Cotton
RESEARCH & DEVELOPMENT

Annual, Progress and Final Reports

Part 1 - Summary Details REPORTS

Please use your tab key to complete parts 1 & 2.

CRDC Project Number: **UQ 31C**
Annual Report: ☐ Due 30-September
Progress Report: ☐ Due 31-January
Final Report: ☒ Due 30-September
(or within 3 months of completion of project)

Project Title: The Impact of LDP Spray Application upon the Biological Efficacy of Cotton Insecticides

Project Commencement Date: 1 July 2000 **Project Completion Date:** 30 June 2002
Research Program: Crop Protection

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Part 3.3 – Final Reports

1. Outline the background to the project.

The national pesticide project "Minimising the impact of pesticides in the riverine environment" (Land and Water Resources Research & Development Corporation (LWRRDC) Occasional Papers 23/98), contributed to the establishment of a comprehensive best management practice program for the Australian Cotton Industry. The Centre for Pesticide Application and Safety (CPAS) was responsible for investigating the aerial transport of pesticides in LWRRDC project UQL5 and CRDC project UQL13. A set of mitigating parameters were developed to reduce the impact of the off target movement of spray droplets Woods et al. (2001).

Fundamental to the reduction in spray drift is the selection and use of large droplet placement (LDP) water based spraying techniques. Used in conjunction with appropriate management strategies, large droplets above about 250 µm diameter (measured as a volume median diameter, VMD) can be used to reduce drift as they have higher sedimentation velocities and fall towards the ground more rapidly than smaller droplet sizes used for ultra low volume (ULV) spraying.

Based upon these data and subsequent modelling undertaken by CPAS, the National Registration Authority (now the Australian Pesticides and Veterinary Medicines Authority, APVMA) developed the 1999/2000 endosulfan cotton label in response to the detection of endosulfan residues in beef cattle during the 98/99 cotton season. The APVMA consequently focussed solely upon reducing off target contamination and aerial transport of droplets, not the biological efficacy of the product.

A three year study was commenced by CPAS in July 1999 *Optimisation of large droplet placement (LDP) technology for the aerial application of insecticides in cotton* (CRDC project UQ 27C). Early results showed that LDP technology could reduce spray drift and change crop deposition profiles in cotton. However the impact of such technology on the efficacy of the principal cotton insecticides was not fully understood. Some growers and applicators were adopting such technology to reduce pesticide drift without a full understanding of the effects on insecticide efficacy. It was thus proposed that a two year project be undertaken to investigate the effect of drift reducing technologies, particularly LDP application, upon biological effectiveness, and that this work be linked to the experiments commissioned in UQ 27C.

To expand the available database, additional deposition data from five CPAS cotton field trials conducted during the LWRRDC/CRDC 1994-1999 trials have been included in this report for a more robust assessment of deposition of spray on foliage (mid and top leaves) and on the ground (hill and furrow).

The downwind spray drift profile results have been incorporated into and fully documented in the UQ 27C project final report.

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

Seven large scale field trials, each with one or two application treatments, were undertaken in the 2000/01 and 2001/02 cotton season at four commercial cotton properties across three valleys and two states. Deposition on foliage and artificial targets, downwind drift profiles and field efficacy evaluations were conducted. Field efficacy was supported by laboratory bioassays of sprayed leaf material. The project objectives and the extent to which these were achieved in relation to the project milestones for each of the two years of the project are discussed below.

Year 1 2000/01

Milestone 1. Establish sites and co-operation with commercial cotton enterprises

Trials were undertaken at the commercial cotton properties of Auscott Narrabri; Auscott Moree ('Midkin'); Twynam Agricultural Group Collarenebri ('Iffley Farm'); and Yanco Farms Cecil Plains using commercial agronomic operations. These properties were selected as they provided sufficient field sizes to conduct aerial and/or ground application trials with adequate downwind buffer areas. These farms were also large enough to provide farm support, such as laboratory and storage space and open areas where meteorological equipment could be located without hindering other farm operations.

Over the years CPAS has been involved in CRDC research programs, a working relationship has been established with farm managers and aerial and ground rig operators, analytical chemists, entomologists, the CRDC program manager and cotton consultants required to successfully conduct such trials. The individuals and organisations who have directly contributed to this project are listed in Table 1.

Table 1 - Cooperators to the UQ 31C project

Assistance	Company	Contact	Location
Manager	CRDC	Dr. Bruce Pyke	Narrabri
Cotton Farm	Auscott Narrabri	Ben Stephens	Narrabri
Cotton Farm	Auscott Moree	Tim Richards	Moree
Cotton Farm	Twynam Agricultural Group, Iffley Farm	Brian Staniforth	Collarenebri
Cotton Farm	Yanco Farms	Dave Armstrong	Cecil Plains
Entomologist	QDPI	Sue Maclin	Toowoomba
Entomologist	QDPI	Dr. David Murray	Toowoomba
Entomologist	CRDC	Dr. Vic Edge	Sydney
Entomologist	NSW Agriculture	Dr. Robin Gunning	Gunnedah
Chemist	QDPI	John Standley	Toowoomba
Chemist	QDPI	Phil Hargarves	Brisbane
Aircraft	Aircair	Peter Williams	Narrabri
Aircraft	Gwydir Air	Harley McKillop	Moree
Aircraft	Gwydir Air	Fred Nolan	Moree
Aircraft	Cropcair Avaiation	Brad Jones	Cecil Plains
Aircraft	Cropjet Aviation	Graham Lowe	Collarenebri
Ground	Lachlan Smith Crop Spraying	Lachlan Smith	Moree
Ground	CropCare Spraying	Joe Robinson	Moree
Exec. Officer	Cotton Consultants of Australia	Jon Baker	Goondiwindi
Exec. Officer	Aerial Agricultural Assoc. of Australia	Phil Hurst	Canberra
Exec. Officer	Groundrig Operators Association	Angela Druery	Moree
Consultant	Institute for Rural Futures, UNE	Brendan Doyle	Armidale
Consultant	Agrisearch Services	Derek Litzrow	Moree
Consultant	Agrisearch Services	Rick Holzknecht	Toowoomba
Consultant	Tatzenco Consultancies	Brad Tatzenco	Pittsworth

Milestone 2. Establish field efficacy protocols in conjunction with QDPI

Several meetings were held with QDPI entomologists Dr David Murray and Mr R Lloyd during 2000, prior to the start of the summer field trials, on cotton insect scouting techniques and methods of recording damage caused by *Helicoverpa* spp (heliothis). From these discussions it was decided that the protocol used by QDPI entomologists should be adapted in order to have a uniform recording technique. The heliothis scouting technique was demonstrated by Mr Lloyd and the methodology incorporated into the field protocols. Agrisearch Services were subcontracted to conduct the field scouting assessments under the supervision of Mr Derek Litzrow.

Milestone 3. Rapidly develop a H. punctigera colony at the University of Queensland, Gatton for efficacy testing of plant material

During the development stage of this project, it was decided that *Helicoverpa punctigera* should be used in efficacy tests. However, in further discussions with entomologists from QDPI and Dr Vic Edge (CRDC), it was agreed that for the efficacy component, it would be better to use *H. armigera* and that QDPI would supply the required amount of neonate. Dr Robin Gunning provided resistance determination of late season heliothis populations. Lepton kits were purchased through Agrisearch Services.

Milestone 4. Determine the influence of LDP technology upon drift reduction, leaf coverage and biological efficacy under commercial production field conditions.

During the 2000/01 and 2001/02 seasons seven trials were completed, each with one or two treatments (Table 2). The first field trial in 2000/01 (Treatments A and B) was conducted when insect economic thresholds were reached on farm, as indicated by the respective senior farm agronomists. Two aerial treatments were applied, endosulfan ULV (ultra low volume) and endosulfan LDP (large droplet placement). To assess the performance of these products, leaf coverage, drift profiles and field efficacy evaluations were carried out. Field efficacy was supported by laboratory bioassays of sprayed leaf material, collected two hours after application. The field trial, sampling procedures and laboratory evaluations were completed successfully and the protocol adopted for subsequent trials, with minimal modifications. Three treatments were undertaken using ground rig equipment (boom sprayers). All aerial application trials were completed successfully, however not all the ground treatments were fully completed due to some ground application equipment failure in the field (Table 2).

Table 2 - Treatments for UQ 31C efficacy trials

ID	Date	Treatments	Insecticide	Location	Complete
A	10/12/00	Aerial ULV	Endosulfan	Auscott Narrabri	✓
B		Aerial LDP			✓
C	27/01/01	Aerial ULV	Chlorpyrifos	Auscott Narrabri	✓
D		Aerial LDP			✓
E	06/12/01	Aerial LDP	Endosulfan	Auscott Midkin, Moree	✓
F		Ground rig LDP			✓
G	19/12/02	Aerial LDP	Endosulfan	Auscott Midkin, Moree Ground Rig broken windscreen	✓
H		Ground rig LDP			✗
I	12/01/02	Aerial LDP	Endosulfan	Twynam, Collarenebri (Iffley Farms) Ground Rig bogged	✓
J		Ground rig LDP			✗
K	19/02/02	Aerial ULV	Chlorpyrifos	Yanco Farms, Cecil Plains. ULV treat.applied ~7h after LDP	✓
L		Aerial LDP			✓
M	08/03/02	Aerial LDP	Chlorpyrifos	Yanco Farms, Cecil Plains	✓
N		Aerial ULV			✓

Milestone 5. Collate available material from growers and aerial operators regarding the relative performance of ULV, LV and LDP application of pesticides

The endosulfan spray records from 136 fields across 5 farms were collected and collated. These data were entered into a database and the spray interval recorded. The median, mean and range in spray interval (measured in days) between successive insecticide sprays for aerial and ground applications was determined. For aerial applications the mean spray interval was 12.9 days compared to 10.5 days for ground applications. The spray interval will be used to determine the difference between aerial LDP and ground applications and assist in setting application windows for LDP application.

Once collated, this data was sent to the Cotton Consultants Australia, (CCA) who commissioned the Institute for Rural Futures (IRF) at The University of New England, Armidale to complete the survey analysis. These data also support the CRDC funded IRF / CCA *Integrated Pest Management Survey Report* (November 2001) which found that the efficacy of LDP endosulfan sprays was assessed to be acceptable overall.

Year 2 2001/02

Milestone 6. Undertake extensive monitoring of commercial application of insecticides using established technologies

Extensive sampling for downwind drift, in-crop deposition and biological efficacy was carried out in the large-scale field trials. For each trial from the 2000/01 and 2001/02 seasons, the number of samples collected is shown in Table 3. Data from five trials conducted between 1994-99 used a similar sampling density and sampling methodology.

Table 3 - Number of samples collected for the UQ 31C trials.

Samples collected at each subplot (for treatments identified)	# samples per subplot	# sample per treatment	# samples in total
top leaves for GC analysis (A-D)	10	90	360
mid leaves for GC analysis (A-D)	10	90	360
top leaves for GC analysis (E-N)	25	225	1,800
mid leaves for GC analysis (E-N)	25	225	1,800
above canopy papers for GC analysis (A-N)	5	45	540
pipe cleaners for GC analysis (A-N)	5	45	540
ground papers from hill for GC analysis (E-N)	5	45	360
ground papers from furrow for GC analysis (E-N)	5	45	360
ground papers across furrow and hill for GC analysis (A-D)	5	45	180
leaves for bioassay @ 2 h (A-N)	25	225	1,800
leaves for bioassay @ 24, 48 HAS (E-N)	50	450	3600
TOTAL (A-D)	115	810	2160
TOTAL (E-N)	145	1,305	10,440
GRAND TOTAL			12,600

NB. Treatmnets A-D did not have 24 and 48 h bioassay leaves collected

NB. Treatments A-D had ground sticks across the hill and furrow. Treatments E-N had ground sticks in the furrow and on the planting hill.

NB. Due to 2 ground treatments not going ahead, the number of treatments is reduced from 10 to 8 in treatments E-N.

Milestone 7. Determine the influence of LDP technology, (eg adjuvants and nozzle selection, from CRDC project UQ27C) upon drift reduction, leaf coverage and biological efficacy)

Results from this project showed that, compared to the aerial application of ULV insecticides, the use of LDP technology reduced the value of the down wind spray drift profile by from ten to fifteen times.

Compared to mean leaf deposits from ULV treatments, it was found that foliage treated using LDP application resulted in 40% less pesticide being deposited on the top canopy. Deposits on the ground (hill and furrow) were fourfold greater when LDP techniques were compared with ULV treatments.

Overall however, there was no significant difference in the control of *Helicoverpa* spp. Recorded using LDP or ULV application techniques. See CRDC UQ 27C Final Report (2003), *Optimisation of large droplet placement (LDP) technology for the aerial application of insecticides in cotton* for an explanation of the downwind drift results, and studies on adjuvant, nozzle selection and evaporation.

3. Detail the methodology and justify the methodology used.

3.1 Laboratory studies – wind tunnel droplet atomisation

To measure the atomisation of sprays at high speeds, a Malvern 2600 laser diffraction analyser was used in conjunction with a traversing nozzle gantry. The Malvern 2600 is an internationally recognised instrument for determining droplet and particle size according to international industry standards.

For droplet size atomisation (DSA) studies, each nozzle is usually placed in the wind tunnel with the nozzle body positioned straight back (parallel to the airstream) and the tunnel set to the required airspeed. For example, in the adjuvant study, the droplet size was measured for a number of ground and aerial nozzle types at ground and aerial application speeds (60, 85, 110 and 130 knots) with spray solutions consisting of water only, water plus an emulsifiable concentrate (EC) blank (pesticide solution with active ingredient removed) and water plus EC blank plus one of ten adjuvants. The EC blank was used to simulate a typical spray mix.

A full description of the methodology adopted for the wind tunnel studies can be viewed in the final report for the UQ 27C project.

3.2 Field studies

3.2.1 Time plan

The commercial aspect, magnitude and seasonal variability of the trial program limited spray application to periods when insect pressure was above the economic threshold, (as determined by grower agronomists). It is interesting to note that during the 2000/01 and 2001/02 seasons, that relatively low insect pressures were present in the Gwydir and Namoi Valleys. This limited the number of trials that were able to be completed during the endosulfan window of application. Consequently, to maintain an adequate number of trial sites, two of the seven trials were conducted during late Stage II to Stage III, using chlorpyrifos as an alternate insecticide.

The trial plans were modified to accommodate a decision by the APVMA to revise the registration status of endosulfan to LDP-only for the beginning of the 2000/01 season, although an off-label use permit was issued for that season to enable a ULV vs LDP comparison trial to be undertaken.

3.2.2 Treatments

In these trials, three types of artificial targets were used to quantify downwind drift and in-crop deposition:

- Horizontal flat plate targets (Plate 1) were used to determine the amount of product reaching the canopy within the treatment subplots and a vertical pipe cleaner to measure the vertical flux, ie. the amount of spray passing the same point,
- Horizontal flat plate targets (as above, this time as downwind arrays) to measure the fallout of droplets and the vertical flux at a range of points downwind of the field being sprayed (0, 50, 100, 200, 300, 400 and 500m), and
- Ground stick targets placed on the ground underneath the canopy (across two rows (2001/02) or in the furrow and on the adjacent planting hill (2001/02)) for assessing the fallout of droplets onto the ground within the treatment subplots.

The insecticide was applied using commercial aircraft and/or ground rig boom sprayers using LDP (VMD >250µm) at 30L/ha by aircraft or 100L sprayed/ha by ground rig and/or ULV (VMD 67-140 µm) at 3L/ha by aircraft (Table 2 and Table 4).

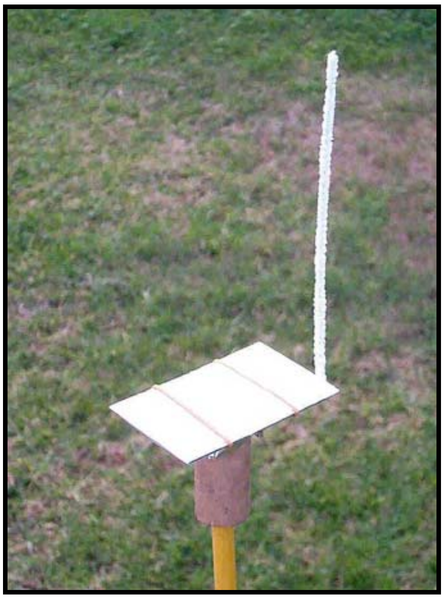

Plate 1 - Horizontal flat plate fitted with chromatography paper and vertical pipe cleaners to measure the fallout and vertical flux of material above the canopy or distances downwind for drift assessment

3.2.3 Field layout

Treatment sites were selected dependent upon field size (at least 600 x 1000 m) and the availability of a sufficient down wind buffer area (at least 500 m). As shown in Table 2, one or two treatments per trial were applied, (eg. treatment A vs. B, treatment C vs. D, etc.). The majority of treatment applications were undertaken to compare the aerial application techniques. Considerable effort was also put into establishing three ground vs aerial trials, however breakdown of contractors ground rig equipment unfortunately reduced two trials to unpaired LDP treatments (the ground rig treatments G and J were discontinued).

Detailed field protocols were written for each trial outlining aims, objectives, processes, the methods and risk assessments specific for each task. The actual application date of trials was dependent upon the weather, insect pressure, insecticide option and the farm/consultants need to spray. The eventual timing of the application events was also dependent upon availability of the aerial or ground rig contractors. For each trial, 5-7 University staff were required for in-field sampling and conducting laboratory bioassays. A stylised method for field trials is presented in Figure 1.

3.2.4 Plot preparation

Two treatment plots were (eg. A and B) were marked out with flags so that a minimum of 30 ha (representing 16-20 swaths of the aircraft) was sprayed for each treatment. This provided sufficient sprayed area for downwind drift assessment and allowed adequate space to centrally locate the sampling zones within the sprayed treatment areas.

Following the method of Shaw and Watson 2001, pre-treatment (less than 24 hours prior to spraying) checks on 20 plants per subplot were carried out by Agrisearch Services. Assessments were made to determine the presence of heliothis eggs, larvae (all stages), other pests and top 5 square damage. Post application, further assessments were conducted from 2 to 9 days after treatment (DAT).

Table 4 - Aircraft and ground application equipment setup details

Treatment	Application conditions	Airspeed (knots) Release height (m) Lane separation (m)	Nozzle and Settings	Area Treated (ha)
A	Aerial ULV, 3 L/ha Endosulfan, 7.2 µg/cm^2 AT 502	110 knots 3m release height 18m lane separation	Micronair 80°, 2000 rpm, 5 VRU 30 cm relative to TE	60 ha
B	Aerial LDP, 30 L/ha Endosulfan, 7.35 µg/cm^2 AT502	110 knots 3m release height 18m lane separation	CP 0°, 275 kPa (40 psi) 16 units per wing Parallel to airstream	60 ha
C	Aerial ULV Endosulfan, 7.2 µg/cm^2 3 L/ha AT 502	110 knots 3m release height 18m lane separation	Micronair 80°, 2000 rpm, 5 VRU 30 cm relative to TE	60 ha
D	Aerial LDP, 30 L/ha Endosulfan, 7.35 µg/cm^2 30 L/ha AT502	110 knots 3m release height 16m lane separation	CP 0°, 275 kPa (40 psi) 16 units per wing Parallel to airstream	60 ha
E	Aerial LDP Endosulfan, 7.35 µg/cm^2 AT S2R-G10502	120 knots 2m release height 16m lane separation	CP, 0°, 275 kPa (40 psi) 16 units per wing Parallel to airstream 65% wing span	80 ha
F	Ground LDP, 100 L/ha, 40% band Endosulfan, 7.35 µg/cm^2 Melrose Spray Coupe Raven controller	18 km/hr 50 cm release height 24 m boom	XR 80015, 250 kPa 3 nozzles per 1 m row Droppers (2 side, 1 middle)	60 ha
G	Aerial LDP, 30 L/ha Endosulfan AT S2R-G10502 7.35 µg/cm^2	120 knots 2 m release height 18 m lane separation	CP, 0°, 250 kPa (40) psi. 16 units/wing Parallel airstream 65% wing span	80 ha
I	Aerial LDP, 30 L/ha Endosulfan AT 502b 7.35 µg/cm^2	120 knots 2-3 m release height 26 m lane separation	CP, 0°, 250 kPa (40 psi) 16 units/wing Parallel airstream 50% wing span	60 ha
K	Aerial ULV Chlorpyrifos, 15.0 µg/cm^2 5 L/ha Piper Pawnee PA-25	85 knots 2 m release height 16 m lane separation	Micronair, 15 psi (110 kPa) 4 units per wing 75°, 2000 rpm, 7 VRU 15 cm relative to TE 65% wing span	20 ha
L	Aerial LDP, 30 L/ha Chlorpyrifos, 15.0 µg/cm^2 AT 502b	120 knots 2 m release height 24 m lane separation	Flat fan 40/10, 200 kPa (30 psi) 90° to airstream 28/30 units port/starboard parallel to airstream 55% wing span 60 cm relative to TE	40 ha
M	Aerial LDP Chlorpyrifos, 15.0 µg/cm^2 30 L/ha AT 502b	120 knots 2 m release height 24 m lane separation	Flat fan 40/10, 200 kPa (30 psi) 90° to airstream 28/30 units port/starboard 55% wing span 60 cm relative to TE	40 ha
N	Aerial ULV Chlorpyrifos, 15.0 µg/cm^2 5 L/ha Piper Pawnee PA-25	85 knots 2 m release height 16 m lane separation	Micronair, 15 psi (110 kPa) 4 units per wing 75°, 2000 rpm, 7 VRU 15 cm relative to TE 65% wing span	40 ha

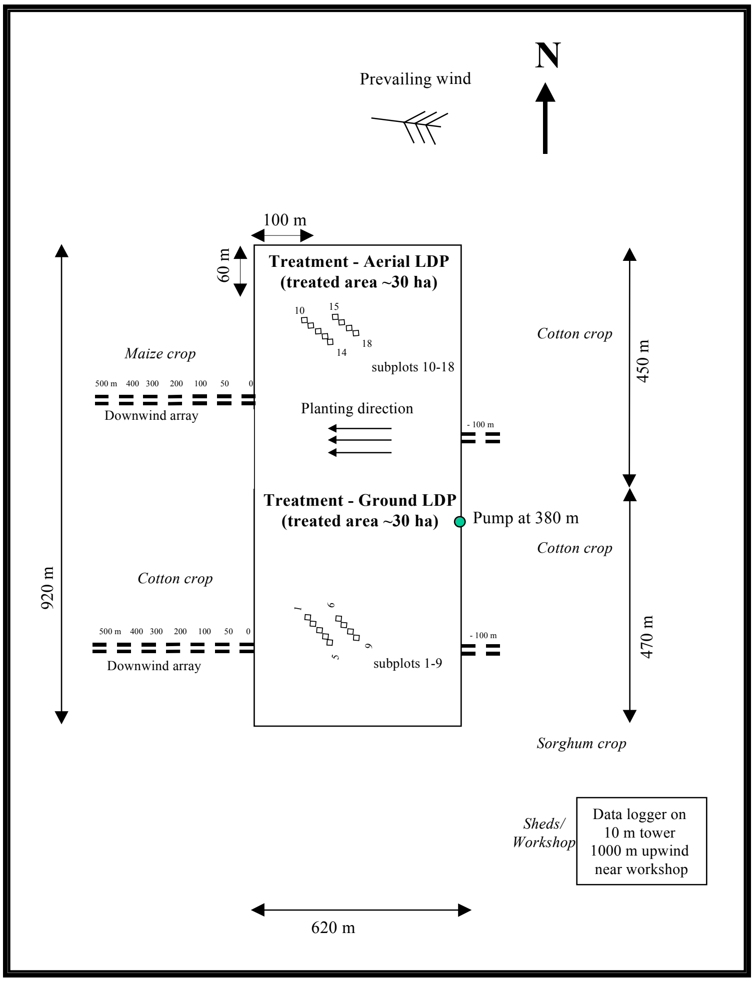

Figure 1 - Stylised field layout for the field trials

3.2.5 Subplot preparation

Nine subplots per treatment were set out no less than 60 m (at least 3 swath widths) from the edge of the field (Figure 2). A subplot measured 20 x 20 m and was separated from the next subplot by 5 m. Depending on the prevailing wind and orientation of the field, subplots were set out in a 'V' pattern, or a two parallel line pattern (separated by 50 m).

The number of samples used in each trial is summarised in (Table 3). For in-crop deposition determination, aluminium flat plate targets mounted on fibreglass rods were positioned above the canopy. Flat plates were placed in 5 locations per subplot (separated by 4 m, Plate 1).

Chromatography paper (52 x 76 mm) and pipe cleaners were fitted to the horizontal flat plates. Chromatography paper was held in the horizontal position by two rubber bands. Pipe cleaners were oriented vertically by inserting one end of the pipe cleaner through hole in corner of aluminium flat plate. Chromatography paper (25 x 500 mm) and pipe cleaners were fitted to foil-covered wooden stake (ground stick). Ground sticks were placed on the ground, either across the row (from one planting hill to another for treatments A-D), or along the planting hill and another along the adjacent furrow (treatments E-N). This was repeated five times per subplot in a diagonal pattern (for flat plate and ground stick targets), so that a total of five flat plate targets and five (treatments A-D) or ten (treatments E-N) ground stick targets were located in each of nine subplots.

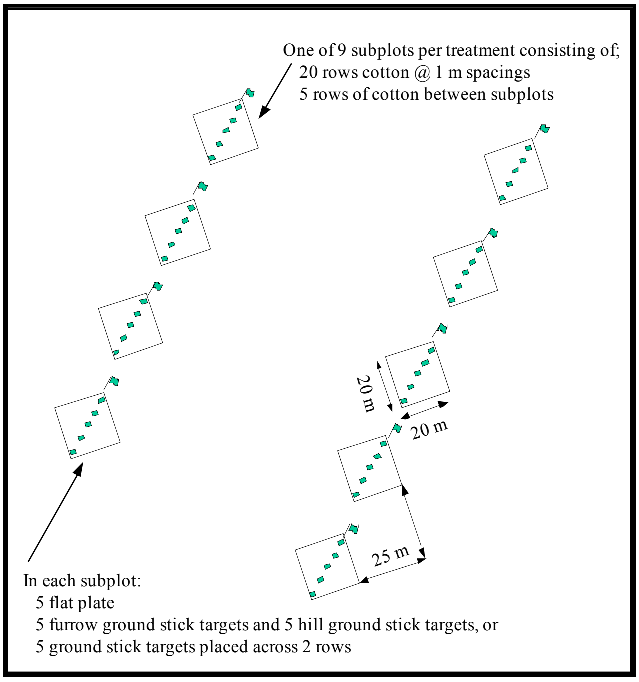

Figure 2 - Subplot layout showing the 9 subplots and the 5 sampling areas within each subplot

3.2.6 Deposition measurement on artificial and natural (leaf) targets

After application, a two hour delay was implemented to give sufficient time for the product to dry and reduce exposure to field staff when collecting samples.

Artificial targets: From each subplot, the five horizontal papers were placed into a sample bottle, five vertical pipe cleaners were placed into a second sample bottle and the five ground stick papers into a third bottle. For treatments E-N, the five furrow ground stick papers were placed into a third sample bottle and the five hill ground stick papers into a fourth sample bottle. Bottles were sealed and placed into a cold, light-free insulated container. Acetone was added to the chromatography paper and pipe cleaner samples and placed back in the cold, light-free insulated container until they could be frozen (-20ºC) and sent off for gas chromatography determination of the insecticide. Samples were analysed by QDPI, Leslie Research Centre (LRC), Toowoomba. Endosulfan 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.

Natural Targets: For GC deposition determination of treatments A-D, 10 top and 10 mid leaves were collected from each subplot, placed in 2 separate sample jars 2 h after spraying and kept in a cooled and light-free insulated container. Hexane was added to the leaf samples and placed back in the cold, light-free insulated container until they could be frozen (-20ºC) and sent off for gas chromatography determination. For treatments E-N, 25 top and 25 mid leaves were collected at 2, 24 and 48 hours after spraying. Fifty field control leaves were collected from each subplot from treatments N and M for individual fresh weight, dry weight and leaf area calculations. 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.

3.2.7 Biological efficacy determination

Leaves for laboratory based biological efficacy studies were collected at the same time as leaves for gas chromatograph (GC) deposition determination. 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 (six leaves per row), two hours after spraying (HAS), placed in paper bags, and kept in a cooled and light free insulated container and transported back to the laboratory. For treatments E to N, 30 leaves from each subplot were also collected 24 and 48 HAS. 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 that 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 (DAT) after the neonates were placed on leaves. For treatments M and N (chlorpyifos), 25 field control top leaves were collected from each plot and used to compare against the glasshouse controls and determine the ‘back ground’ affect.

3.2.8 Measurement of meteorological parameters

For each trial, relative humidity, temperature and wind speed was recorded at the time of application using a handheld Kestral 3000 Pocket Weather Meter. For some trials, additional wind direction measurement @ 2m was recorded at the same time using a portable datalogger (fitted with “Young” sensors). This was located upwind of the trial site. In addition, continuous (1 minute) recordings were taken using an Environdata datalogger connected to wind speed (2m and 5m), wind direction (2m), temperature (2m and 10m) and relative humidity (2m) sensors placed on one of the 20m telescopic masts. To estimate the stability of the air above the crop the stability ratio for each run was calculated using the Environdata sensor readings (T°C 10m – T°C 2m/(Wind speed @ 5m)^2).

3.2.9 LDP survey of growers

The farm agronomists from Auscott Midkin (Tim Anderson), Twynam Farms [Collymongle Station (Nick Barton), Merrowie Station (Simon Anderson), Elengerah Station (Brett Downey)], and Yanco Farms (Dave Armstrong) were asked to fill in pre-prepared spreadsheets with the number of days between successive insecticide applications (the spray interval) from the 2001/02 season, noting when and where endosulfan was used. Participants supplied details of their ground and aerial application programs, in conjunction with detailed insect scouting reports produced from CottonLogic®. The median, mean and range in spray interval (days) was then determined for ground and aerial applications for each month that data was available. The spray interval was used to determine the difference between aerial LDP and ground applications.

Once collated, this data was sent to the Cotton Consultants Australia, (CCA). The Institute for Rural Futures (IRF) at The University of New England, Armidale (Brendan Doyle) completed the survey analysis using the Kruskal-Wallis Rank Test. This test is the nonparametric analog of one-way ANOVA and is particularly useful when measurements are distorted so as to violate the basic assumptions of normality and homogeneity of group variances. The statistical conclusion offered by the test relates solely to observed group differences.

4. Detail and discuss the results including the statistical analysis of results.

4.1 Deposition studies

Deposition values on crop canopy (top and mid leaves) and on the ground (hill and furrow, or average ground) are presented in this repoprt. The amount of endosulfan deposited is presented in micrograms per unit leaf area (μg/cm^2) and for LV, ULV and ground and as a percentage of ULV. The deposition results for chlorpyrifos are not presented in this report, as there was insufficient information to make a complete comparison between all four application methods.

The field bioefficacy results are presented in terms of (a) larval abundance, (b) presence of eggs, (mean), (c) damaged to squares/bolls and (d) fruit retention ratio (FRR). The data are further separated into the three application practices investigated (ULV, LDP and ground) and the insecticide used (endosulfan and chlorpyrifos). In this way broad trends could be identified and assessed across a range of conditions.

Due to the complexity and enormity of the trials, the results could not be analysed as a complete factorial, so there are no over all comparisons with levels of significance attached. Most trials were carried out under a different set of environmental circumstances, and under different management regimes. As a compromise, data were analysed using oneway ANOVAs. However the non-collinearity of data meant that even these comparisons could become specialised, limiting the comparisons that could be made on the broader scale. However, statistical analysis clearly showed that there was more variation between trials than within trials. This was an expected finding as each trial was conducted under a different set of environmental conditions.

The data presented in this report is presented pictorially as a series of means. In this way, comparisons can be made by 'stepping back' and looking at the application techniques and minimising the influence of individual trial effects.

To increase the robustness of the analysis, in addition to the trials completed for this study, results from five seasons' deposition studies for ULV, LV and ground application conducted between 1994-1999 have been included in the study. This enabled a broader data set to be compiled and conclusions drawn for a wider set of input variables.

4.1.1 Deposition on top and mid leaves

Deposition was measured as the amount of endosulfan deposited per unit area of foliage, and is represented as μg endosulfan/cm^2 (Figure 3). Deposition at the top of the crop canopy was maximised using ULV application (9.1 μg/cm^2), followed closely by LV application (83% of ULV, 7.6 μg/cm^2). Aerial applications using LDP techniques (3.5 μg/cm^2) and ground application (3.1 μg/cm^2) reduced the amount of material retained on top leaves (less than 40% of the material deposited using ULV application).

In aerial application the droplets have a greater horizontal trajectory and a more turbulent path (a result of the aerodynamic forces of a flying aircraft 2-3 m above the ground) and combined with the airspeed induced shear forces reducing droplet size, leads to greater proportion of deposits being retained by foliage sprayed with aircraft compared to ground rigs.

Deposits on the mid leaves were approximately 50% lower than the top leaves in all treatments. The greatest deposits were from the LV treatment (4.3 μg/cm^2; 113% that of ULV). Aerial application using LDP (1.6 μg/cm^2) and ground application (1.7 μg/cm^2) resulted in less than 45% of the dose applied using ULV. This reduction in deposition on mid compared to top leaves was expected, due to the shading and filtering effect from spray droplets by the top leaves.

About 40% less endosulfan was recovered from leaves sprayed with LDP and ground treatments and on mid leaves from the LV treatment, compared to the ULV treatment. However, there was no overall effect of application method on the control of *Helicoverpa* spp.

4.1.2. Deposition on hills and furrows (on ground)

Deposition on the ground (either as an average amount deposited across the hill and furrow area, or on the hill and furrow area separately) increased as droplet size increased.

The smallest amount of deposit measured on ground was recorded using ULV application. A threefold (average over hill and furrow) increase in deposit on the ground was recorded using LV, a 5.6 and 3.6 fold increase using LDP (hill and ground respectively) and a 2.9 and 4.7 fold increase occurred using ground application (hill and ground respectively) compared to ULV. These ground deposit values are important as they suggest that the transport of insecticide could be influenced by the transport and recirculation of water on farm. Deposits on a non-target site also represent a waste of active ingredient, as these deposits do not normally contribute to the biological activity a contact insecticide.

Comparing the distribution of material on the soil in a young canopy, a similar amount of endosulfan was recorded on the furrow and the hill when applied by aircraft using a ULV formulation. This contrasts to aerial LDP application where 50% more was deposited on the hill than furrow. As the season progressed and the canopy closed, less spray made contact with the ground. Compared to aerial LV and LDP applications, which are a blanket application across foliage and the ground, ground applications ‘band’ along the foliage line. However the increased application volume and the minimal turbulence created during ground applications can lead to a reduced horizontal redistribution of droplets, which lead to increased deposition in the furrows (2.2 $\mu g/cm^2$ for aerial compared 2.9 $\mu g/cm^2$ for ground application). The data shows that with banding via ground application, there are deposits in the furrow where no spray was directly applied. This was a surprising result, as a benefit of banding on insecticides is that ground contamination was thought to be minimised. This suggests that banding with ground rigs is not as effective on reducing ground contamination as accepted by Industry.

It is hypothesised that the differences in the droplet distribution and transport processes between aerial and ground applications affect droplet movement in and around the canopy. Aerial application is dominated by droplets that shatter when released into a relatively fast moving and sometimes turbulent airstream. Droplets are largely dispersed and distributed around a crop canopy by wind generated mechanical turbulence. By comparison, ground application usually consists of larger droplets generated by hydraulic pressure and applied as a directed spray in a slower moving airstream.

With both LDP and ULV application, approximately the same amount of active ingredient is deposited per unit area, however the active material is applied in different volumes of carrier. For example, during ULV application about 7.2 μg endosulfan /cm^2 is applied in 3-5 L/ha of an oil based carrier. For LDP application about 7.35 μg endosulfan/cm^2 is applied in 30 L/ha of water). Although it can be argued the concentration of active ingredient in individual droplets is different for each application technique, the influence this parameter has on bioefficacy is thought to be relatively small. Other more significant factors that influence these application processes include the delivery (application) system, carrier volume, carrier type (oil, water), meteorology, (temperature, relative humidity), droplet size, travel speed and formulation.

4.2 Field bioefficacy studies

Over a range of conditions, seasons and equipment, it was shown that in the field, LDP aerial and ground applications were as effective as ULV applications in controlling *Helicoverpa* spp

(Figure 4 to Figure 7). There was no clear 'best' application method for all circumstances reported on.

Direct statistical comparisons between treatments were difficult to make; since trials were conducted over a number of sites, over several seasons and under realistic commercial field conditions. This involved different farming practices, equipment types environmental and meteorological conditions. However the main trends were clear.

4.2.1 Larval abundance

Results showed that there was no difference in larval abundance and egg numbers between ground, ULV and LDP application. All three application methods were as effective at controlling early larval stages of *Helicoverpa* spp. This similarity in control occurred despite the variation in formulations (oil-based ULV vs emulsifiable concentrate-based LDP) droplet size, spray solution concentration, the density of droplets and the persistence of product once it deposits on foliage.

When comparing the two insecticides and application methods, endosulfan ULV was found to be more effective at reducing larval numbers compared to chlorpyrifos ULV. It should be noted however that some of the larvae in the later season chlorpyrifos trials were medium (or greater) in size, compared to small to medium size larvae found in the majority of the earlier season endosulfan trials.

There was little difference between endosulfan and chlorpyrifos LDP on larval abundance. Both endosulfan and chlorpyrifos LDP treatments showed an increase in larval numbers 2-3 days after application. The rate of increase was sharper with LDP chlorpyrifos compared to LDP endosulfan, perhaps because of the different larval sizes, or a hatching of eggs that followed the application of the chlorpyrifos spray. It is postulated that the gradual increase in larval numbers observed after the application of LDP endosulfan was due to that fact that the larval population contained later instars against which endosulfan was not effective. Nevertheless an increase in larval abundance would have provided a base for natural enemies of *Helicoverpa* spp to parasitise the larvae and help the re-establishment of natural enemies.

4.2.2 Egg numbers

Although only one ground treatment was completed, a very good control of eggs was achieved comparing the boom sprayer application to all aerial treatments.

Both chlorpyrifos and endosulfan LDP generated a decrease in egg counts. Endosulfan showed a lower initial egg count compared to chlorpyrifos. However in two of the LDP endosulfan trials (Treatments B and D), the egg counts were higher than the third trial (Treatment E). It is postulated that this observation was caused by egg laying after treatment by *Helicoverpa* spp*,* as endosulfan has no ovicidal effect. However as endosulfan is softer on natural enemies than chlorpyrifos, it is possible that these eggs would have been taken out by egg parasites or predators.

4.2.3 Damaged squares/bolls

Overall, there was little difference in damaged square/boll numbers when application treatment and formulation were compared. Damage to squares/bolls were less than 5% in most cases, reflecting the low insect pressure over the two seasons. In one trial, endosulfan LDP caused markedly greater damage compared to the endosulfan ULV treatments (up to 15 % bolls were damaged). This increase in damaged square/bolls is similar to that noted in larval abundance and could indicate that there was a correlation between larval abundance and early damage to squares/bolls.

4.2.4 Fruit retention ratio

Similar trends were observed comparing fruit retention ratio (FRR) and damaged squares/boll graphs as in the larval abundance and egg data. One endosulfan ULV treatment yielded a higher FRR than the chlorpyrifos ULV treatments, with the remaining endosulfan ULV treatment being comparable. One endosulfan LDP treatment was similar to the best endosulfan ULV treatment (almost 100% FRR) and showed a much better performance compared to ground application. However the remaining two endosulfan LDP treatments were similar to the endosulfan ground and chlorpyrifos ULV and LDP applications, being slightly lower than endosulfan ULV.

4.3 Laboratory bioefficacy studies

The laboratory bioassays showed that there was a difference in control of 1-2 day old neonates from leaves collected 2 and 24 hours after application of endosulfan and chlorpyrifos (Figure 8 and Figure 9). When applying endosulfan by air using LDP techniques, greater and quicker control of neonates was achieved compared to ground application. There was no comparison beyond the 2 hour sprayed leaves for the ULV treatment. When chlorpyrifos was applied, the ULV treatment controlled more neonates, but the rate of control was the same as the LDP treatment.

For leaves collected 24 hours after the application of endosulfan, complete mortality was reached after 4 days. On leaves collected 24 hours after application, neonate mortality after 1 day using the boom sprayer was one half that of achieved using aerial LDP application. For leaves collected 48 hours after application, neonate mortality after 1 day using ground application was 20% of that achieved with aerial LDP application and after 4 days, 90% mortality was reached for LDP and 70% mortality for ground. The bioefficacy technique adopted (Shaw and Watson 2001) was found to be very sensitive (sprayed leaves are placed in a closed petri dish), and demonstrated the difference between LDP aerial and ground application systems.

The chlorpyrifos results showed a similar, but less dramatic sensitivity. Neonate mortality using aerial LDP application was initially 80% of that achieved using aerial ULV application.

The leaf bioassay program offered a repeatable, less variable but more sensitive measure of efficacy than the field assessment method detailed above.

Naturally, field populations of *H. armigera* add variability to the assessment system and may exhibit greater resistance than cultured populations to the common insecticides. In these experiments, the *H. armigera* culture at the DPIQ Toowoomba was considered remote from the field population since at least 20 or more generations had reproduced since being infused with field material. The laboratory colony was considered quite susceptible to most insecticides. It is noted that resistance to endosulfan (OC) in the field has been recorded at around 20-40%, although in the last season there was a noticeable drop in endosulfan resistance (Murray 2002 *pers com*.)

4.4 Field downwind drift studies

Drift studies were undertaken simultaneously with the UQ 27C project. Data showed that that LDP applications reduced the downwind drift ten to fifteen times, compared to ULV applications. This finding clearly strengthens the desire to use LDP, as a less environmentally contaminating but as effective technique as ULV application.

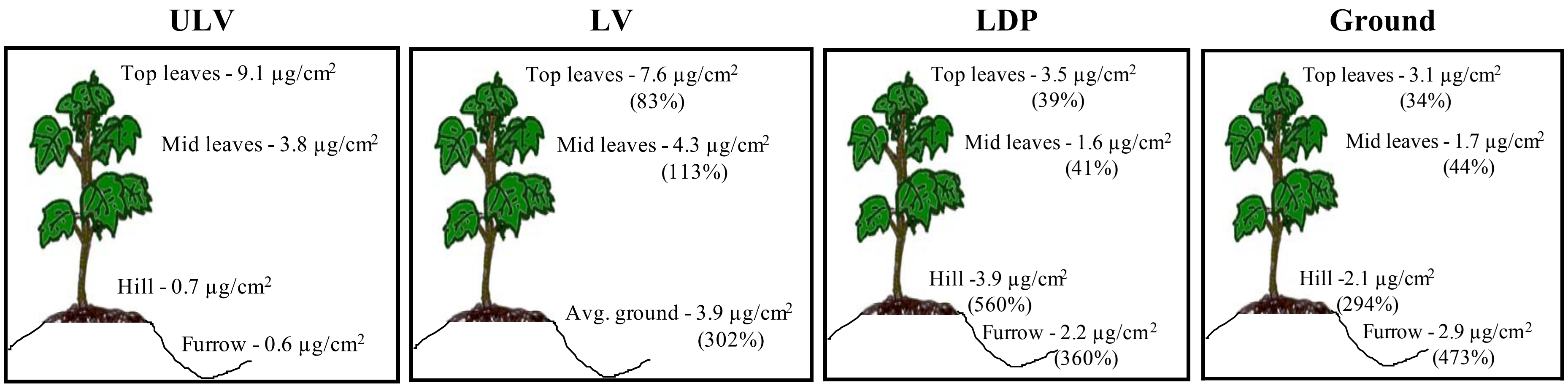

Figure 3 - Field Bioefficacy Studies. Deposition in canopy and on soil. Distribution of spray deposit (µg/cm^2 and (% of that recorded using ULV) for data collected 1994-1999, 2000-01 and 2001-02) on cotton foliage (top and mid leaves) and the ground (furrow and hill) from four application methods used to apply endosulfan (ULV ultra low volume, LV low volume, LDP large droplet placement and ground).

NB. ULV has been an unregistered application method for endosulfan in cotton since 2001/02.

Individual readings for hill and furrow ground deposition for LV application was not collected. An average ground deposit is presented.

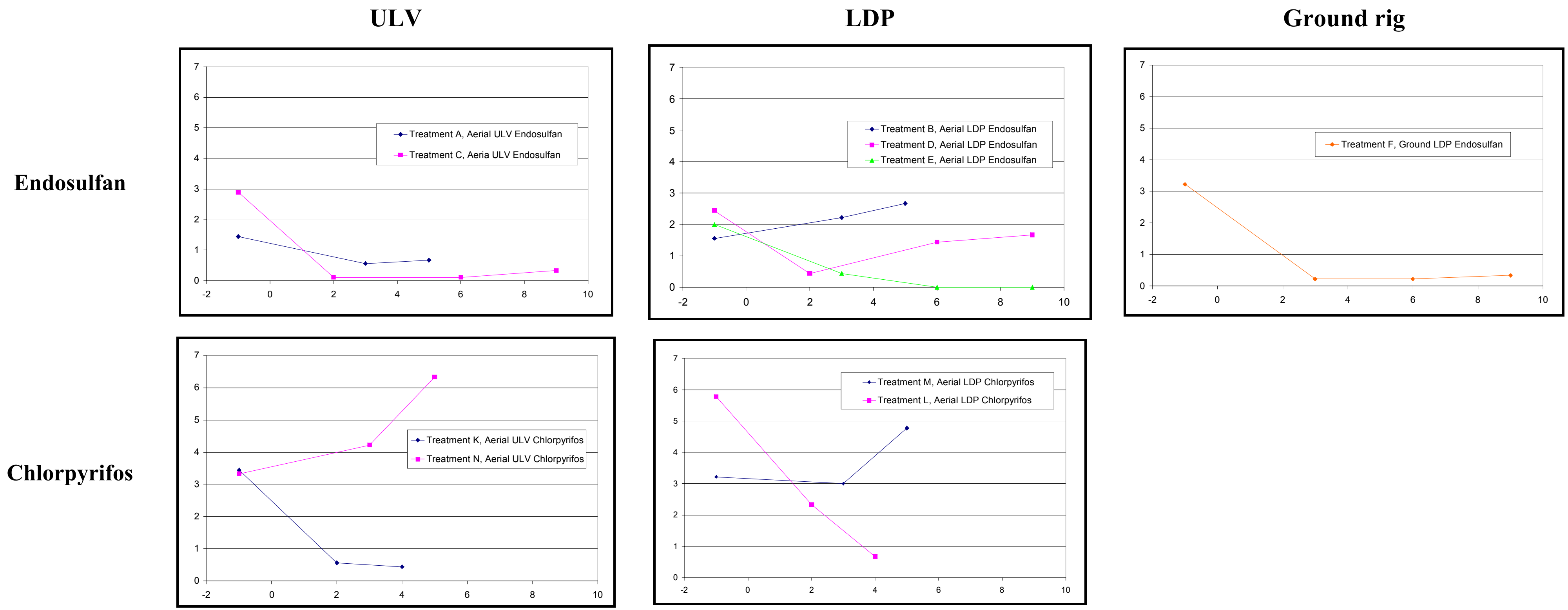

Figure 4 - Field Bioefficacy Studies. Larval abundance vs days after treatment. In field larval abundance results from assessmnets made pre-treatment to 9 days after treatment with endouslfan and chlorpyrifos. Y-axis is Larval Abundance (number of larvae, including very small, small, med and large), X-axis is Days Before And After Insecticide Application.

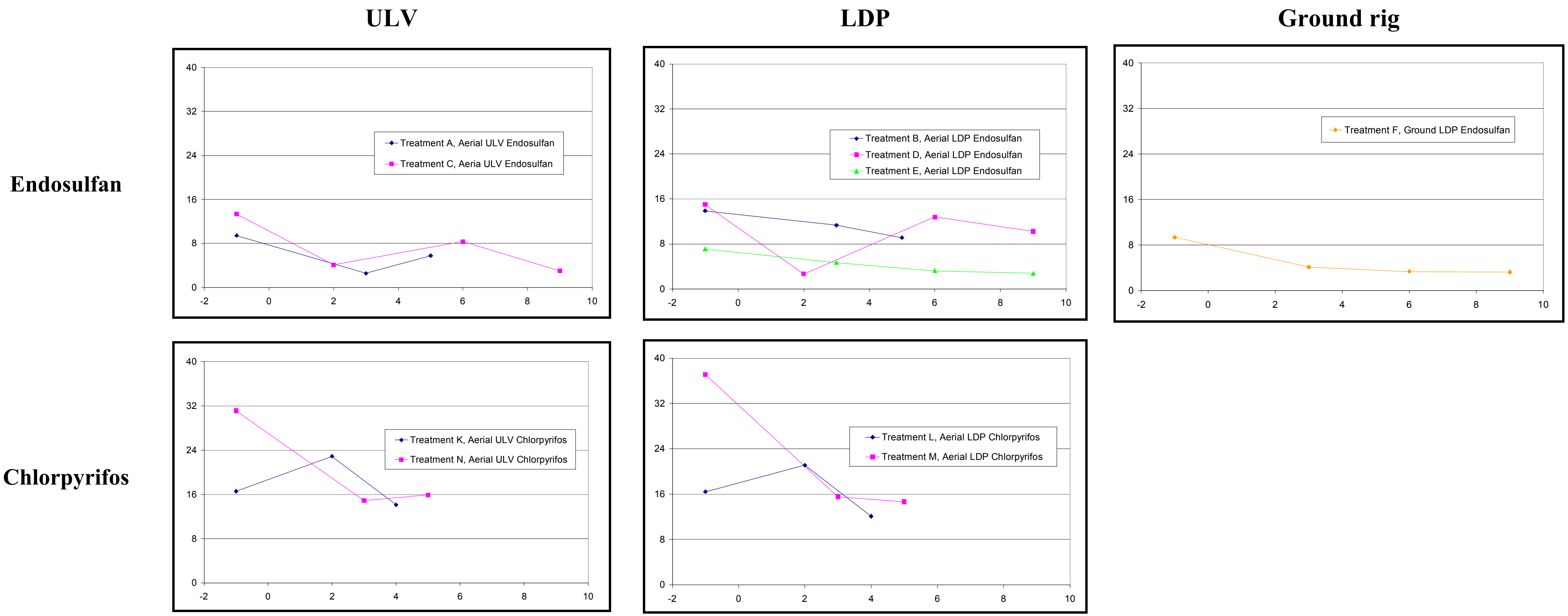

Figure 5 - Field Bioefficacy Studies. Mean eggs. In field mean eggs count results from assessmnets made pre-treatment to 9 days after treatment with endouslfan and chlorpyrifos. Y-axis is Mean Egg Numbers, X-axis is Days Before And After Insecticide Application.

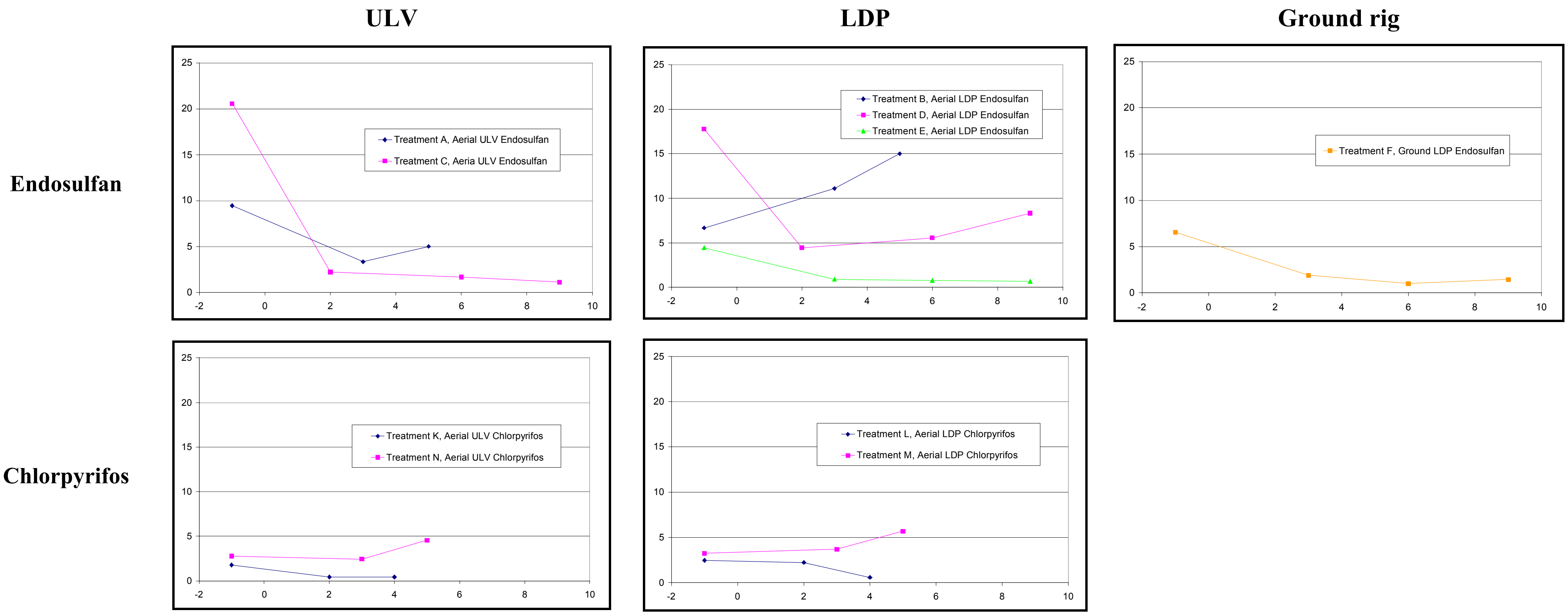

Figure 6 - Field Bioefficacy Studies. Damaged squares/boll (%) vs days after treatment. In field damage levels to squares and bolls results from assessmnets made pre-treatment to 9 days after treatment with endouslfan and chlorpyrifos. Y-axis is Damaged Squares/Bolls, X-axis is Days Before And After Insecticide Application.

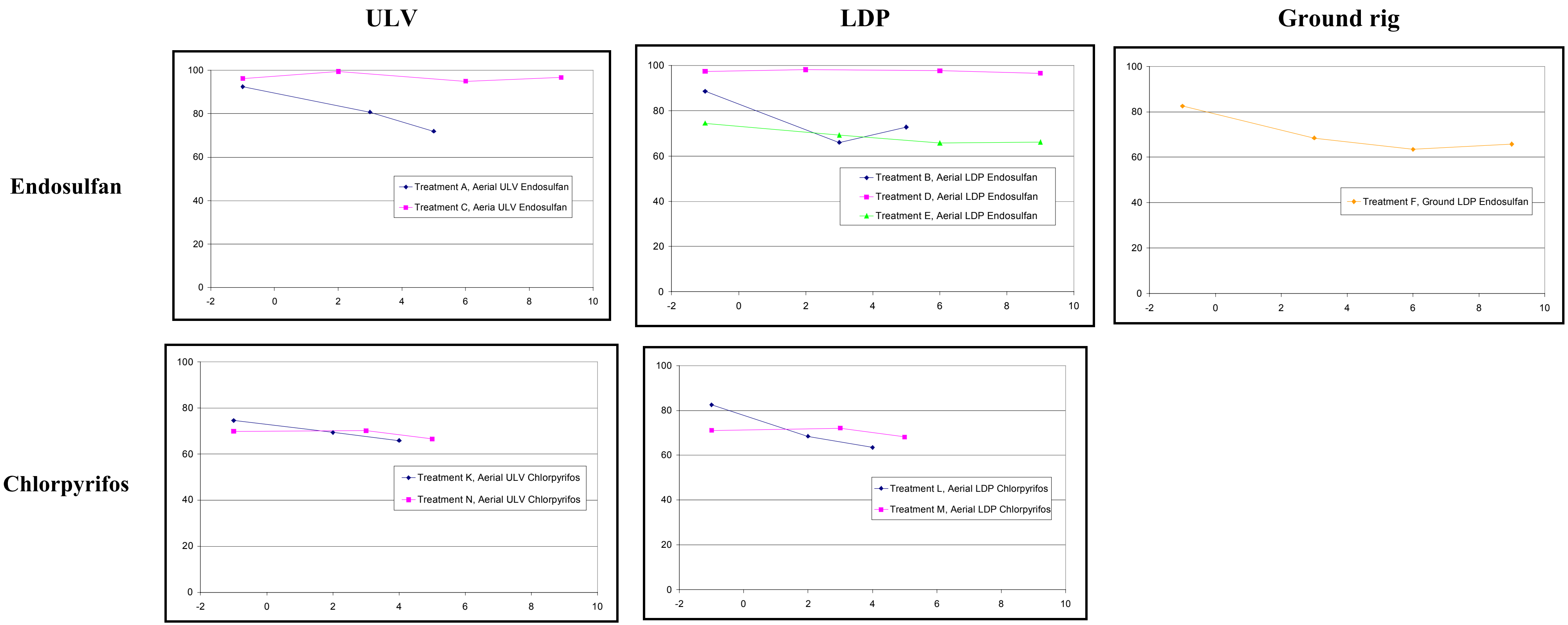

Figure 7 – Field Bioefficacy Studies. Fruit retention ratio (%). In-field fruit retention ratio results from assessmnets made pre-treatment to 9 days after treatment with endouslfan and chlorpyrifos. Y-axis is Fruit Retention Ratio, X-axis is Days Before And After Insecticide Application.

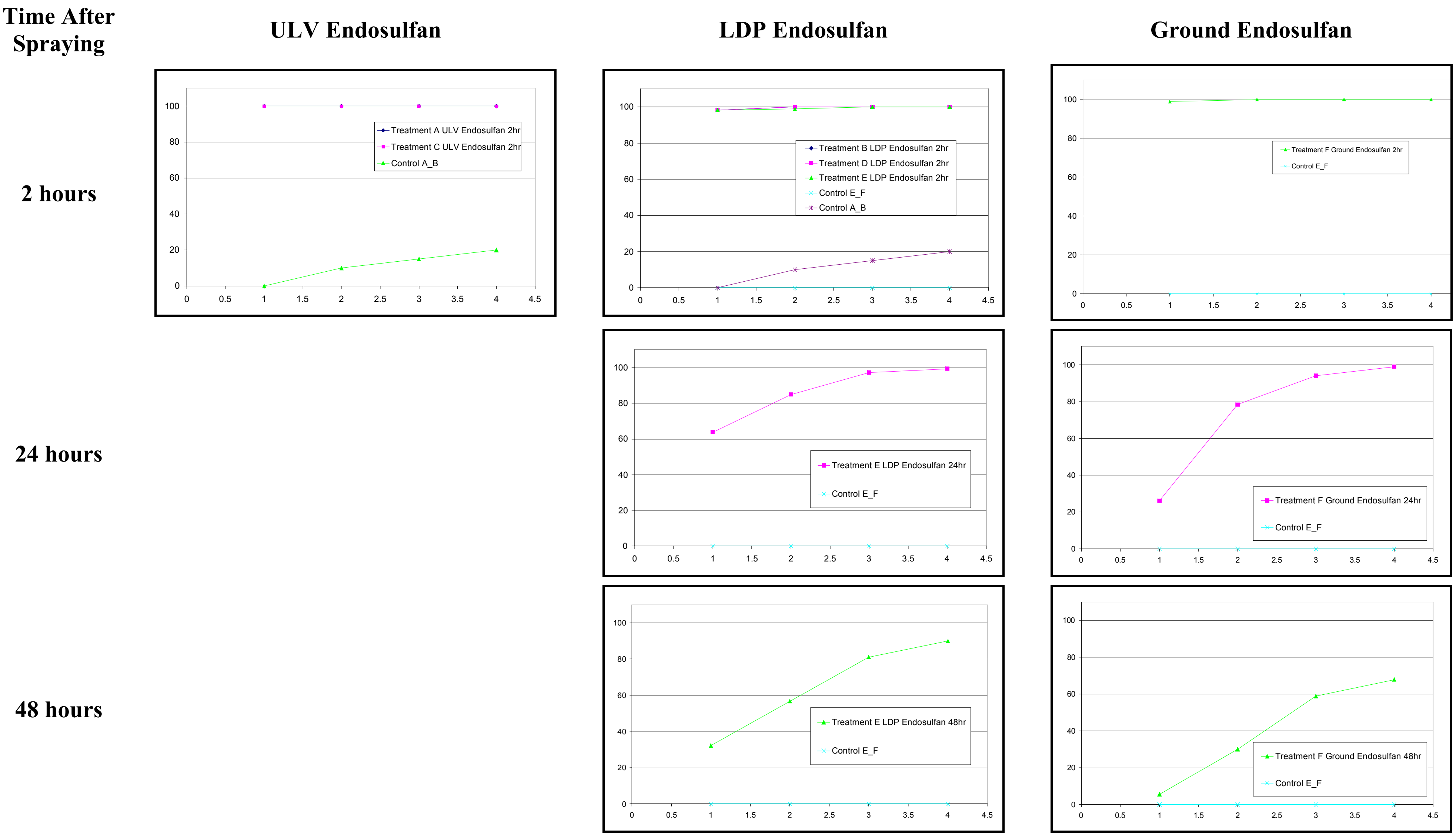

Figure 8 – Laboratory Bioefficacy Studies. Endosulfan. 96 hour (4 day) *Helicoverpa armigera* endosulfan bioefficacy laboratory results on top leaves collected 2, 24 and 48 hours after spraying for aerial ULV, aerial LDP and ground applications. Y-axis is % Mortality. X-axis is days after treatment.

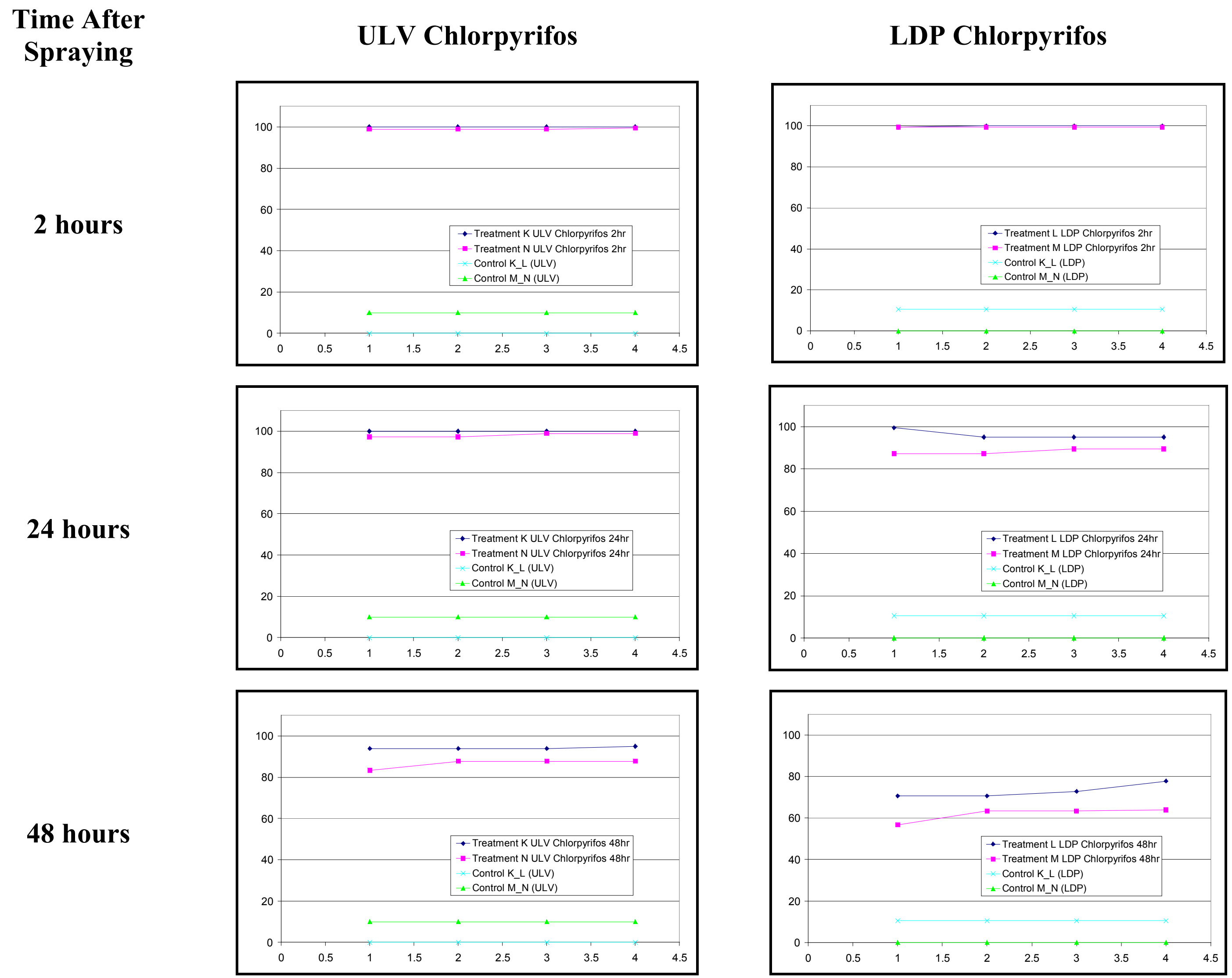

Figure 9 - Laboratory Bioefficacy Studies. Chlorpyrifos. 96 hour (4 day) *Helicoverpa armigera* chlorpyrifos bioefficacy laboratory results on top leaves collected 2, 24 and 48 hours after spraying for aerial ULV and aerial LDP applications. Y-axis is % Mortality. X-axis is days after treatment.

4.5 LDP survey of growers

The data is presented in Table 5 and Figure 10. The median, mean and range spray interval for aerial LDP applications was 14, 12.9 and 3-31 days, compared to 9.5, 10.5 and 1-36 days for ground applications respectively. The difference in spray interval between ground and aerial applications was 4.5 days (median) or 2.5 days (mean). This is significant (P=0.0215).

This suggests that field aerial applications of insecticide persist for longer than ground applications. This is supported by the increased deposit found on foliage from the intensive field sampling undertaken in aerial compared to ground application and also by laboratory bioassay studies. The bioassay studies found that after 48 hours, 90% of neonates died from aerial LDP compared to 70% for ground application. However, from the one field trial where ground and aerial were compared under like conditions, there was no evidence to support any differences in larval abundance, FRR, mean eggs, damaged squares/bolls or fruit retention ration.

The Institute for Rural Futures (IRF) *Integrated Pest Management Survey Report* (November 2001) reported that endosulfan was used almost exclusively by ground and aerial LDP applications, the majority being ground. The author reported that endosulfan is a very important chemical to the cotton Industry, as it is relatively soft, is vital to IPM strategies and when used in conjunction with LDP is low drift option.

Table 5 - LDP Survey results 2001/02. The monthly breakdown of the interval in days between consecutive sprays of endosulfan

	October 2001		November 2001		December 2001		January 2002	
	Ground	Aerial	Ground	Aerial	Ground	Aerial	Ground	Aerial
Median	26		8	31	8	14	15	8
Mean	25.8		8.5	31	8.4	11.9	14.4	13.2
Range	15 - 36		1 - 23	31	2 - 15	3 - 17	5 - 25	7 - 24
No. of samples	6	0	49	1	34	20	19	9

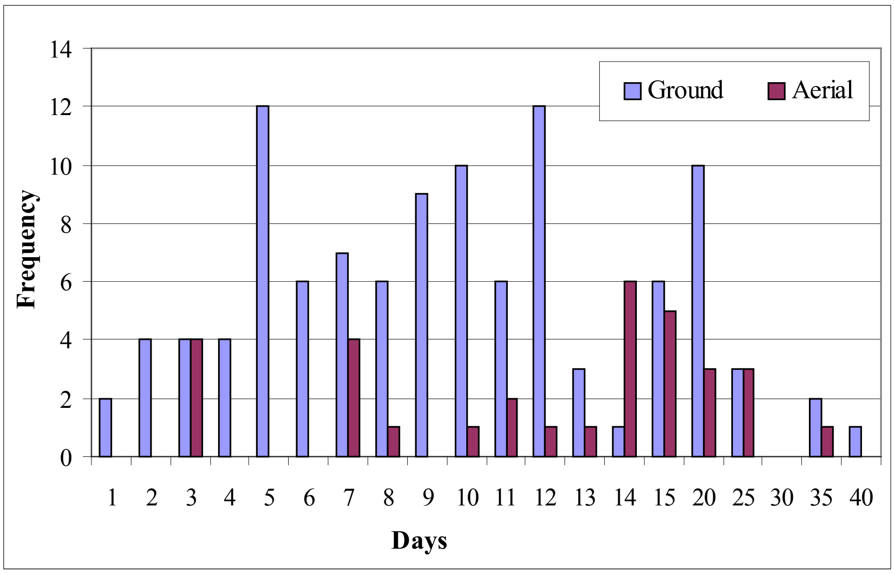

Figure 10 - LDP Survey results 2001/02. The frequency histogram of the spray interval in days between consecutive sprays of endosulfan

5. Provide a conclusion as to research outcomes compared with objectives. What are the "take home messages"?

In a two season study, results from large scale field trials, supported by laboratory bio-efficacy experiments showed that the adoption of Large Droplet Placement (LDP) techniques for the aerial application of insecticides, (endosulfan and chlorpyrifos) did not have a significant effect in reducing the biological efficacy of the pesticides when compared to aerial Ultra Low Volume (ULV) and ground rig application.

Drift studies undertaken simultaneous with this project by the Centre for Pesticide Application & Safety, (CRDC UQ 27C, *Optimisation of large droplet placement (LDP) technology for the aerial application of insecticides in cotton)* showed that the use of LDP application techniques reduced the downwind drift ten to fifteen times, compared to ULV applications. This finding shows that LDP techniques can be adopted to reduce the potential for spray drift resulting from the aerial application of pesticides whilst maintaining the effectiveness of certain contact insecticides on heliothis mortality.

6. Detail how your research has addressed the Corporation's three Outputs - Economic, Environmental and Social?

The results from this study will have a significant effect upon reducing the potential for spray drift resulting from the use of insecticide in the Australian cotton industry. By showing that the efficacy of insecticides was not compromised with the adoption of low spray drift aerial application techniques, the use of LPD technology in BMP can be extended and used with greater confidence. For the CRDC it will increase the Corporations capacity to support be more sustainable and profitable cotton industry by providing significant environmental benefits.

7. Provide a summary of the project ensuring the following areas are addressed:

a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.)

Not Applicable

b) other information developed from research (eg discoveries in methodology, equipment design, etc.)

Not Applicable

c) are changes to the Intellectual Property register required?

No

8. Detail a plan for the activities or other steps that may be taken:

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

- Make data available to Industry and regulators
- Incorporate the implications of this study into the BMP module
- Strengthen the opportunities to use LDP aerial application systems for the application of certain contact insecticides.

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

- Publication of conference papers in the Association of Applied Biology Conference, London, January 2004.
- 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

(c) for future research.

- Initiate studies at the droplet/canopy interface to provide answers to the role that transport processes have on deposition
- During 2002, CPAS was successful in obtaining Australian Research Council (ARC) funds to extend and improve the wind tunnel facility. A new low speed working section has been constructed and an Oxford Lasers imaging system purchased to enable research on the interaction of droplets around the three dimensional droplet/canopy interface to be investigated in greater detail.

9. List the publications arising from the research project and/or a publication plan.

Parkin, C.S., Walklate, P.J. and Nicholls, J.W. (2003). Effect of drop evaporation on spray drift and buffer zone risk assessments. *In Press*. British Crop Protection Council, Scotland. November 2003.

Nicholls, J.W., Talukder F.A., Hassan, E., Woods, N.W., Dorr G., and Gordon, B. (2002). Heliothis management, spray drift, and in-crop deposition using LDP spraying techniques in cotton. *In* Proceedings 11th Australian Cotton Conference. ACGRA Inc. 13-15 August 2002. pp 243-250.

Gordon, B., Nicholls, J.W., Dorr G., Mischke, S., Jones, M and Byrnes, M. (2002). The use of adjuvants for reducing spray drift. A Poster *In* Proceedings 11th Australian Cotton Conference. ACGRA Inc. 13-15 August 2002.

Gordon, B., Jones, M., Nicholls, J.W., Dorr G., Mischke, S., Woods, N.W., Talukder F.A. and Hassan, E. (2002) Comparing ground and Aerial applications of endosulfan to early season cotton under stable conditions. A Poster *In* Proceedings 11th Australian Cotton Conference. ACGRA Inc. 13-15 August 2002.

Gordon, B., Nicholls, J.W. and Dorr G. (2002). Comparing the deposition of the spectrum electrostatic system (10L/ha) and the Micronair AU5000 (30L/ha) onto mature cotton. CPAS Fact Sheet. The University of Queensland Gatton Campus, School of Agriculture and Horticulture, Centre for Pesticide Application and Safety, Gatton QLD 4343.

Gordon, B., Nicholls, J.W., Dorr G., Mischke, S., Jones, M and Byrnes, M. (2002). The use of adjuvants for reducing spray drift. CPAS Fact Sheet. The University of Queensland Gatton Campus, School of Agriculture and Horticulture, Centre for Pesticide Application and Safety, Gatton QLD 4343.

Dorr, G., Byrnes, M., Gordon, B., Jones, M and Woods, N.W. (2002). Recent Innovations in atomiser design. Results of CPAS tests. . CPAS Fact Sheet. The University of Queensland Gatton Campus, School of Agriculture and Horticulture, Centre for Pesticide Application and Safety, Gatton QLD 4343.

Gordon, B., Jones, M., Nicholls, J.W., Dorr G., Mischke, S., Woods, N.W., Talukder F.A., Hassan, E., Comparing ground and Aerial applications of endosulfan to early season cotton under stable conditions. CPAS Fact Sheet. The University of Queensland Gatton Campus, School of Agriculture and Horticulture, Centre for Pesticide Application and Safety, Gatton QLD 4343.

10. 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 or the Australian community.

These important findings strengthen the opportunity to use LDP aerial application systems for the application of certain contact insecticides. It supports the adoption of LDP application as part of wider BMP management programs and will contribute to the maintenance of a sustainable, profitable and competitive cotton production system in Australia. They will also provide the regulators, such as APVMA (ex National Registration Authority) and the Department of Environment and Heritage (ex Environment Australia) with a robust data set to continue to support the safe use of farm chemicals in Australia.

Part 4 – Final Report Executive Summary

A national pesticide project *Minimising the impact of pesticides in the riverine environment* (Land and Water Resources Research & Development Corporation Occasional Papers 23/98), led to the establishment of a comprehensive best management practice program for the Australian Cotton Industry. A set of mitigating parameters were developed to reduce the impact of the off target movement of spray droplets Woods et al. (2001).

Fundamental to the reduction in spray drift was the selection and use of large droplet placement (LDP) water based spraying techniques. Used in conjunction with appropriate management strategies, large droplets above about 250 μm diameter (measured as a volume median diameter, VMD) were suggested as they have higher sedimentation velocities and tend to fall towards the ground more rapidly than smaller droplet sizes used for ultra low volume (ULV) spraying, thereby reducing the potential for spray drift.

A three year study started in July 1999, determined the downwind spray drift profiles of aerial LDP, ULV and ground boom sprayer techniques in broad acre cotton production in Australia. This project found that LDP aerial application techniques reduced the downwind drift ten to fifteen times, compared to standard ULV applications (CRDC UQ 27C, *Optimisation of large droplet placement (LDP) technology for the aerial application of insecticides in cotton*).

As part of a concurrent study, a series of tests were conducted to test the efficacy of endosulfan and chlorpyrifos against heliothis larvae in both young and mature cotton canopies, when LDP techniques were adopted. Using traditional field monitoring techniques as well as assay tests based on laboratory colonies of heliothis larvae, it was found that the use of large droplets did not adversely affect the performance of the insecticides.

These important findings strengthen the opportunity to use LDP aerial application systems for the application of certain contact insecticides. It supports the adoption of LDP application as part of wider BMP management programs and will contribute to the maintenance of a sustainable, profitable and competitive cotton production system in Australia.

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