

Australian Developments in Spray Drift Management

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Abstract

This paper reviews some of the science currently being undertaken to reduce spray drift in Australia by improving the understanding of droplet generation, transmission and capture processes. Research into the behaviour of adjuvants and nozzle systems is leading to the development of aircraft onboard systems that are capable of automatically maintaining a nominated droplet size in flight. The use of large droplet application techniques and spray drift models is contributing to the generation of lower spray drift profiles in broad-acre agriculture. Recent research is developing models that simulate the downwind trajectory of spray droplets from a hydraulic nozzle. The models are being developed to measure and predict the interaction and capture of droplets by simple and complex canopy surfaces. With good science and training and a broad approach to spray management, the potential for spray drift can be reduced concurrently with optimisation of total pesticide delivery systems.

Introduction

Many agricultural cropping systems remain dependent upon the safe and efficient application of a range of crop protection and production materials. Timely and strategic use of pesticides, often only possible using aircraft, is required to maintain adequate control of pest species and efficient crop production. Most pesticide products are formulated as liquids. This enables small quantities of biological active ingredients to be dispersed evenly and precisely across a target area as long as atomisation of the liquid by a nozzle system is both adequate and uniform. With suitable nozzle systems, liquid formulations of pesticides and fertilisers may be applied by air at rates varying from 1 to greater than 100 L/ha, depending upon the target site, the mode of action of the product and on environmental considerations.

Specialised agricultural aircraft developed post war largely as a result of the greater speed, better timing and efficiency of application offered by aerial distribution. Crossing the ground in excess of 200 km/hr, aircraft are able to apply agricultural or public health products rapidly over large areas within narrow optimum application windows. When crop height and water logged areas restrict the passage of wheeled vehicles, aircraft are able to place pesticides strategically on crops in response to economic thresholds, without contributing to soil compaction and structural breakdown.

However irrespective of the efficiency of the delivery system, if pesticide droplets are allowed to be transported downwind away from a sprayed area, potential exists for the contamination of off-target and subsequent disruption of neighbouring agricultural systems.

For example in Australia during the mid to late 90's endosulfan contamination of pasture and beef caused significant disruption of the meat export industry and resulted in the temporary closure of some overseas markets. Although it was found that little of this trespass was caused by spray drift from aircraft, much work had to be conducted to calculate down wind deposition profiles and establish appropriate down wind buffer distances.

In Australia, some 300 aircraft are used to apply about 20% of the local crop protection chemical market to an average of about 10 million hectares annually. Aircraft are used in broad-acre and tropical agriculture, forestry, (herbicide, fertiliser and insecticide application) and regional mosquito control programmes, (primarily larvicide operations).

Three main transport processes can be used to describe the distribution of a liquid biocide from an aircraft:

1. Droplet generation (creating a large number of droplets)
2. Droplet transmission, (the movement of the droplets from the nozzle through the air to the target)
3. Droplet capture, (the impaction of droplets on a target)

In Australia research is currently being conducted on each of these transport processes to optimise the application process and increase control over the application process.

Droplet Generation

For the application of most liquid products, the droplet size of the emitted spray is the most important criterion. Plant, soil or insect coverage levels, drift profiles and product efficacy are all strongly influenced by the size of the droplets generated by an aircraft. Consequently for precision application a detailed knowledge of nozzle performance and the characteristics of formulations is required.

A wind tunnel research facility, located at the Gatton Campus of the University of Queensland has been used to evaluate nozzle systems and create support tools for applicators and spray managers, (Figure 1). The facility comprises an open circuit wind tunnel, a transparent working section, a Malvern 2600 laser diffraction analyser and an exhaust air scrubber extraction system. A 400mm by 400mm contraction section is used to accelerate air up to operational speeds of 75 m/s. Two gantries are used to independently position the laser-diffraction particle-size analyser and nozzle systems under test. The emitted spray plume is traversed through the laser beam to enable representative cross section sampling. The test facility is fitted with transducers to monitor fan speed, air temperature, humidity, air velocity, pressure and flow rate.



Figure 1. Pesticide Wind Tunnel Research Facility.

Recent design initiatives in Australia have seen the development by Unispray of a narrow spectrum centrifugal energy nozzle for helicopters, (Figure 2). The “Unimizer” 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 narrow range of droplet sizes, (having a relative span of less than 0.8 compared with 1.2 –1.6 for most currently available hydraulic nozzles) and a volume median diameter of 250 μm .

Some results are shown in Figure 3. At an airspeed of 26 m/s it can be seen that the structure of the cage in this device enabled droplet spectra to be developed with VMD values up to 382 μm . In these tests a minimum relative span of 0.59 was recorded at a rotation rate of 3100rpm and liquid flowrate of 14 L/min. As to be expected AgDRIFT assessments of this droplet size spectrum have been shown to generate lower downwind spray drift profiles, than most other nozzles systems currently available to aerial applicators, due to the removal of “fines” from the spray (Woods and Dorr 2002)



Figure 2. The Unimizer (helicopter version) nozzle

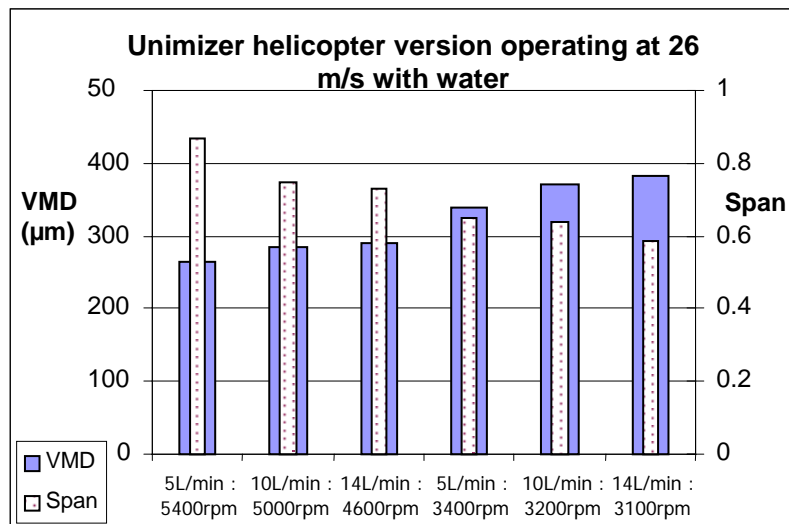


Figure 3. Volume median diameter (VMD) and relative span for Unimizer helicopter nozzle operated in a 26m/s airstream and spraying water

In generating accurate droplet sizing information (and input data for international models such as AgDRIFT®), this research is enabling manufacturers to fine tune nozzle development and lower the drift potential associated with the application of many pesticide products.

However such analysis can be taken further and be used to generate smart products to assist the development of practical spray drift mitigation in the field. Atomisation studies using the wind tunnel facility have enabled the development of algorithms that predict the performance of nozzles when fitted to agricultural aircraft. For example, specific “droplet size calculators” have been developed for Micronair rotary atomiser, the Unimizer and the JARBA boom. These models enable users to accurately predict droplet size as a function of flight parameters, nozzle characteristics and tank mix type. They have been used to provide information for pilots and applicators via the internet and in some cases develop onboard application computers.

For example, algorithms developed (by CPAS) from wind tunnel studies lies at the heart of the JARBA boom control processor. In this system, the angle of the hydraulic nozzles on the boom is automatically changed in flight to maintain a pre-specified droplet size, (Figure 4). In this way, the droplet size can be changed in flight by the pilot or a nominated droplet size maintained as the airspeed of the aircraft changes. This is an advanced system and has the potential to significantly influence the precision of aerial application technology.



Figure 4. JARBA Boom showing the capacity of the nozzles to be rotated in flight (Jones Air)

Droplet Transmission

Previous research, (Woods et al 2001) quantified typical downwind insecticide deposition profiles for ultra low volume (ULV) and low volume (LV) application of insecticides and showed that a combination of application parameters could reduce spray drift values. Subsequent to this work, the Australian Pesticide and Veterinary Medicines Authority (APVMA) introduced a regime for the 1999/2000 cotton season that stipulated that the insecticide endosulfan should be applied by aircraft using Large Droplet Placement (LDP) techniques. Fundamentally, this application technique specified the application of sprays from agricultural aircraft using droplets with a VMD greater than 250 μm , water volumes greater than 30 L/ha and the use of spray booms where the distance between the two outermost nozzles did not exceed 65% of the wingspan. Used in conjunction with appropriate management strategies, it was postulated that a droplet spectrum with a VMD greater than 250 μm could reduce downwind drift levels as a result of the inherent higher droplet sedimentation velocities.

To support this initiative, an extensive series of field trials were conducted in Australia over two years to monitor and measure downwind spray drift profiles of aerial applied insecticides in the cotton industry and compare the results with those predicted from widely available spray drift models. To reduce the influence of meteorological conditions between treatments, and assist normalisation of the data, the LDP treatments were usually paired against a ground boom sprayer application or aerial ULV treatment. Treatment sites were selected dependent upon field size (at least 600 x 1000 m) and the availability of a sufficient downwind buffer area (at least 500m) to collect drift deposits.

Generally, two paired treatment plots were marked out with flags so that approximately 30 ha (representing 16-20 swaths of the aircraft) were sprayed for each treatment. This provided sufficient sprayed area for downwind drift assessment. Insecticides were applied by commercial agricultural aircraft using LDP technique (VMD 250 μ m) at 30 L/ha or ULV (VMD <150 μ m) at 3L/ha and ground rig boom sprayers at 100 L sprayed/ha.

To measure the fallout of droplets and the vertical flux, horizontal aluminium flat plates mounted on fibreglass rods (40 cm above the ground) were positioned at a range of points downwind of the field being sprayed (0, 50, 100, 200, 300, 400 and 500 m). Chromatography paper (76 x 52 mm) and a vertical pipe cleaner were attached to each horizontal plate prior to application. The horizontal papers provide an indication of deposition by sedimentation, of interest in assessing potential drift exposure to water bodies and terrestrial areas such as flat ground. The pipe cleaners provide collection by impaction, of relevance to exposure by vertical surfaces.

After application, papers from each subplot were placed into sample bottles. Acetone was added and the samples sealed and frozen (-20°C). In the laboratory the quantity of active constituent isomers was determined using a gas chromatography mass spectrometer (GC/MS - selected ion mode).

The data were further combined with deposition results recorded using similar methods for other ground and aerial application techniques, (Woods et al 2001). In the ten year period from 1994, numerous experiments were conducted where downwind drift data were collected from ULV, LV, LDP and ground application trials. Figure 5 shows the downwind deposit graphs for the four application techniques, (Woods et al, 2004)

The four application techniques were monitored and the resulting data sets analysed to establish statistical models. Both the statistical model and the data independent AgDRIFT® (Lagrangian) model identically ranked the four application methods, although lower measured ULV values were recorded close to the downwind edge of the treatment areas, (Figure 6).

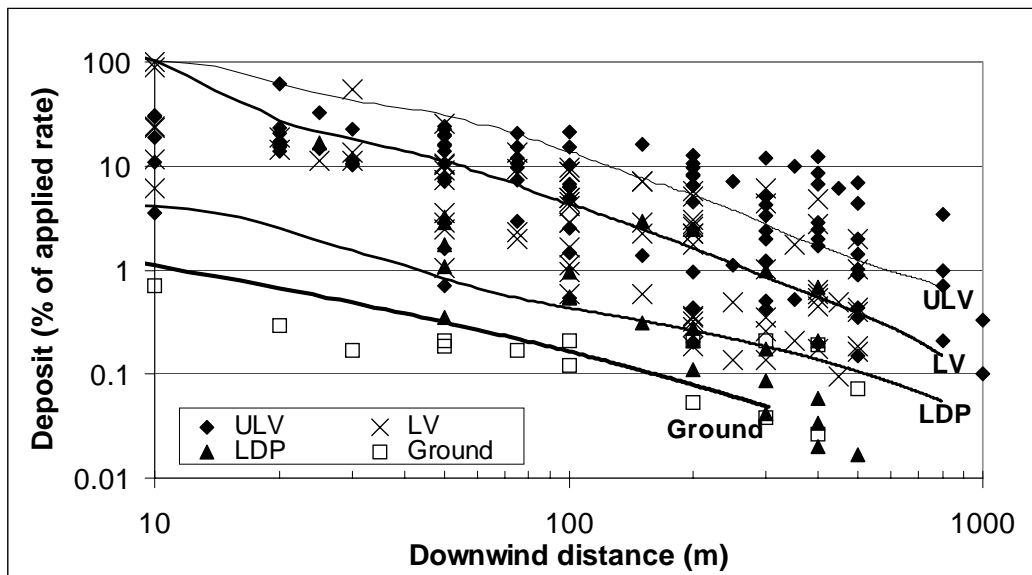


Figure 5- Measured downwind spray drift values (points) and AgDRIFT® predictions (lines) from ULV, LDP, LV and ground downwind drift assessments 1994-2003.

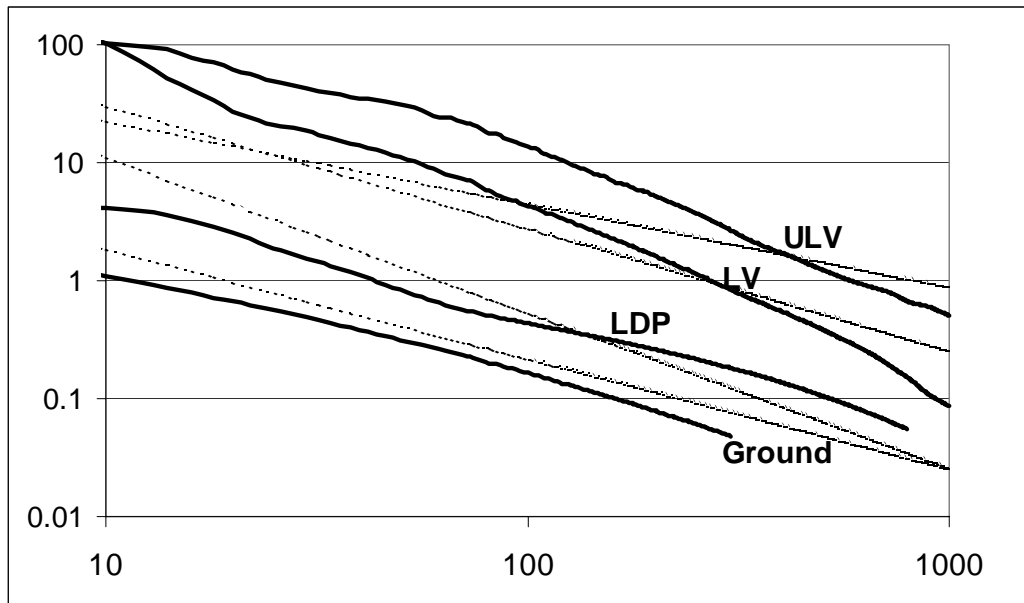


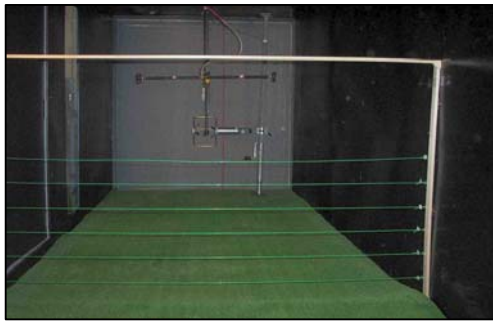
Figure 6. Model fitting of downwind deposits (dashed lines) against AgDRIFT® predictions (full lines) from ULV, LDP, LV and ground downwind drift assessments 1994-2003.

Although AgDRIFT® predicts parallel downwind deposition responses, the measured data tended to indicate that there was no difference between any aerial application technique 10 metres downwind of the field, (perhaps because of aircraft vortex effects or release height issues close to the edge of the field). However by 1000 metres downwind there was a clear statistical difference between the three aerial application techniques, favouring LDP application.

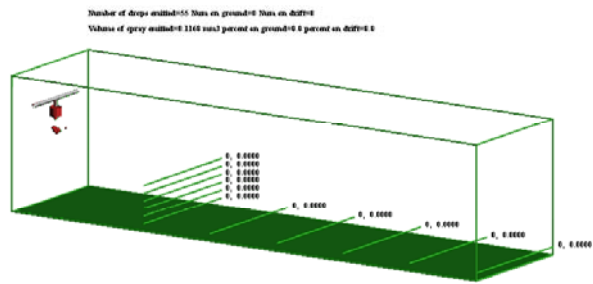
Importantly for the Australian cotton industry, the measured data and the AgDRIFT® modelling confirmed that LDP application does significantly reduce the downwind horizontal ground spray deposition profile. 100 metres downwind of the field edge, LDP applications generated significantly less spray drift than LV or ULV application. Indeed, LDP application gave similar down wind drift profiles to those measured from ground boom sprayer applications in this trial programme, (Woods et al, 2004).

Droplet Capture

Recently the wind tunnel has been expanded and re-equipped with the support of Australian Research Council to undertake innovative research programmes investigating spray droplet movement and canopy interaction. A low speed wind tunnel was constructed enabling crop canopies to be sprayed with a remote controlled boom in wind speeds up to 20 km/hr. The facility can also be used to precisely determine spray drift from single hydraulic nozzles up to 10 meters downwind of the release point. Equipped with an Oxford Lasers Digital Imaging system, the velocity and size of droplets can be tracked around canopies at an equivalent film speed of 50,000 frames a second.



(a)



(b)

Figure 7 (a). The inside of the low speed working section showing string collectors set up to determine the vertical spray drift profile downwind of a static hydraulic nozzle (b) Virtual representation of working section allowing the model simulation (L-Studio) of the downwind vertical and horizontal spray drift profile from a hydraulic nozzle

Currently work is underway not only to simulate the downwind trajectory of spray droplets from a hydraulic nozzle, but measure and predict their interaction and capture by simple and complex canopy surfaces. The modelling work is being linked to virtual plant models already developed for a cotton canopy with the objective of modelling and predicting (within specified limits) droplet distribution in complex plant canopies. If successful, such models will enable a more accurate assessment of spray drift risk assessments to be conducted, (Figure 7). It is also planned to assess droplet collection of other spray targets such as live insects

Spray Drift Management

In Australia, as in the U.S., there is increasing interest in the use of adjuvants for reducing spray drift. A large study was conducted to test all of the major chemistry types for drift control adjuvants, in both the wind tunnel (for effects on driftable small droplets) and in the field (for effects on spray drift). Since the behavior of an adjuvant depends in part on the tank mix partners, these tests were conducted both with water and with an EC blank. Drift was measured in the field using analytical techniques offering much higher precision and without collection efficiency issues associated with water sensitive papers. To remove the effects of meteorological variables, a covariate analysis was used for the studies, applying standard and variable treatments concurrently through standard sprayers (aircraft) as recommended previously by the U.S. Spray Drift Task Force. The studies showed that different products produced different effects on droplet size spectra which correlated well with drift potential observed in the field. One of the notable effects was that (invert and regular) emulsion-based adjuvants often produced fewer driftable “fines” and less drift than some polymers. However, different trends might occur with different types of nozzle and with some specific products.

Successful spray drift management requires more than good science. In order to facilitate the development of holistic spray drift management plans across a range of agricultural enterprises, the Australian government recently produced and released a publication, *Spray Drift Management, Principles, Strategies and Supporting Information*, (PISC 200). Now freely available on the internet, www.publish@csiro.au this document seeks to provide information for user groups to design specific local spray drift management strategies. As well as introducing the concept of awareness zones in planning for spray operations, the material discusses the role and importance of developing buffers and vegetative areas to assist in protecting sensitive areas. In the late 1990's for example, the Queensland Government introduced guidelines for the establishment of vegetative buffer zones between rural and urban development areas, (Capelin 2001).

Conclusions

This paper has briefly reviewed some of the science currently being undertaken to reduce spray drift in Australia by improving the understanding of droplet generation, transmission and capture processes. Pesticides remain an essential tool for agricultural industries in the production of high quality produce and a key component of integrated crop management (ICM) systems in most Australian production systems. With good science and training and a broad approach to spray management, the potential for spray drift can be reduced concurrently with optimisation of total pesticide delivery systems.

References

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