HELIOTHIS MANAGEMENT, SPRAY DRIFT AND IN-CROP DEPOSITION USING LDP SPRAYING TECHNIQUES IN COTTON

J.W. Nicholls [1], F.A. Talukder [2], E. Hassan [2], N. Woods [1], G. Dorr [1] and B. A. Gordon [1]

[1] Centre for Pesticide Application and Safety (CPAS), School of Agriculture and Horticulture, The University of Queensland, Gatton Campus, Gatton Qld 4343

[2] School of Agriculture and Horticulture, The University of Queensland, Gatton Campus, Gatton Qld 4343

SUMMARY

Ground rig and aerial application treatments were setup to deliver endosulfan to young cotton using 'large droplet placement' (LDP). Both treatments delivered similar amounts of the product to the target, despite the aircraft applying the full rate of the product, versus a banded rate (40%) for the ground rig treatment. In field efficacy conducted at commercial checking intervals (as measured by larval mortality, fruit retention ratios and damage levels) were equivalent for both the ground rig and aerially applied endosulfan. Laboratory bioassays conducted on field sprayed leaves showed a greater decline in larval mortality over time for the ground rig than the aerial treatment. The fate of the additional insecticide applied by the aircraft was distributed between increased deposition on the ground and as drift leaving the field. At 400 metres downwind, the ground rig treatment resulted in one sixteenth the drift compared to the aerial treatment. The potential for commercially available anti-evaporant adjuvants to help reduce off target movement of fine droplets was evaluated using a new facility and techniques developed by CPAS.

INTRODUCTION

In northern NSW and Queensland, methodologies for the chemical control of heliothis (*Helicoverpa* spp.) in cotton have evolved markedly. Prior to the 1999/00 season, Micronair ultra low volume (ULV) AU5000 nozzles were extensively used to distribute fine droplet sprays of endosulfan over and within the cotton crop. The use of small droplets enhances the productivity of aerial application, enables coverage of leaves and bolls to be maximised and permits effective control of small to medium heliothis larvae in cotton. However, although efficient, when such application techniques are adopted, some of the spray has the potential to move downwind off target and onto pasture (Woods *et al.* 1998a,b, 2001), where the potential may exist for ingestion by grazing cattle.

To prevent maximum residue limits in beef for export being exceeded, the National Registration Authority for Agricultural & Veterinary Chemicals worked with Industry during 2000 to introduce new extended downwind buffer distances for the application of endosulfan in cotton. In addition, the use of sprays with a droplet diameter (Volume Median Diameter, VMD) greater than 250 μm was implemented and 'Large Droplet Placement' (LDP) aerial application techniques were adopted to reduce the potential for spray drift.

During the 2000/01 and 2001/02 seasons, the Centre for Pesticide Application & Safety (CPAS), School of Agriculture and Horticulture, The University of Queensland, Gatton Campus, conducted extensive studies to closely analyse the technology associated with LDP application and its impact on the control of heliothis. Funded by the Cotton Research & Development Corporation, four major studies were conducted: (1) an investigation of the droplet size produced by nozzles fitted to aircraft for cotton spraying using a pesticide wind tunnel facility; (2) an evaluation of spray drift adjuvants, particularly their influence on droplet evaporation; (3) efficacy of LDP application on heliothis through field data and laboratory bioassays; and (4) an assessment of canopy coverage and spray drift resulting from the use of LDP application.

This paper is the first publication to discuss the findings from these studies and outlines the scope of the work done on the testing of anti-evaporant adjuvants in a newly constructed in-flight droplet evaporation tube and the impact of LDP application on the efficacy of endosulfan.

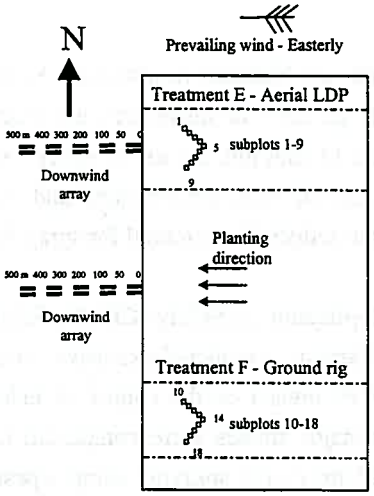
MATERIALS AND METHODS

Spray coverage and efficacy field trial

Field setup

A large study was undertaken during December 2001 to compare the performance of LDP aerial application against the commercial ground application (40% band) of endosulfan in a young cotton crop. A 3000 x 800 m commercially prepared and managed field was planted in 1 m rows with V16 Siokra cotton on 2nd October 2001 at Auscott Midkin, Moree NSW. Crop height was 30 cm and row closure 10 - 20% for both treatments. The southern end of the field was in stronger condition (it appeared greener and had a more consistent growth habit) than that seen in the northern end of the field. Other treatment details are presented in Table 1. Treatment E (800 m x 650 m) was located at the northern end and Treatment F (800 m x 650 m) at the southern end of the field. Nine subplots 20 x 20 m were located 100 m in from the western edge of the field and in the middle of each treatment block (Table 1). Each subplot was separated from adjacent subplots by a 5 m buffer. Within each sub-plot, 5 sampling points were separated by a 5 m buffer. At each sampling point, leaves, ground stick and flat plate chromatography papers were collected 2, 24 and 48 hours after spraying (HAS). Meteorological data was recorded continuously via a data logger (wind speed at 2 m and 10 m; wind direction; temperature at 0.5, 1, 2, 5 and 10 m; relative humidity and solar radiation). During the application period, a hand held logger was also used to record temperature, relative humidity and wind speed, (Kestral 3000 pocket weather meter).

Table 1 - Field layout, meteorological observations and treatment summary

Field Layout	Treatment E Aerial	Treatment F Ground rig
	Time, date: 00:05-01:19, 5/12/01 Plane: S2R-G10 Flight pattern: Racetrack Airspeed: 120 knots Application height: 3 m Lane separation: 18 m Application volume: 30 L/ha Insecticide: 2.1 L/ha (350 g a.c./L endosulfan) Nozzles: CP, 0° deflection Number of nozzles: 32 (16 each wing), 65% wingspan Pressure: 250 kPa **Meteorology** First load: 12:05-12:40 eastern standard daylight saving time (esdst) Second load: 12:44-1:19 esdst Wind direction: E-ENE Wind speed: 0.5-1.0 m/s Temperature: 25.5°C RH%: 43.0-48.0	Time, date: 01:20-02:07 5/12/01 Ground rig: Melrose Spray Coupe, Raven spray controller Ground speed: 18 km/hr Application height: 50 cm Boom width: 24 m Application volume: 100 L per sprayed ha (40% band) Insecticide: 2.1 L product/sprayed ha (350 g a.c./L endosulfan) Nozzles: XR 80015 Number of nozzles: 3 per 1m row (1 over row, outer 2 on droppers) Pressure: 250 kPa **Meteorology** First load: 01:20 – 02:07 esdst Wind direction: E-ESE Wind speed: 0.8-2.3 m/s Temperature: 24.2°C RH%: 44.9

Field and laboratory efficacy studies

Pre-treatment checks on 20 plants per subplot (presence of heliothis eggs, larvae (all stages), other pests and top 5 square damage assessment) were conducted on the day of spraying by Agrisearch following the method of Shaw and Watson 2001. These assessments were also carried out 3, 6 and 9 days after treatment (DAT).

As a parallel to field efficacy, insect mortality was determined through laboratory bioassays using *Helicoverpa armigera* neonates obtained from the Queensland Department of Primary Industries (QDPI), Toowoomba. A total of 30 top (first fully expanded) leaves were collected from each subplot (6 leaves per row) 2, 24 and 48 hours after spraying (HAS), placed in paper bags, stored in a cool esky and transported back to the laboratory. Untreated (control) leaves (V16 Siokra) were grown in the glasshouse at The University of Queensland, Gatton Campus. A total of 20 leaves collected from subplots were placed in individual 50 mm diameter Falcon petri dishes + 20 untreated (control) leaves. Individual neonates were transferred onto leaves and placed into sealed petri dishes which were kept at a constant temperature room for the duration of the experiment (temperature 25°C, relative humidity 75%, light to dark 16/8 hours). Larval mortality was recorded at 1, 2, 3 and 4 days after the neonates (DAT) were placed on leaves.

In-crop deposition (top and mid leaves)

For each subplot from each treatment collected at 2, 24 and 48 HAS and 30 top (first fully expanded) leaves were also placed in a labelled 120 mL glass jar. Similarly, 30 mid (middle of the plant structure) leaves were placed in a labelled 120 mL (early season) or 500 mL (mid-late season) glass jar and stored on ice in an esky. Hexane (30 or 100 mL) was added and the samples were stored on ice until being transferred to a –20°C freezer for storage. Analysis was conducted by the Department of Natural Resources and Mines (DNRM) Natural Resource Sciences Laboratories (NRSL) Indooroopilly. Solvent from the sample was decanted off and leaves briefly air-dried and weighed. Endosulfan was extracted by blending the leaf sample with methanol then filtered and the extract partitioned with hexane followed by a clean-up step and a reduction in volume. A portion of this sample was injected into a gas chromatograph (GC - electron capture or mass spectrometer detectors). The active constituents were determined by comparison to pure standards of known concentration.

Ground stick (furrow and hill) and above canopy papers

Ground level targets were made by attaching 26 x 500 mm chromatography paper by rubber bands to a 1 m x 30 mm x 8 mm, foil-wrapped length of wood. These were placed parallel both along the furrows and on top of the adjacent hill at each of the 5 sampling points in each of the 9 sub-plots. At 2 HAS, the 5 ground stick papers from both the hill and furrow were placed in separate 120 mL glass jars, sealed and stored on ice in an esky. Acetone (30 mL) was added and the samples were stored on ice until being transferred to a –20°C freezer for storage.

At 2 HAS, the 5 above canopy chromatography papers from each subplot were bulked together and placed in 120 mL glass jars, sealed and stored on ice in an esky. Acetone (30 mL) was added and the samples were stored on ice until being transferred to a –20°C freezer for storage. Samples were analysed by QDPI, Leslie Research Centre (LRC), Toowoomba. Samples had a 3-ion standard added to them and shaken for 1 hour. A 1 mL aliquot was removed and another internal endosulfan standard added. This was injected into a gas chromatography mass spectrometer (GC/MS - selected ion mode) and the quantity of active constituent isomers determined.

Drift targets

Flat plate artificial targets were placed in linear arrays, downwind from the middle of treatment areas (Table 1). The flat plates were mounted on fibreglass rods 50 mm above canopy surface. Each target consisted of a horizontal chromatography paper (76 x 52 mm) and a vertical pipe cleaner (nominally 5 x 140 mm) oriented parallel to the direction of application. Twin rows of targets (10 m apart) were placed 0, 50, 100, 200, 300, 400 and 500 m downwind and one target 100 m upwind at the opposite end of the field, (control) from each treatment area.

The two downwind array samples from each distance were collected 2 HAS and the paper and pipe cleaner samples placed in separate 30 mL glass McCartney bottles, sealed and stored on ice in an esky. Acetone (10 mL) was added and the samples stored on ice until being transferred to a –20°C freezer for storage. Samples were analysed by QDPI, LRC Toowoomba, using the same method as was used for the chromatography paper targets, described above.

Evaporation of droplets – screening of spray adjuvants

Laboratory based studies were undertaken at The University of Queensland, Gatton Campus. Multiple droplets of known diameter were produced at the top of a 4.0 x 0.85 m fully extended cylindrical air-conditioning tube (Plate 1) by a monosize droplet generator (BioDot, Ltd. Huntingdon Cambridgeshire, UK, (Plate 2)). The nozzle was operated at a frequency of 32kHz, a voltage of 120V and at a range of liquid pressures, air pressures and flow rates. Liquid flow rate was measured by collecting the spray solution at the orifice (75 µm orifice in a piezo-electric crystal) into a beaker containing vegetable oil (to reduce evaporation) over a period of 4 minutes. A 5 mm diameter stream of compressed air at 45° to the droplet stream was introduced 50 mm below the orifice, to disperse the stream of droplets into a narrow plume of droplets. The plume of droplets was collected at the bottom of the tube into a 0.5 m diameter tray containing vegetable oil over a 4 minute period. From the flow rate, droplet diameter was calculated by dividing the flow rate (mL/min) by the frequency of piezo-electric crystal vibration in the orifice (32 000 individual mono-sized droplets per).

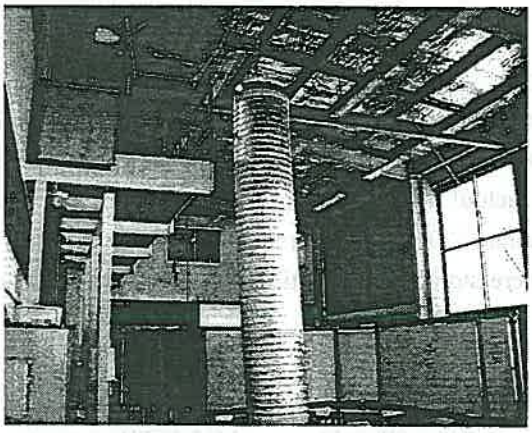


Plate 1 - Evaporation tube facility

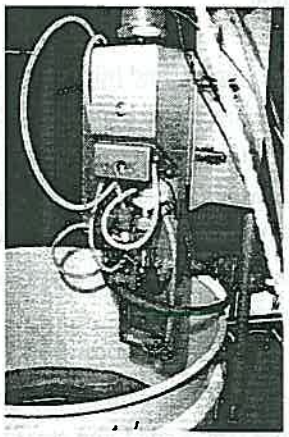


Plate 2 - Mono-sized droplet generator

A number of adjuvant products, including crop (SSE 370) and petroleum oils (DCTron®), standard non-ionic adjuvants (Agral®) and a number of insecticide/adjuvant combinations (Placement® and Placement® + DCTron®) were evaluated. Tap water was used (19-21°C). Wet and dry bulb temperature (ΔT, dry – wet bulb temperature) were recorded for each treatment. Spray solutions containing water and water + adjuvant were tested over a range of ΔT's. Droplet diameters from a range of solutions were compared to water, according

to their influence on in-flight droplet evaporation. This data was entered into a spreadsheet developed by Dr Steve Parkin of the Silsoe Research Institute, UK in order to relate to other published droplet evaporation models (Teske *et al.* 2002). The program uses psychometric functions to predict the changes in diameter of droplets.

RESULTS AND DISCUSSION

Spray coverage and efficacy field trial

Field and laboratory efficacy studies

Laboratory bioassays with field leaves showed that both aerial and ground rig applications resulted in complete heliothis larval mortality on leaves collected at 2 HAS (Figure 1). For leaves collected at 24 HAS, heliothis larval mortality was significantly higher at 1 DAT for aerial than for ground rig application, but is not significantly different at 2 – 4 DAT. For leaves collected at 48 HAS, aerial application provided significantly greater control (at least 30% greater) of heliothis larvae for the entire 4 day bioassay period.

Pre-treatment field assessments of the ground rig applied area showed significantly elevated numbers of heliothis eggs (Figure 2), different stages of larvae (Figure 3), numbers of damaged squares and bolls (Figure 4) and a higher fruit retention ratio (Figure 5) than in the aerial treated area. It is assumed that the more vigorous cotton at the southern end would be more attractive to the heliothis females for laying eggs, which would then explain the increased larval presence and greater damage to squares and bolls.

The average number of heliothis eggs, different stages of larvae, number of damaged squares and bolls and fruit retention rates were rapidly reduced 3 days after spraying (DAS). However, observations during 3 - 9 DAS, showed no significant difference in the above factors between application techniques.

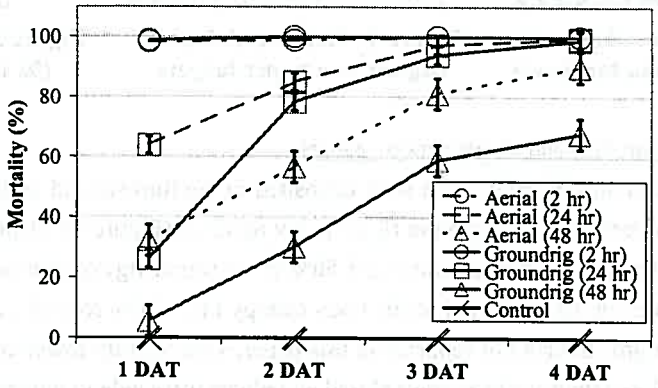


Figure 1 - Mean insect mortality

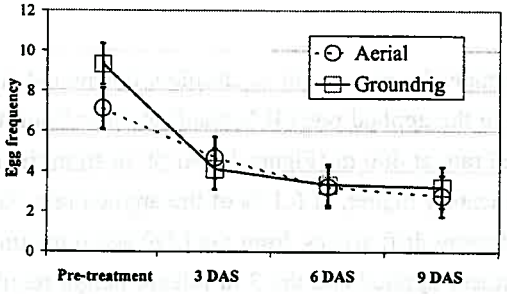


Figure 2 - Distribution of heliothis eggs

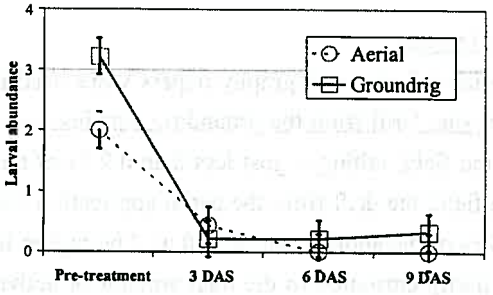


Figure 3 - Distribution of heliothis larvae

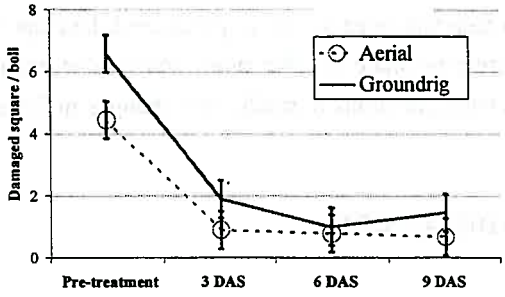


Figure 1 - Damaged square / boll pattern

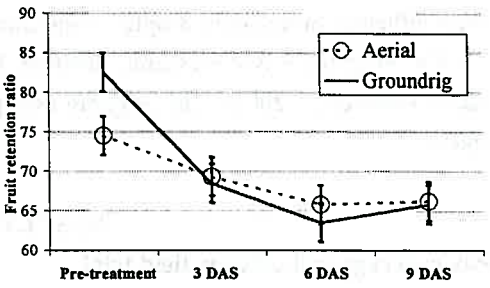


Figure 2 - Fruit retention ratio

In-crop deposition (top and mid leaves)

Significantly (P = 0.071) more insecticide was applied over the crop by the aircraft (5.7 ± 1.7 µg/cm^2) than by the ground rig (4.1 ± 1.8 µg/cm^2), as indicated by the recovery on the flat plates (Figure 3). However, there was no significant difference in the amount of endosulfan extracted from leaves sampled from the top or mid positions (Figure 4). Thus, in both treatments, the same amount of endosulfan was available for control of heliothis. The same amount of endosulfan was deposited on top (8.7 µg/cm^2) and mid (8.0 µg/cm^2) leaves when the ground rig was used. However, there was a significant reduction (50%) in the amount of endosulfan recovered on mid leaves when the insecticide was applied by air (top 12.2 µg/cm^2, mid 6.0 µg/cm^2).

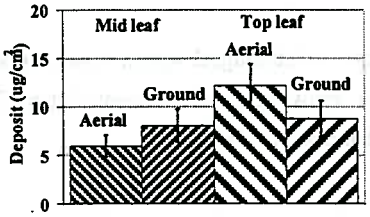


Figure 3 - Recovered deposit (µg/cm^2) on mid and top leaves

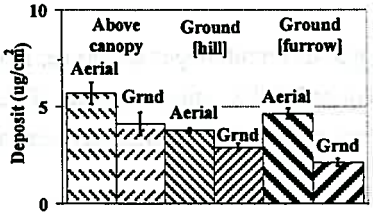


Figure 4 - Recovered deposit (µg/cm^2) on paper targets

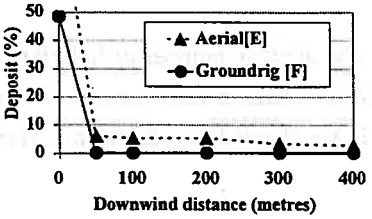


Figure 5 – Downwind deposit (% recommended rate)

Ground stick (furrow and hill) and above canopy papers

Significantly greater amounts of endosulfan were deposited in the furrows and on the hills (of the soil bed) by the aircraft (4.6, 3.8 µg/cm^2) than the ground rig (2.1, 2.9 µg/cm^2) (Figure 4). Deposition of endosulfan in the furrows consisted of about 80% (for aircraft) and 50% (for ground rig) of that arriving at the canopy. This distribution of pesticide can be attributed to the open canopy (10 - 20% row closure) and the small structure of the plants (30 cm high). In data not reported in this paper, significantly lower concentrations of insecticide were recovered from the ground sticks as rows closed and plants were able to intercept more of the spray.

Drift targets

Horizontal chromatography papers were used to determine the movement of droplets downwind from the trial site. Drift from the ground rig was just over 0.2 % of the applied rate (40% band) at 50 m from the edge of the field, falling to just less than 0.2 % of the applied rate at 400 m (Figure 5). At 50 m from the edge of the field, the drift from the aerial application was significantly higher, at 6.1 % of the applied rate, falling to 2.8 % of the applied rate at 400 m. The higher levels of spray drift arising from the LDP aerial treatment can be partly attributed to the total amount of active constituent applied and the 3 m release height required for aerial applications. The vertical pipe cleaners indicated a similar trend.

Evaporation of droplets – screening of spray adjuvants

For an anti-evaporant adjuvant to reduce the rate of evaporation of free-falling droplets and thereby reduce the potential for spray drift, an adjuvant must reduce the loss of water from the outer skin of the droplet or physically increase the size of the droplet. This reduces the surface area to volume ratio.

A number of adjuvant products were screened (SSE 370 1 mL/L, DCTron® 20 mL/L, Agral® 1 mL/L, Placement® 5 mL/L and Placement® 5 mL/L + DCTron® 20 mL/L) in this study. They showed a range of responses over a range of ΔTs (Figure 9). The volume of 160 µm droplets (of water only) decreased 11 - 20% over the 4 m fall height, which is the standard to which adjuvant solutions were compared. The adjuvant products tested had little influence on the change in droplet volume over the 4 m fall, indicating that the products tested could not claim to be anti-evaporant adjuvants for water. Although SSE 370® consistently halved the loss of water in earlier unpublished tests, this response was not shown in this later study. It was clear that Agral® markedly increased the rate of evaporation from the droplets (59% reduction in droplet volume) compared to water alone. Such an adjuvant may not be suitable for use as an anti-drift adjuvant, based on a water only spray solution. The long chain polymeric adjuvants, such as 41A®, did not form mono-size droplets, so were not included in this study.

Trial results were very encouraging. Data generated from the evaporation tube are being used to screen adjuvants for field studies. Some low humidity (35 - 45%), low speed (2 m/s), wind tunnel verification studies have already been completed in cooperation with Silsoe Research Institute in the UK, using hydraulic nozzles. This will be reported toward the end of 2002 as part of a new humidity based model for assessing droplet evaporation.

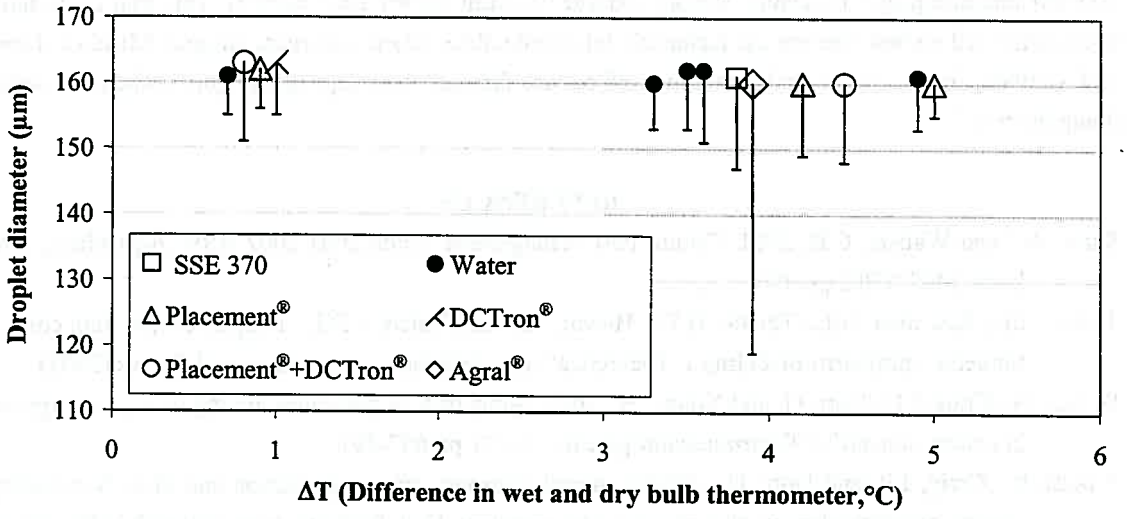


Figure 9 - Evaporation of droplets measured over 4 m fall for solutions containing water and SSE 370®, DCTron® petroleum oil, Agral®, Placement®, Placement®+DCTron® over a range of humidities (ΔT, or difference in wet and dry bulb temperature). Vertical lines with markers represent change in diameter of free-falling droplets from top (of tube) to the bottom (of tube).

CONCLUSIONS

The following conclusions are based on this study;

- There was no significant difference in the field control of heliothis eggs, larvae, damaged squares and bolls and fruit retention ratio between LDP aerial and ground rig applications of endosulfan.

- There was no significant difference in the amount of endosulfan recovered when comparing mid to mid leaves and top to top leaves for the aerial LDP and ground rig treatments. For aerial application however, there was significantly more endosulfan recovered on top leaves when compared to mid leaves.
- There was no significant difference in heliothis mortality between ground rig and aerial LDP application when larvae were exposed to bioassay leaves collected at 2 and 24 HAS.
- When larvae were exposed to bioassay leaves sampled 48 HAS, aerial application provided significantly higher heliothis mortality compared to those from the ground rig application.
- The ground rig treatment generated significantly less drift than the aerial LDP treatment. There were significant differences in spray drift recorded 400 m downwind of the trial site between the two treatments (0.19 $\mu g/cm^2$ for ground rig compared to 2.77 $\mu g/cm^2$ for LDP).
- Significant advances in the understanding of droplet evaporation have been made with the development of a facility to study the evaporation from droplets in-flight.
- Spray solutions containing a range of commercially available adjuvants can either reduce or increase droplet evaporation, thereby affecting the propensity of spray drift.
- Work is on-going to determine the influence of specific application parameters on the deposition and spray drift characteristics of aerial LDP application.

ACKNOWLEDGEMENTS

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