayer must be capable of producing a consistent droplet spectrum with at least 50% of the spray volume in the size range 50 –100 um when spraying UL formulations or equivalent blank	✔	✔	✔	✔	Pending evidence of droplet spectrum	Pass		Pass	Pending evidence of droplet spectrum	Pass	Pass	Pending laser analysis written assurance by manuf.

	formulations, as determined by laser droplet analysis. The manufacturer should provide data and written assurance of this together with the sprayer instruction manual (see Section 1.18).												
94.	The sprayer should have a means of altering the VMD to cope with different weather conditions. No major dismantling should be required.	✔	✔	✔	✔		Pass						

Appendix 10. REQUIREMENTS THAT ARE NOT APPLICABLE (N/A) AND THEIR WEIGHTINGS

Number	Requirement	Weighting	Chema K13	Micron Ulva +	Micron Ulva + with backpack	Micronair AU8000	Fontan Portastar	Micron V4 M/E	Micronair AU8115 M/E	Fontan Mobilstar ER
1.10	The backpack/shoulder slung sprayer/tank should be stable and stand upright on slopes up to 15% (1 in 7), irrespective of the amount of liquid in the tank, or the direction of the slope.	1		n/a						
2.7	The strainer should be easy to remove and fit with gloved hands.	1		n/a						
2.8	For sprayers with no additional strainers, the tank opening strainer should have a mesh aperture size no greater than the smallest restrictor orifice recommended by the manufacturer.	1		n/a						
2.9	The strainer mesh should be securely fitted to, or form part of, the strainer body.	1		n/a						
2.10	The tank strainer should be close fitting and permit safe, easy filling from a non-profiled container (i.e. one without a lip or spout) at a rate of 25 litres per minute without overflowing, splashing or lifting from its seat. Opening diameter should not be less than 100 mm across.	1		n/a						
3.8	When the spray liquid to the atomizer is supplied solely from the bottle on the spray head (i.e. not re-filled from a back pack tank), it should be possible to fill the bottle via a funnel with an integral strainer, without spilling or splashing, at a rate of 5 litres per minute.	1		1	n/a					
5.1	Straps, padding and fixings should be strong, durable and made of non-absorbent material which retains a minimal volume of pesticide	3		n/a						

5.2	Straps and padding should resist undue deterioration from contact with ULV pesticide formulations. The manufacturer should provide written assurance of this with the sprayer instruction manual (see Section 1.18).	1		n/a						
5.3	The load-bearing part of shoulder straps should be a minimum of 50 mm wide, except in the case of those RA sprayers that have a pesticide tank with less than 10 litres capacity, in which case the straps should be a minimum of 30 mm wide.	1		n/a						
5.4	When adjustable shoulder pads are included, they should remain firmly in place in their adjusted positions when the sprayer is in use.	1		n/a	n/a	n/a				
5.5	Straps fitted to a backpack sprayer or tank should be easily adjustable without assistance when the sprayer is full and in the working position on the operator's back.	1		n/a						
5.6	Straps should be equipped with quick release catches that function efficiently when the tank is full and in the working position on the operator's back.	1		n/a						
5.7	Backpack tanks when in the working position should be designed to be comfortable for the operator, either through the shape of the tank or through the provision of a back-frame.	1		n/a						
5.8	The sprayer should have a transport position to ensure the atomizer head or its supporting structure is not damaged in transit, unless the atomizer head is well supported with a structure that can withstand rough roads.	1								n/a
6.10	The noise level at the ear of the operator should not exceed 85 dB.	3	n/a			n/a	n/a		n/a	n/a
6.12	When a two-stroke engine is present, the fuel tank should be	1	n/a						n/a	n/a

	durably marked with the required fuel/oil ratio.									
6.14	The fan should be protected by a casing measuring no more than 45 cm. in diameter.	1					n/a			
6.15	The inlet to the fan should be equipped with a guard with a mesh-aperture size of between 5 mm and 10 mm.	1					n/a			n/a
7.2	Where the flow rate is controlled by system of interchangeable or indexed restrictors, these should be clearly marked or colour coded and it should be possible to change them without special tools (i.e. without tools developed specifically for the sprayer).	1	n/a							n/a
7.3	Flow rate from restrictors with the same identity code and/or colour, i.e. which claim to have the same characteristics, should not differ by more than ± 5% from the nominal output. POSSIBLY INCREASE TO 10% - REVIEW IN THE FIELD	1	n/a			n/a	n/a	n/a	n/a	N/a
	TOTAL number		**4**	**12**	**2**	**3**	**4**	**1**	**3**	**6**
	Total weighted number		**6**	**14**	**2**	**5**	**6**	**1**	**5**	**8**

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Appendix 12. LIST OF ACRONYMS

CLCPRO	The Commission for Controlling the Desert Locust in the Western Region
CRC	The Commission for Controlling the Desert Locust in the Central Region
EMPRES/CR	Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases Programme for Central Region
FAO	Food and Agriculture Organization of the United Nations
MB	Mist Blower
NGOs	Non Government Organizations
NRI	Natural Resources Institute
PPE	Personal Protective Equipment
RA	Rotary Atomizer
SWAC	The Commission for Controlling the Desert Locust in South West Asis
UL	Ultra Low
ULV	Ultra Low Volume
µm	micometre
US	United States
VA	Vehicle Mounted Airblast Sprayer
VMD	Volume Median Diameter
VP	Vehicle Mounted Passive Drift Sprayer
WS	Workshop