FINAL REPORT

CRDC UQ 33C

Laboratory and Field Evaluation of the Narrow Spectrum 'Unimizer' Nozzle

**The Following staff from
The Centre for Pesticide Application and Safety (CPAS),
The School of Agronomy and Horticulture,
The University of Queensland, Gatton Campus
have contributed to this project;**

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Cotton
RESEARCH & DEVELOPMENT

Annual, Progress and Final Reports

REPORTS

Part 1 - Summary Details

Please use your TAB key to complete part 1 & 2.

CRDC Project Number: **UQ33C**

Annual Report: ☐ Due 30-Sep-03

Progress Report: ☐ Due 29-Jan-03

Final Report: ☒ Due 30-Sep-03

(or within 3 months of completion of project)

Project Title: Laboratory and field evaluation of the narrow spectrum Unimizer nozzle

Project Commencement Date: 1/12/01 **Project Completion Date:** 1/12/02

Research Program: Insect Management

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Part 3.3 – Final Reports

The points below are to be used as a guideline when completing your final report.

1. Outline the background to the project.

Unispray have developed a new centrifugal energy nozzle, the "Unimizer", for the aerial application of pesticides. The new nozzle is designed to substantially reduce pesticide spray drift resulting from the aerial application of pesticides in the cotton industry. The nozzle is designed to generate a very low range of droplet sizes, (having a relative span of less than 0.8 compared with 1.2 –1.6 for most currently available nozzles) and a volume median diameter of 250 µm.

Initial testing of prototypes, conducted (fee for service) by CPAS at the University of Queensland, Gatton using the UQ/CRDC wind tunnel pesticide research facility, suggested that the "Unimizer" could potentially reduce spray drift by between three and five times when the performance is compared to its nearest commercially available competitor. This is a significant improvement on current technology. Further details on the nozzle and test results are available at http://www.atomisers.com.

Based upon the success of the prototype in the early wind tunnel studies further studies were undertaken to independently assess and validate the drift reducing capability of the Unimizer nozzle system

2. List the project objectives and the extent to which these have been achieved.

Objective	**Extent to which objective achieved**
1) Quantify the performance of the nozzle under a range of operating conditions using the pesticide wind tunnel research facility.	Several nozzle variants, including a fixed wing, helicopter and Micronair retrofit version were tested in the wind tunnel. The wind tunnel studies were used to refine and improve the nozzle system.
2) Pattern test a single aircraft for use in the field studies.	A helicopter has been pattern tested with the helicopter version of the nozzle.
3) Determine drift profiles on 20m high towers from two simultaneous applications of fluorescent tracer applied using Unimizer nozzles and CP nozzles under a range of environmental conditions	Based on results from the wind tunnel studies, pattern testing and market requirements, Unispray decided to concentrate on a "retro fit" version that can easily be added to existing Micronair units. It was decided to delay field testing for this version. Due to delays in construction by the manufacturer, only one test version was available for the wind tunnel studies. To date an aircraft has not been fully fitted with these nozzles for field evaluation. The Agdrift model however was used extensively to provide a predictive assessment of spray drift based on droplet size measured in the wind tunnel.
4) Assess the performance of the nozzle under commercial field conditions using protocols established in UQ27C & UQ31C.	Due to the unavailability of nozzles an aircraft has not been fully fitted with these nozzles to enable a field evaluation to be conducted.
5) Develop a set of operating procedures in preparation for testing by Australian industry (beta trials).	A model has been produced that predicts the droplet size emitted by the Micronair version of the nozzle for various nozzle operating parameters

3. **How has your research addressed the Corporations three outputs: Sustainability, profitability and international competitiveness, and/or people and community?**

This project has assisted in the development of holistic environmental systems by introducing a new nozzle to reduce the adverse environmental impact of spray drift. It will also improve chemical management of pests by allowing access to a greater treatment window.

4. **Detail the methodology and justify the methodology used.**

4.1. Droplet size measurement

The wind tunnel research facility located at the University of Queensland, Gatton Campus was extensively utilised in this project to measure the droplet size generated by the Unimizer nozzle. The CRDC provided a major financial contribution towards the establishment of the wind tunnel as part of project UQ27C. The wind tunnel facility is described in detail in the Final Report for project UQ27C.

The facility comprised an open circuit wind tunnel, a transparent working section, a Malvern 2600 laser diffraction analyser and associated gantry and an exhaust air scrubber extraction system. A 400mm by 400mm contraction section was used to accelerate the air up to operational speeds of 75 m/s (140 knots). Two gantries were used to independently position the laser-diffraction particle-size analyser and, the nozzle system. This allowed the emitted spray plume to be traversed through the laser beam. A diagram of the facility is shown in Figure 1 and photographs of the facility are shown in Figure 2.

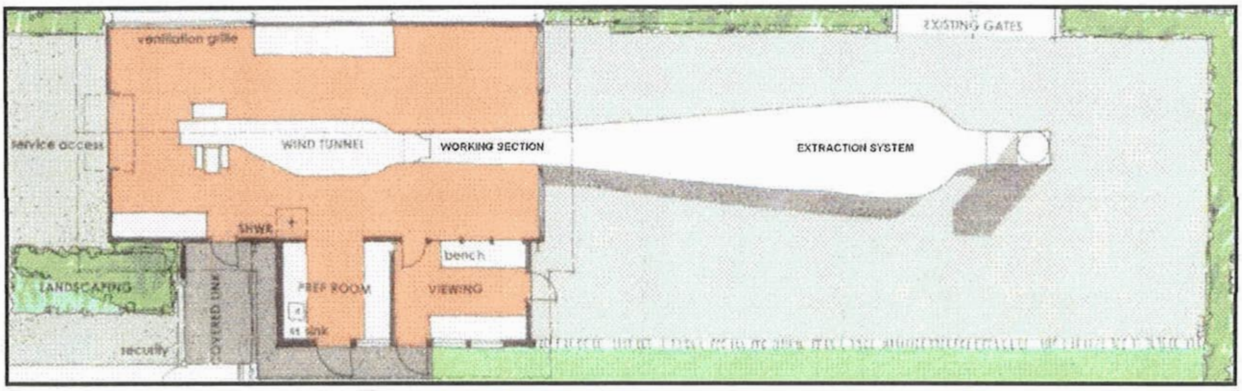

Figure 1. Plan view of the pesticide wind tunnel research facility.

Figure 2. Pesticide Wind Tunnel Research Facility.

A laser-diffraction device (Malvern 2600, Malvern Instruments, UK) was used to measure the droplet size. The Malvern is an internationally recognised industry standard for droplet and particle characterisation. It has a range of lenses and accessories for characterising sprays, powders and liquid emulsions. The 800 mm focal length lens was selected to enable particle sizes range between 4 μm and 1504 μm to be measured. In use, the sample is illuminated by a visible-wavelength He/Ne laser.

The particles or droplets scatter some of the light at angles which are characteristic of their size, forming a series of annular diffraction rings. The scattered light is collected by a Fourier optical system and focused on a radial diode array detector. The signal from each detector is amplified and digitised and the complete light energy pattern is analysed by a computer to derive the size distribution. The laser beam of the Malvern 2600 was located approximately 200 mm from the end of the nozzle.

The Unimizer nozzles were mounted in the working section of the wind tunnel. Figure 3a shows the Unimizer prototype (hrlicopter version) mounted in the working section and Figure 3b shows the Micronair retrofit version.

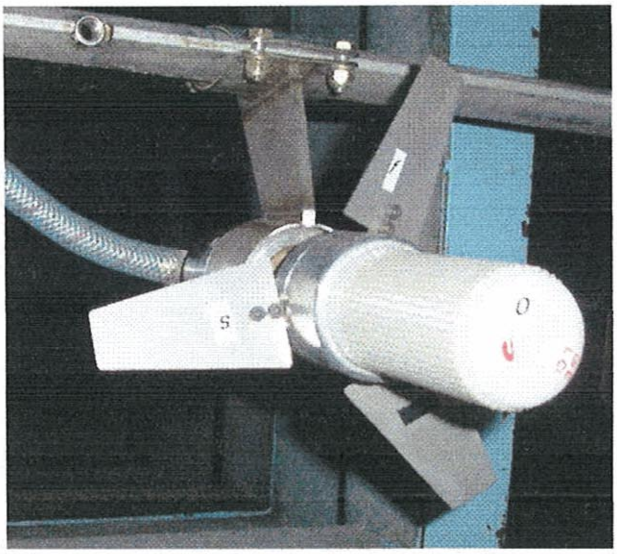

Figure 3a. Unimizer prototype helicopter version

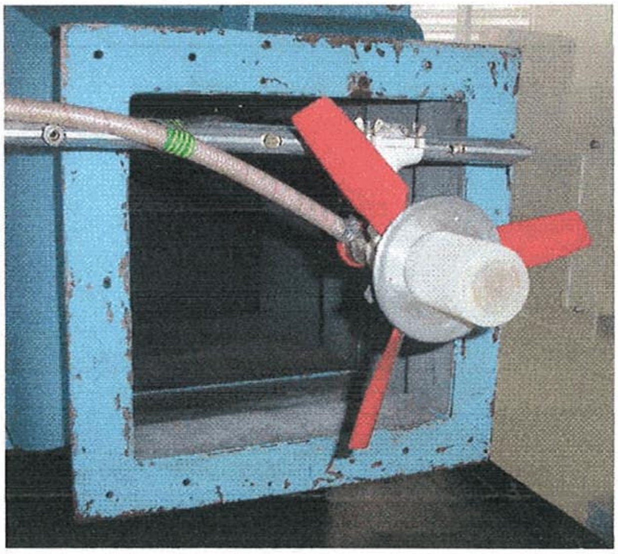

Figure 3b. Unimizer "Micronair retrofit" version

Changing the blade angle setting varied rotational speed of the Unimiser nozzle. The rotational speed for the Micronair retrofit version was measured both dry (without liquid flow) and wet (with liquid flow) using a Micronair transducer. A strobe light was used to measure the rotational speed of the helicopter Unimizer version.

The test formulations were placed in a 14L tank and an electric variable speed motor and lobe pump used to deliver the required flowrate to the nozzle. Each treatment was replicated twice.

4.2. Pattern testing of a helicopter fitted with Unimizer nozzles

A series of flight tests were conducted to establish the linear ground deposit pattern and optimum flight lane separation of a Bell 47 helicopter (VH-SON) fitted with up to six helicopter versions of the Unimizer nozzle.

To determine the pattern beneath the aircraft, a movable array (40 m long) was positioned perpendicular to the flight direction of the aircraft. The array was designed to pivot around the centre position of the array so that the samplers could be rapidly orientated to be perpendicular or parallel with the prevailing wind direction (Figure 4). Water sensitive cards were placed at 1 metre spacing along the length of the array. After each pass of the helicopter, the cards were collected and a portable image analysis system used to record spray deposits on the cards. (Swathkit, Droplet Technologies). The deposition of the spray (water) was expressed in terms of droplet number (droplets per cm^2), area (percentage surface area covered) and volume (L/ha).

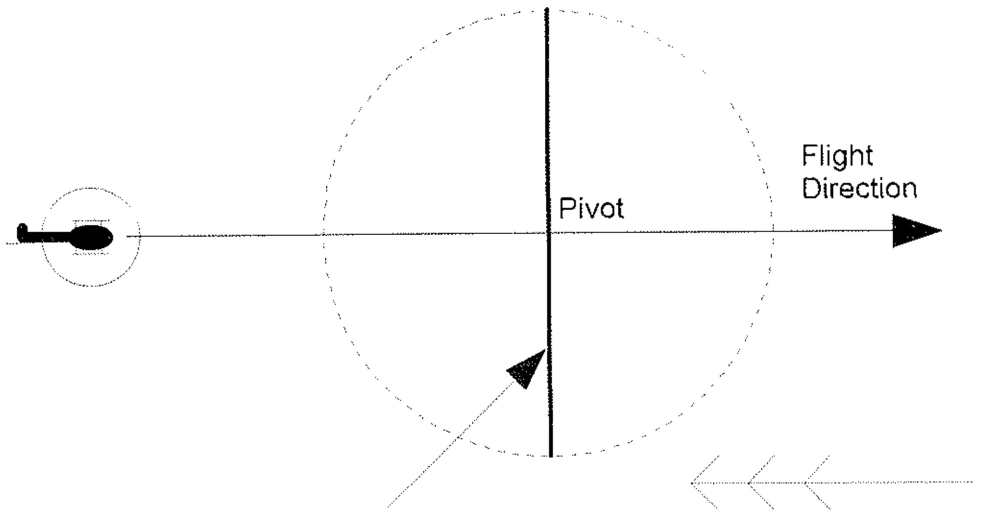

Figure 4 Sampler layout for determining the effective swath, and optimum flight lane separation of a helicopter fitted with six Unimiser nozzles

The local meteorology, (temperature, relative humidity, wind direction and speed) was recorded during the spray trials.

The droplet distribution patterns were analysed to:

(i) determine the effect of various nozzle configurations on the ground distribution pattern

(ii) calculate the optimum flight lane separation. The deposit patterns were overlapped to determine the optimum flight lane separation for each of the nozzle configurations tested.

Using suitable computer software (Swathkit) each single flight line deposit pattern was used to calculate the coefficient of variation (CV), and theoretical mean application rate that would be obtained at different lane separations if the ground pattern was overlapped by a sequential build up of a number of runs. The CV gives a measure of the uniformity of the total spray distributed across the paddock, as built up over a number of runs. A low CV indicates that an even distribution would be achieved over a field. In conjunction with mean deposit levels, this data can be used to help predict the most suitable flight lane separation for specific application missions. The outputs were calculated assuming that the aircraft was flying a 'racetrack' pattern.

4.3. Downwind drift modelling

The full droplet spectrum as measured in the wind tunnel was used in conjunction with spray drift simulation models such as the United States Spray Drift Task Force (SDTF) drift model AgDRIFT® to predict spray drift values downwind of treatment area. The AgDRIFT® spray drift model was designed to assist in the registration of agrochemicals and assess off target risks based on realistic input parameters.

5. Detail results including the statistical analysis of results.

5.1. Droplet size measurement

5.1.1. Unimizer prototype – helicopter version

A summary of the results is shown in Table 1. The volume median diameter (VMD) and the relative span from these tests at rotational speeds of 5000rpm and 3000rpm are shown in Figure 5. Table 2 and Figure 6 show the effect of various spray mixtures on the droplet size. Droplet size from earlier prototype versions can be found at http://www.atomisers.com.

Table 1. Summary of droplet size measurements. Unimizer (heliocpter version) spraying potable water in an airstream of 26 m/s

Flowrate L/min	Blade Setting mm	Rotational Speed dry rpm	Rotational Speed wet rpm	Droplet Size (µm) VMD	Droplet Size (µm) D[v,0.1]	Droplet Size (µm) D[v,0.9]	Relative Span
5	20	7200	~~5600~~	264	173	393	0.84
10	20	7200	5200	281	195	399	0.72
14	20	7200	4900	280	192	399	0.74
5	22	6500	5400	264	166	396	0.87
10	22	6500	5000	285	197	411	0.75
14	22	6500	4600	290	207	419	0.73
5	28	3600	3400	339	241	461	0.65
10	28	3600	3200	370	249	486	0.64
14	28	3600	3100	382	283	506	0.59

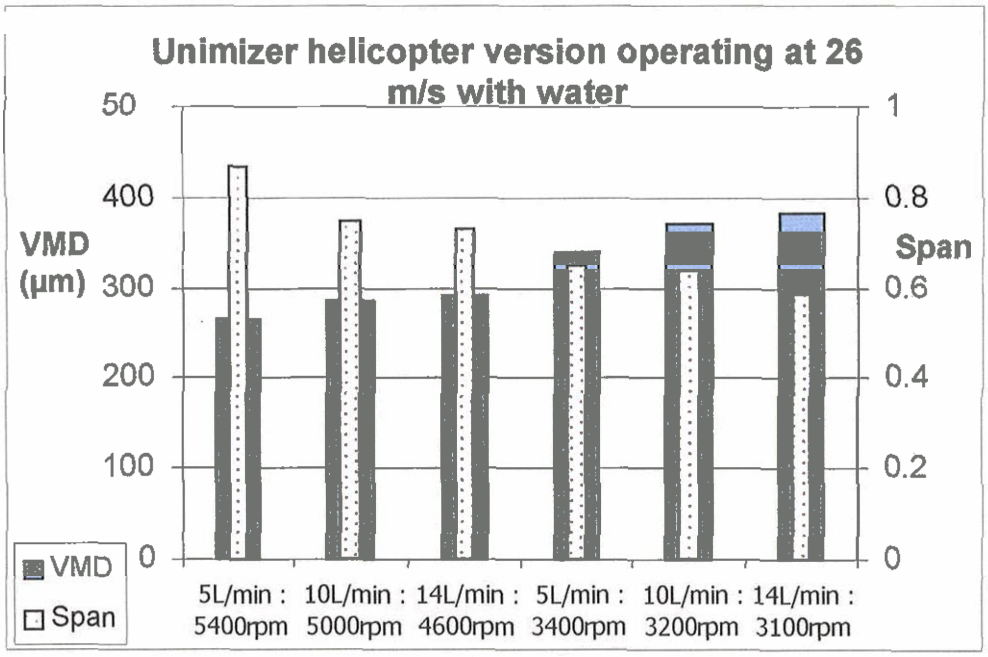

Figure 5. Volume median diameter (VMD) and relative span for Unimizer helicopter nozzle operated at 26m/s and spraying water

Table 2. Summary of droplet size measurements from Unimizer spraying various spray mixes in an airstream of 26 m/s and flow rate of 10 L/min

Mix	Blade setting mm	Rotational Speed dry Rpm	Rotational Speed Wet Rpm	Droplet Size (µm) VMD	Droplet Size (µm) D[v,0.1]	Droplet Size (µm) D[v,0.9]	Relative Span
Water	22	6500	5000	267	194	379	0.69
0.1% Agral	22	6500	5000	270	187	401	0.80
10% DC-Tron	22	6500	5000	278	191	390	0.72
10% DC-Tron + 0.6g/L 41-A	22	6500	5000	437	226	697	1.08

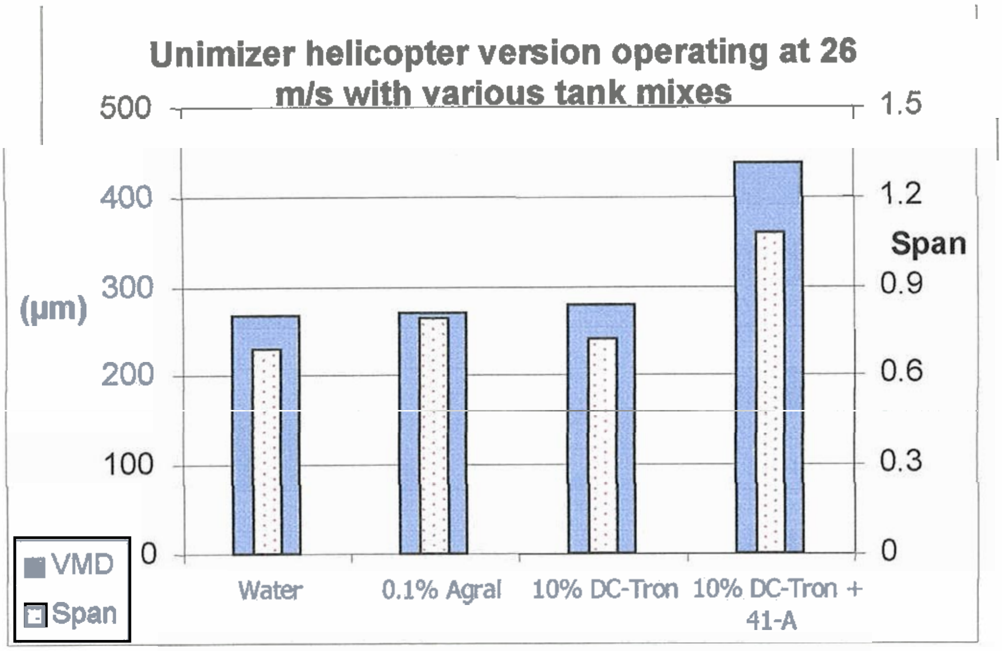

Figure 6. The effect of spray mixture on volume median diameter (VMD) and rleative span for the Unimizer nozzle operated at 26m/s

5.1.2. Micronair Retrofit version

Droplet size was measured over a range of nozzle rotational speeds, liquid flowrates and airspeeds that could be encountered in the field. Testing was initially undertaken with water only and then later repeated with a Water + 0.1% Agral mix. The Agral was added to modify the physical characteristics the formulation and make the solution more representative of an actual tank mix. In general a slightly larger range of droplet sizes (larger span) was generated with the Water + Agral mix.

From the wind tunnel measurements, a regression analysis was performed on the data to develop a predictive model that would determine droplet size as a function of the variables tested in the wind tunnel. The general form of the equations from the regression analysis is given below:

$$Size = A + B \times Flow + C \times Airspeed + D \times \log(RPM) + E \times Flow^2 + F \times Airspeed^2 + G \times \log(RPM)^2$$
$$+ H \times Flow \times Airspeed + I \times Flow \times \log(RPM) + J \times Airspeed \times \log(RPM)$$

The coefficient for each droplet size parameter and the adjusted R^2 values are given in Table 3 for both Water alone and Water + 0.1% Agral. From this analysis, an EXCEL based "nozzle calculator" was developed. (Figure 7). A full working copy of the calculator has been included with this report. Figures 8 and 9 show the predicted values compared to the measured values.

Table 3 Coefficients used in the model for each droplet size statistic and the resultant R^2 value

Coefficients	Water			Water + Agral		
	VMD	D[v,0.1]	D[v,0.9]	VMD	D[v,0.1]	D[v,0.9]
A	-1.168	-15.67	0.13	12.884	3.531	18.786
B	-0.05984	-0.03075	0.05063	-0.04124	0.00498	-0.07782
C	-0.01041	-0.03903	-0.01106	-0.01239	-0.02988	0.000831
D	2.862	11.372	2.078	-4.8643	0.444	-8.064
E	-0.00011	-0.0003	4.13E-05	-0.00029	-0.00041	-0.00016
F	-3.5E-05	-9.6E-05	-7.7E-06	-3E-05	-1.9E-05	-1.4E-05
G	-0.5346	-1.811	-0.3933	0.5382	-0.2152	0.9899
H	-9.8E-05	-0.0002	-0.00013	-1.9E-05	-5.8E-05	-1.7E-05
I	0.020335	0.01408	-0.00941	0.014634	0.0032	0.023613
J	0.004237	0.014441	0.003247	0.003925	0.007479	-0.00012
R^2	**96.3%**	**92.3%**	**97.9%**	**97.6%**	**97.9%**	**94.5%**

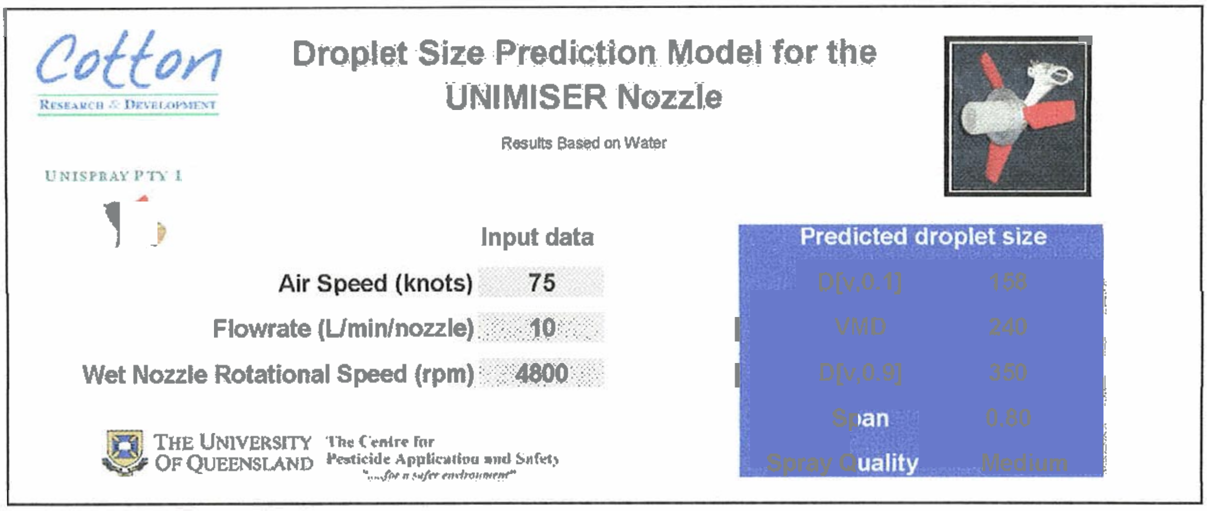

Figure 7. "Nozzle calculator" to predict droplet size emitted by a Unimiser nozzle.

5.2. Pattern Testing of Helicopter fitted with Unimizer Nozzles

Figure 10 shows the ground deposit pattern achieved with three Unimizer nozzles mounted on each side of the helicopter and Figure 11 shows the ground deposit recorded with two nozzles in operation on each side of the aircraft. The patterns show that a low amount of material was consistently deposited beneath the centreline of the helicopter. This is also illustrated in photographs taken at the time (Figure 12a). In an effort to fill this gap, two additional hollow cone D4/25 hydraulic nozzles were fitted beneath the centre of the helicopter and operated in conjunction with the Unimizer nozzle units. Figure 12b and Figure 13 show that this modification increased the amount of material deposited directly beneath the helicopter.

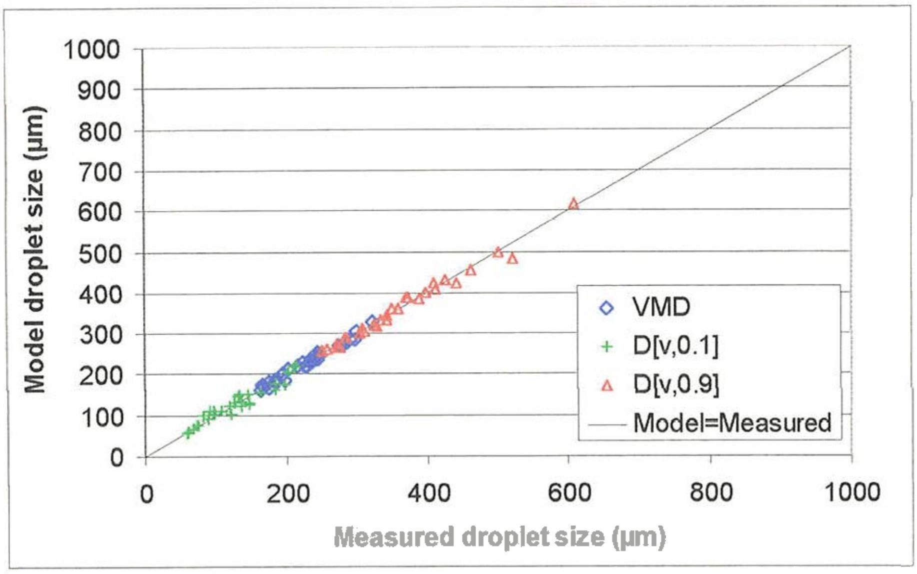

Figure 8 Comparison of predicted values (model) against measured values (laser diffraction) when spraying water

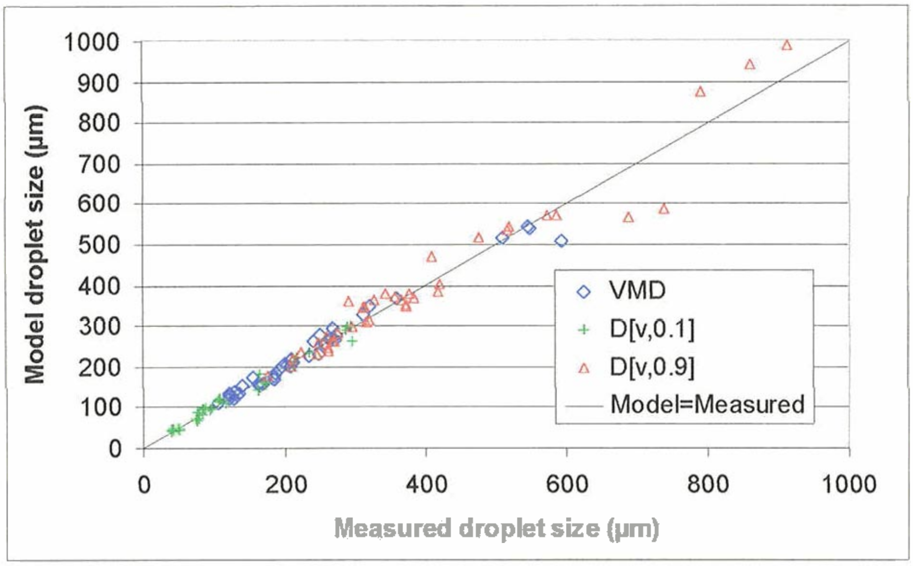

Figure 9 Comparison of predicted values (model) against measured values (laser diffraction) when spraying a mix of water plus 0.1% Agral

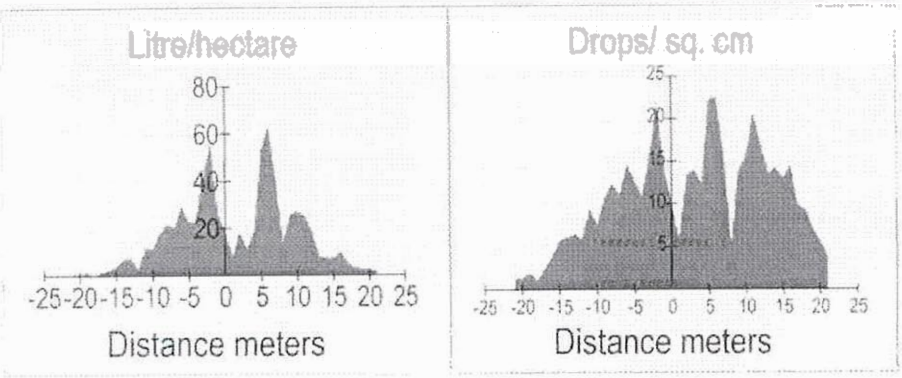

Figure 10 Helicopter ground deposit pattern using three Unimizer nozzles per side

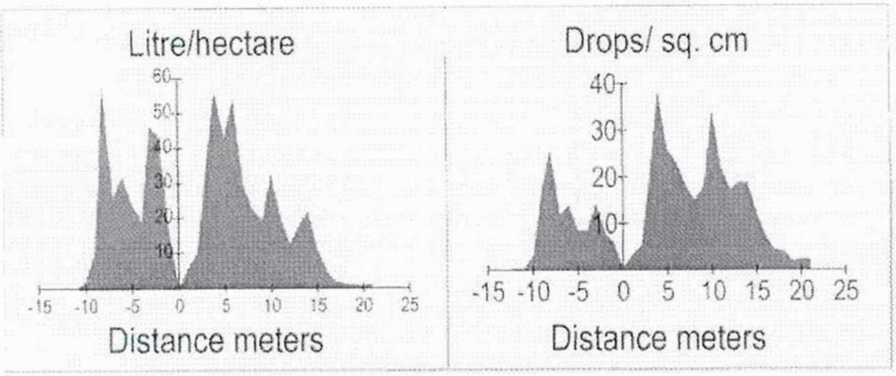

Figure 11 Helicopter ground deposit pattern for two Unimizer nozzles per side

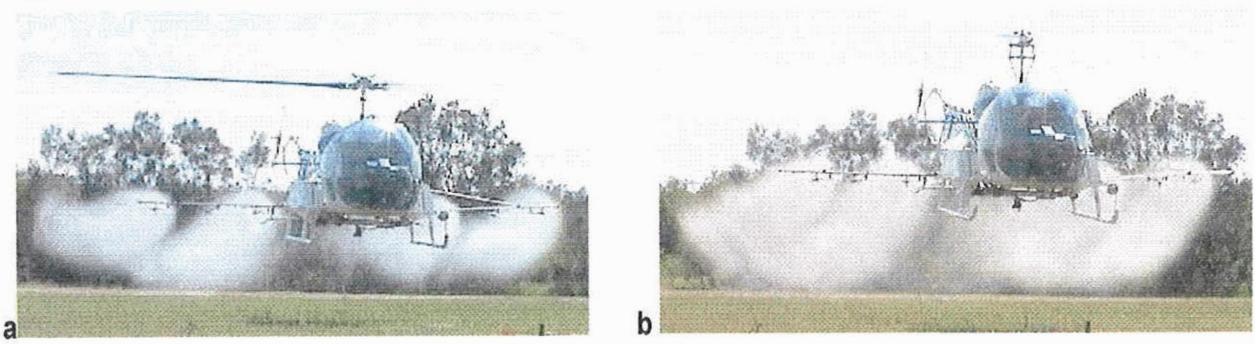

Figure 12 Spray deposit patterns for two nozzles per side without additional nozzles (a) and with two D4/25 nozzles positioned beneath the centreline of the aircraft (b)

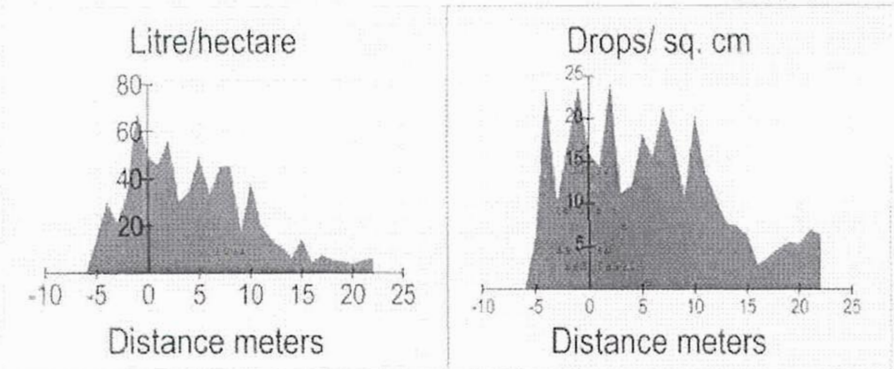

Figure 13 Ground deposit pattern for two nozzles per side with two D4/25 hollow cone nozzle located beneath the centreline of the helicopter. Note that the centre of the distribution pattern has been filled

5.3. Downwind spray drift modelling

Figure 14 (left hand side graph) shows a histogram of droplet sizes generated by the Unimizer nozzle spraying water at 50, 75 and 100 knots compared to a standard Micronair AU5000. The downwind drift profiles predicted by AgDRIFT® for each of these droplet spectra are also shown in Figure 14, (right hand side graph). The AgDRIFT® profiles demonstrate that the drift can be significantly reduced if the relative span (an indication of the range of droplet sizes produced by a nozzle) is reduced.

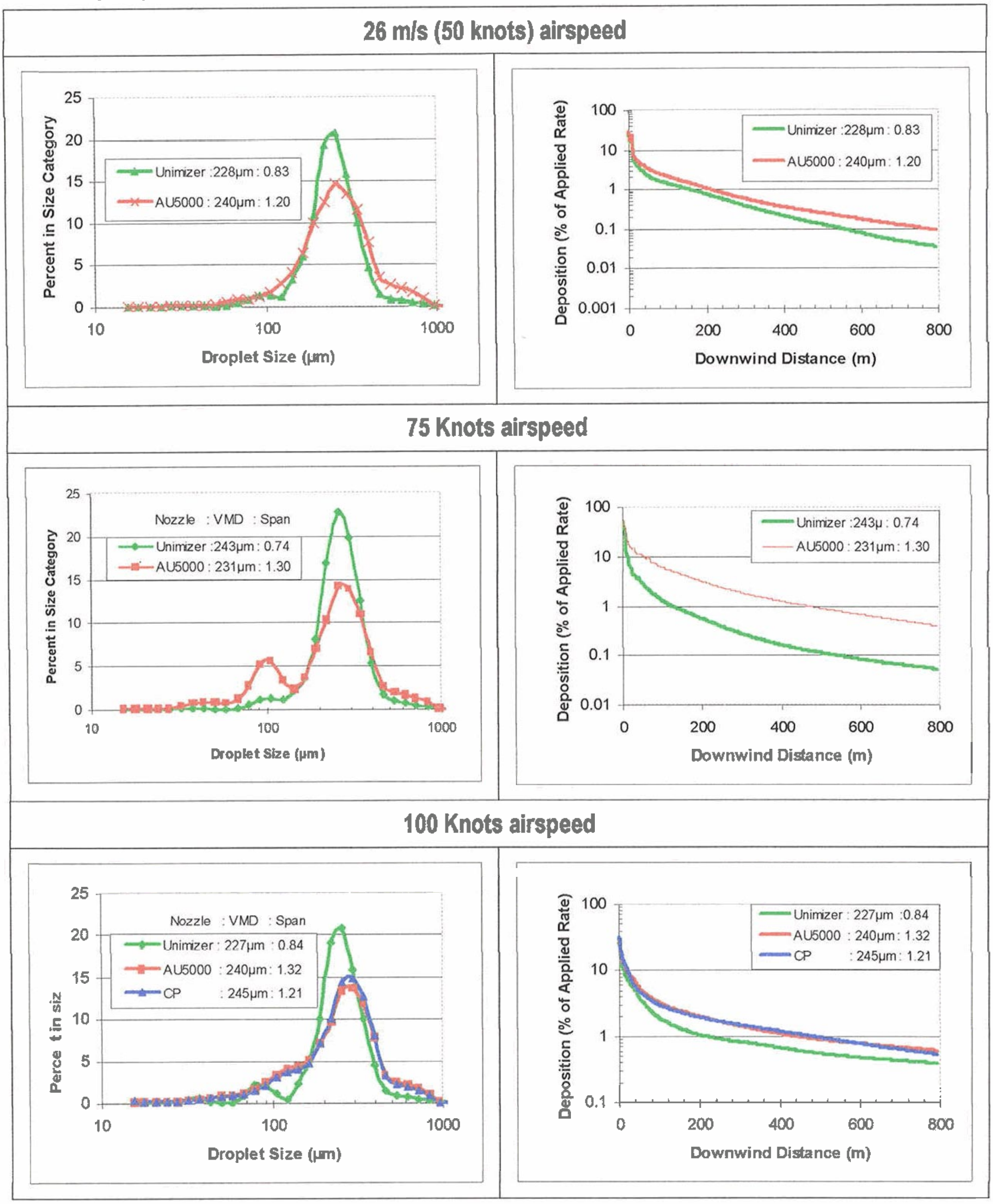

Figure 14. Typical droplet spectra and AgDRIFT® predicted downwind spray deposits for various nozzles at airspeeds of 50, 75 and 100 knots

6. Discuss the results, and include an analysis of research outcomes compared with objectives. What are the "take home messages"?

6.1. Droplet Size Measurement

6.1.1. Unimiser prototype

Similar to the performance characteristics of other centrifugal energy nozzles, the Unimizer nozzle generated higher VMD values as the rotational speed of the unit was decreased, (Table 1). A VMD of 382 μm was recorded at a rotational speed of 3100 rpm (wet). A VMD of 264 μm was measured at a wet rotational speed of 5400 rpm. These data suggest that the nozzle (at an airspeed of 26 m/s (50 knots)) is capable of generating droplets of a sufficient size for the placement application of pesticides. Of note, Figure 5 clearly illustrates that the relative span also decreased as the rotational speed of the nozzle was decreased. In these tests a minimum relative span of 0.59 was recorded at a rotational speed of 3100rpm and flowrate of 14 L/min. This value is comparable to data previously reported (Spillman 2001) and significantly lower than some other nozzle systems currently available.

The influence of three formulation changes is illustrated in Figure 6. Holding the airspeed and rotational speed constant, (26 m/s, 5000 rpm), it was found that a 0.1% solution of Agral and 10% solution of DC Tron did not strongly influence the spectra generated by the nozzle. The addition of 41-A at a concentration of (0.6 g/L) did however significantly increase the VMD and widen the relative span of the spray.

6.1.2. Micronair Retrofit version

Although the Micronair retrofit version tested does not generate as narrow a spectrum as the original prototype versions, it can still be narrower (depending on setting) than other commercially available nozzle options. It is considered that since many aerial operators currently have a Micronair system it could be cost effective and easier to install the retrofit version than a complete new nozzle system. This will increase the likelihood of adoption of the technology.

6.2. Pattern Testing of Helicopter fitted with Unimiser Nozzles

The results from the single flight line deposit measurements showed that there was a consistent area of low deposit beneath the centre-line of the helicopter. Since it is impractical to mount an air driven rotary nozzle in the slow moving air close to the airframe beneath the centreline of a helicopter, a small number of additional hydraulic nozzles were fitted. This small modification improved the uniformity of the deposit. The tests showed that more uniform ground deposit patterns were obtained when three Unimizer nozzles were operated on each side of the helicopter.

When the distribution patterns from each test were overlapped to determine the uniformity of deposit that would be achieved across a field, it was found that this nozzle configuration generated the most uniform deposit at a practical flight lane separation of 12 metres. At flight lane separations of 10 and 15 metres, a mean of 33 and 22 water droplets per cm^2 were deposited in an estimated volume of 61 and 41 L/ha.

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. Where possible include a statement of the costs and potential benefits to the Australian cotton industry and future research needs.

The results have demonstrated that the Unimizer nozzle is able to generate a narrower range of droplet sizes, as indicated by a lower relative span, than any other commercially available alternative. It is expected that drift from this nozzle is likely to be lower than for other nozzle used on aircraft in the cotton industry.

All tests in this report are on an unshielded version of the nozzle. Earlier tests with the prototype version demonstrated that with an appropriate shield, a narrow spectrum and large droplet size could be maintained even at the higher airspeeds (see Unimizer website). Unfortunately the shield tested in the wind tunnel did not prove practical to operate due to an increase in drag generated by the nozzle assembly. An improved shield design that would generate similar droplet sizes as the prototype, but with less drag, would greatly improve the drift reducing ability of the Unimizer nozzle.

8. Detail how your research has addressed the Corporations three Outputs: Sustainability, and/or Profitability & International Competitiveness, and/or People & Communities?

The results from this study have contributed to the development and testing of technologies designed to reduce the potential for spray drift resulting from the use of insecticide in the Australian cotton industry. The Unimizer nozzle system, with some further refinement, is able to reduce the relative span of spectra generated agricultural aircraft and thus reduce the potential for pesticide drift.

The project has developed new algorithms and a model that can be used to predict the droplet size generated by the the nozzle system as a function of airspeed and noaale rotational velocity. These algorithms may provide assistance to both regulators and industry involved in environmental management.

9. Describe the project technology (eg. commercially significant developments, patents applied for or granted licenses etc).

Unispray hold an International PCT Patent Application, which covers 110 countries including the United States of America and Australia, (see http://www.atomisers.com).

10. Provide a technical summary of any other information developed as part of the research project. Include discoveries in methodology, equipment design, etc.

Not Applicable

11. Detail a plan for the activities or other steps that may be taken;

(a) to further develop or to exploit the project technology.

- Make current data and droplet calculator model available to industry and regulators
- Develop additional (pesticide specific) droplet calculator models as funds and demand allow
- Continue to support nozzle research and development of production nozzles as funds allow

(b) for the future presentation and dissemination of the project outcomes.

- Industry media and press articles, such as the *Australian Cottongrower* and Fact sheets.
- Contact with the Cotton IDOs, aerial and ground rig operators and through the Cotton CRC

12. List the publications arising from the research project.

Woods,N and Dorr,G (2002) A New CDA nozzle ('Unimizer') for the Aerial Application of Pesticides: A Detailed Performance Analysis, 2002, ASAE Annual International Meeting / CIGR XVth World Congress, Paper Number: 021031 Chicago, USA July 2002

13. Are changes to the Intellectual Property register required?

No.

Part 4 – Final Report Executive Summary

Provide a half to one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. List the main outcomes and contact details for more information.

Unispray have developed a new centrifugal energy nozzle, the "Unimiser", for the aerial application of pesticides. The new nozzle is designed to substantially reduce pesticide spray drift resulting from the aerial application of pesticides in the cotton industry. The nozzle was designed to generate a very low range of droplet sizes, (having a relative span of less than 0.8 compared with 1.2 –1.6 for most currently available nozzles) and a volume median diameter of 250 μm.

Testing of prototype models have demonstrated that that the Unimiser nozzle is able to generate a narrower range of droplet sizes, as indicated by a lower span, than any other commercially available alternative. It is expected that drift from this nozzle is likely to be lower than for other nozzle used on aircraft in the cotton industry.

During the course of this project Unispray decided to initially concentrate on a Helicopter version of the initial prototype. The results from the single flight line deposit measurements showed that there was a consistent area of low deposit beneath the centre-line of the helicopter. Since it was impractical to mount an air driven rotary nozzle in the slow moving air close to the airframe beneath the centre line of a helicopter, a small number of additional hydraulic nozzles were fitted. This small modification improved the uniformity of the deposit. The tests showed that more uniform ground deposit patterns were obtained when three Unimiser nozzles were operated on each side of the helicopter.

Based on results from the wind tunnel studies, pattern testing and market requirements, Unispray decided to concentrate on a "retro fit" version that can easily be added to existing Micronair units. Droplet size was measured over the range of nozzle rotational speeds, liquid flowrates and airspeeds that are likely to be encountered in the field. Testing was initially undertaken with water only but was later repeated with a Water + 0.1% Agral mix. The Agral was added as it is often considered to be more representative of an actual tank mix. In general a slightly larger range of droplet sizes (larger span) was generated with the Water + Agral mix. From the measurements a regression analysis was undertaken to enable prediction of droplet size using the range of variable tested in the wind tunnel From this analysis an EXCEL based "nozzle calculator" was developed and a full working copy of the calculator has been included with this report.