Direct comparison of deposit from aerial and ground ULV applications of malathion with AGDISP predictions

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Direct comparison of deposit from aerial and ground ULV applications of malathion with AGDISP predictions

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EXECUTIVE SUMMARY

A series of field trials were completed to inter-compare ground deposition from ground and aerial sprays of Fyfanon® ULV adulticide and to compare these results with others predicted by AGDISP. A ground cold-aerosol generator (Clarke GRIZZLY) was used in wind conditions ranging from 3.6 to 12.4 kph. Deposit samples (fiberglass filters) were taken at 10 m intervals to 500 m downwind. Collocated at alternate sites, the spray cloud at 1.4 m height was characterized using rotating 3 mm rods to measure drop density and size within the cloud. Aerial trials using PJ20 high-pressure nozzles were completed in winds of 17-25 kph at spray height (60 m). Ground deposit was measured at 100 m intervals to 5 km while the spray cloud was characterized at 200 m intervals.

Under the meteorological conditions during the field trials, peak deposition from ground (11 μm VMD) and aerial (32 μm VMD, 60 m height) were equivalent despite the 4-fold application rate increase for aerial spraying. However, drop densities from the ground application were 4-fold greater than for the aerial application. At spray heights of 60 m, peak deposit was observed 800 m downwind of the flight line while drop density peaked nearly 1 km further down range. For ground application, average deposit peaked nearly 150 m from the spray line and drop density about 100 m further down range. Wind speed had a significant impact on deposit level from ground sprays. Malathion recovery to 500 m indicated between 10-50% of the spray was deposited depending on wind speed. For aerial sprays, 35-50% of emitted malathion deposited within 5 km as winds at spray height ranged from 17-25 kph.

Integrated deposition to the end of the sampling grid was accurately predicted by AGDISP. This model also predicted maximum deposits that were equivalent to those that were measured in the field. For ground trials in high winds, the AGDISP peak deposit was beyond the location of field measurement while in light winds it was closer. For aerial trials, the predicted peak was beyond the location measured in the field. Predicted peak 1-hr average air concentrations from aerial trials were significantly lower than for ground sprays being less than 2 ng/L (1-hr average) compared with 5 ng/L for high wind ground sprays and 20 ng/L for low wind ground sprays.

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1. INTRODUCTION

Adulticide spraying is one of the available methods to control West Nile Virus during the emergence of an important epidemic situation. However, it is necessary to estimate the toxicological and environmental risk for these pesticide use strategies. While mathematical spray-dispersion models (Wallace *et al.*, 1995; Bilanain *et al.*, 1989) can provide a less expensive method than individual field trials to estimate ground deposition and air concentrations from pesticide spraying, field trials in realistic operational conditions are necessary to validate model predictions.

AGDISP, a spray-fate model, is presently being used to evaluate drift from aerial treatments. However, no specific field trials have been conducted to assess the model's capabilities when applied to mosquito adulticide programs. Recently, a module has been added to AGDISP for ground application simulation. With the development of new spray equipment (high pressure system), the validation of model predictions for ground deposit and air concentration is warranted. In the context of risk analysis for the Province of Québec, model validation for the aerial and ground application of malathion is necessary before utilization of the model for impact assessment.

This report documents a series of field trials that were completed in Florida to inter-compare ground deposition from ground ULV and aerial adulticide sprays of Fyfanon® ULV and to compare these results with AGDISP predictions.

2. BACKGROUND AND OBJECTIVES

2.1 Effect of drop size on efficiency of spray program

A recent review of the prerequisites and equipment availability for an efficient adulticide program (Mickle, 2004) highlighted the need to produce drop sizes that deliver a single lethal dose when impinging on an adult mosquito. The optimum drop size for adult mosquitoes was reviewed by Mount (1970), and more recently by Mount *et al.* (1996). Based on wind tunnel results, Weidhaus *et al*. (1970) calculated that the minimum lethal dose (LD_{100}) of undiluted technical malathion for *Ae. taeniorynchus* was contained in a 25 μm droplet. Because a single drop can only impact one mosquito, this means that drops larger than 25 μm will be wasteful since they carry more than a single toxic dose.

Through the 1970s and early 1980s, a number of laboratory studies were completed to establish the collection efficiency of drops on mosquitoes. Lofgren *et al*. (1973) used electron microscope techniques to measure the size of aerosol droplets impinging on mosquitoes. Droplets in the 2-16 μm range were found to impinge more frequently on mosquito wings than smaller or larger drops. Haile *et al*. (1982), in a wind tunnel study at 3.7 kph using mono-sized drops of malathion, defined the relationship between adult mosquito mortality and drop diameter (Fig. 1). The results indicated the optimum drop size range for adult mosquito kill was 10-15 μm. However, little difference in efficiency was noted when the size range was extended to 7-22 μm. Wind tunnel tests of atomizers used for adulticide sprays now use percent volume in the 7-22 μm range to classify the relative efficiency of different nozzles.

During aerial treatments, spray clouds include a large range of drop sizes reflecting droplet production at the nozzle. In the Mickle report (2004), the impact of Volume Median Diameter (VMD) on the potential to produce drops in the optimal drop range was investigated (Fig. 2). For the range of VMDs associated with ULV spraying, emitted volume in the 7-22 μm class was found to range from less than 10% for VMD = 80 μm nozzles to nearly 60% for VMD = 10 μm atomizers.

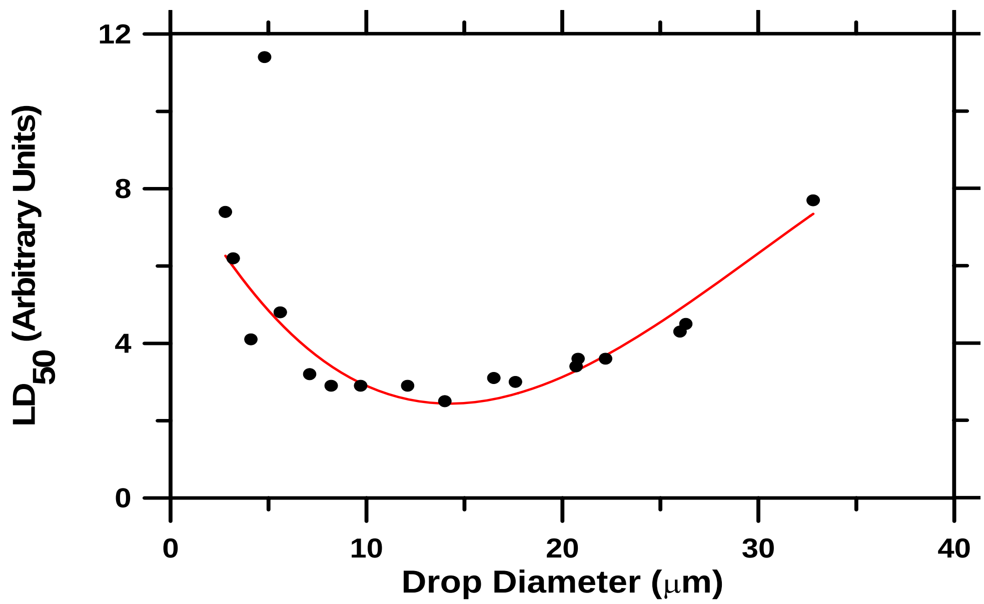

Figure 1. **Relationship between LD_{50} and drop size for malathion. (Haile *et al*. 1982)**

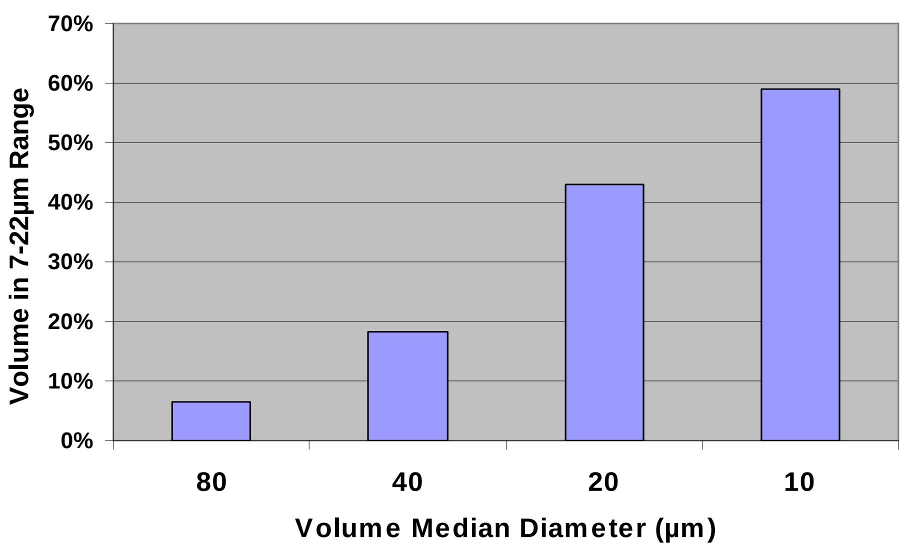

Figure 2. **Efficiency (7-22 µm) for reference nozzles**

Atomizers that have been wind-tunnel tested and exhibit sub-30 µm VMDs fall into two categories; high pressure and rotary. Ag/forestry nozzles even at 80 psi do not provide adequate atomization for adulticide sprays. Figure 3 shows the VMD for new high pressure and rotary atomizers. Details of the wind tunnel tests are tabulated in Table 1.

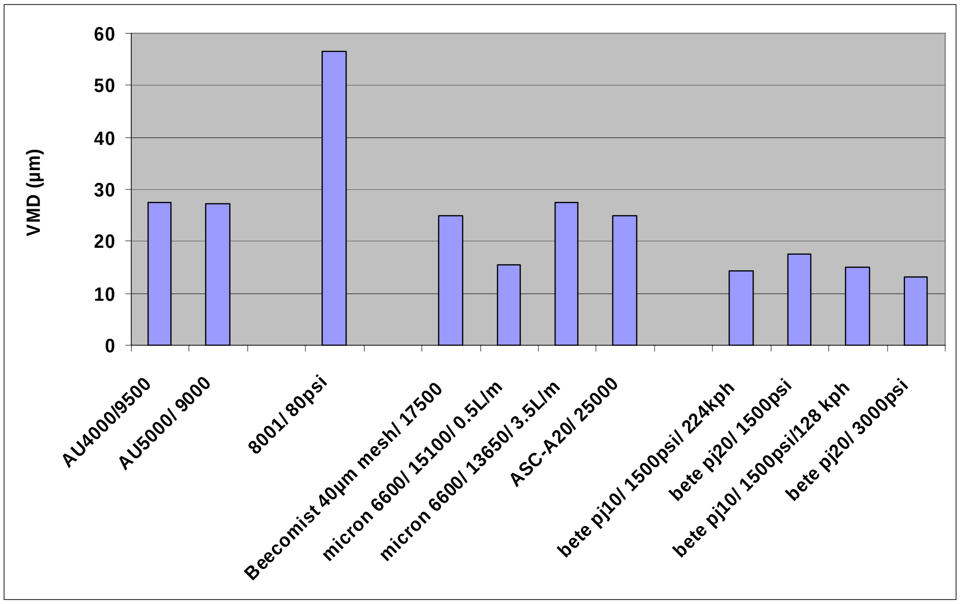

Figure 3. VMD for new high pressure and rotary atomizers. The 8001 at 80 psi is included as a reference

Manufacturer	Atomizer	VMD	RPM Speed (kph)/Angle	Pressure (psi)	Flow (L/min)	Efficiency % Volume (7-22um)
Micron UK www.micron.co.uk	AU4000	27	9500		1	<35
	AU5000	27	9000		0.3	<27
	Micron 6600	16	15100		0.5	44
		27	13600		3.5	30
Clarke Mosquito Control www.cmosquito.com	Beecomist	25	17500		0.6	<44
Spraying Systems Co www.teejet.com	8001	57	224/135	80	0.6	11
Bete Fog Nozzle, Inc www.bete.com	PJ10	15	128	1500	0.4	55
		14	224	1500	0.4	53
	PJ20	18	192	1500	0.9	44
		13	192	3000	1.3	55
Curtis Dyna-Fog www.dynafog.com	ASC-A20	25	25000		0.8	No Data

Table 1. Parameters for wind tunnel tests

Wind tunnel data were supplied by Jonathan Hornby (Lee County Mosquito Control) and Andrew Hewitt (CPAC, University of Queensland). All data sets were generated using Malvern laser systems. Malathion was not used in any of the tests. Of the nozzles evaluated, flat fan nozzles, even when pointed forward 45^{o}, still only produced around 10 % of emitted volume in the desirable range. With VMDs approaching 30 µm, rotary atomizers produce nearly 30% of emitted volume in the optimized drop range. Sub-30 µm VMD with rotary atomizers has been achieved by resizing the basket screen and increasing the rpm. Both the Clarke Beecomist and Micron 6600 are electric atomizers that can achieve VMDs ~25 µm independent of air speed. Rotational speeds exceeding 13000 rpm are required for the small drop atomization. Small VMDs were achieved at low flow rates (0.5 L/min). Reducing the VMD by using High Pressure (>1000 psi) nozzles increased the emitted volume to greater than 40% of emitted volume in the desirable range. HP nozzles (PJ10, PJ20) operating at pressures of 1500-3000 psi were capable of providing sub-20 µm VMDs (using Orchex oil) at flows ranging from 0.4-1.3 L/min. The Mickle report (2004) concluded that atomizer VMD should be maintained below 30 µm for aerial adulticide programs.

For ground application in the United States, the mosquito industry has moved away from sub-10 µm thermal foggers and is now using cold-aerosol generators for ground fogging treatments. In Canada, the malathion label specifically states that the VMD should not exceed 17 µm with less than 3% of the spray drops exceeding 32 µm and no drops exceeding 48 µm. The 48 µm statement is a precaution against paint damage on cars.

Aerosol generators for ground treatment of mosquitoes are listed in Table 2. All equipment is stated by the manufacturer to meet or exceed label requirements, *i.e.* VMD is less than 17 µm. No recent wind tunnel studies have been made to characterize drop sizes due to the physical size of the equipment. Limited field studies using slide impingers or AIMS hot wire systems are available. Results are listed in the table. Hand waving a Teflon-coated slide near the outlet is generally used to calibrate equipment to ensure that the VMD remains less than 17 µm.

Manufacturers	Equipment	Max Flow (L/min)	Horse Power	Label Language	Field Study VMD (um)	Notes
London Foggers, Inc www.Londonfoggers.com	18-20	0.59	18	1	16-18	
	XKE	0.53	8			
Phoenix Fogger www.phoenixfogger.com	500LD	0.59	5.5	2		
	800MD	1.0	8			
	1800HD	1.0	18			
Curtis Dyna-Fog, Ltd www.dynafog.com	Typhoon I		9	3		
	Typhoon II	0.53	11			
	Typhoon IIP		9,11			
	Maxi-Pro 1-45	0.6	18			
	Maxi-Pro 4	0.6	18		15-17	
	Maxi-Pro 4P					4-nozzles
	Maxi-Pro 2P	1.18	18			
	Maxi-Pro 2D	3.8	18			at high flows 40um drops
	Maxi-Pro 1800	0.6	18			
Clarke Mosquito Control www.cmosquito.com	Cougar	0.53	8	4		
	Fox	0.18 siphon	8			
	Grizzly	0.53	18		14-16	

Label Language

1 produces the correct particle size to meet all insecticide label requirements at vehicle speeds up to 20 miles/hr

2 Meets or exceeds all label requirements for ground ULV products, including malathion

3 90% of spray droplets below 20 microns

4. Meets all label requirements for ground ULV chemicals including Malathion

Table 2. Specifications for Ground Aerosol Generators

From the literature review, a few basic facts were clear:

1. Droplet sizes around the LD_{100} diameter are preferred for aerial sprays. For malathion, this drop size is 25 μm.
2. Reducing the VMD of aerial operations to near 25 μm will significantly reduce deposition and can significantly increase mosquito mortality over extended distances.
3. High mosquito population reduction is possible with small drop (VMD 20-25 μm) sprays as long as aircraft offsets and spray-line patterns reflect local meteorology during the treatment program.

Deposition of the mosquito adulticide contributes to efficacy loss as well as a potential environmental or human health impact. In the Mickle (2004) report, existing field trials were reviewed to evaluate the potential for deposit from operational ground and aerial mosquito adulticide equipment. No field trials were found that directly compared deposit from aerial and ground-based sprays using optimal spray equipment for adult-mosquito control. Based on wind tunnel studies and operational parameters for optimal ground and aerial programs, potential deposition levels were compared using the spray-fate model, AGDISP.

Initial model runs indicated:

1. Positions of peak deposit can be predicted relatively accurately when input data reflect actual spray conditions. Field verification of modeled deposit levels needs to be continued.
2. Peak deposit from ground applications may exceed those from aerial applications even when aerial rates are 4-fold greater. No field studies have directly compared deposit from aerial (VMD $< 30\ \mu m$) and ground applications. Field studies to document differences need to be completed.
3. Aerial applications can be optimized to minimize pesticide usage and reduce environmental contamination. Close contacts should be maintained with the American Mosquito Control Association to monitor advances in this area.
4. Field studies are needed to document the accuracy of AGDISP to predict ground deposit when using new optimal spray equipment for adult mosquito control.

2.2 Objectives of the study

The main objective of the present study was to assess the accuracy of the AGDISP model to predict ground deposit and aerial concentrations for ground ULV and aerial sprays. Specific objectives were:

1. Obtain accurate field data to intercompare deposit and drift from ground ULV and aerial adulticide sprays of Fyfanon® ULV under open field conditions.

2. Compare these data sets with AGDISP predictions.

3. MATERIAL AND METHOD

3.1 Field Trials

With the assistance of the Pasco County Mosquito Control District (PCMCD) and the Manatee Mosquito Control District (MMCD), a series of field trials were conducted in Florida to compare deposition from ground and aerial applications of Fyfanon® ULV (96.5% malathion). Application equipment, provided by PCMCD, represented atomizers that maximized droplet size in the range relevant to adult mosquito control.

3.2 Application Equipment

3.2.1 Ground

Ground application utilized a Clarke Grizzly nozzle (Fig. 4) mounted 1.85 m above ground and angled up at 45^o. Fyfanon® ULV was injected into the nozzle at 6 psi and dispersed using a Roots blower. Flow was controlled (Fig. 5) to provide 0.127 L/min at 16 kph and adjusted as truck speed changed. At a label rate of 60.8 g a.i. malathion/ha, this provided pesticide for an equivalent swath of 93 m (Appendix 5). Using the waved-slide technique, the emitted drop-size distribution was found to have a VMD near 11 μm.

Figure 4. Ground application equipment with close-up of Clarke Grizzly nozzle

Figure 5. Holding tank and flow controller linked to speedometer to adjust flow to match truck speed

3.2.2 Aerial

The PCMCD Piper Aztec (Fig. 6) was equipped with 6-PJ20 nozzles mounted at the tip of the starboard wing. Flow through the nozzles was fixed at 8.18 L/min. Boom pressure was maintained at 1520 psi. Wind tunnel tests (Jonathan Hornby, Lee County Mosquito Control) of the 6-PJ20 nozzles used on the Aztec spraying Fyfanon® produced sprays with VMDs ($D_{v0.5}$) around 32 μm (Table 3). Comparison of these same nozzles spraying oil (Table 2) showed a significant shift to larger VMD when Fyfanon® was used. For a ground speed of 240 kph, a swath of only 93.3 m (similar to ground application) could be realized for a label rate of 260 g a.i. malathion/ha (i.e. 4x the application rate). Spray height was maintained at 60 m above ground level (AGL).

Figure 6. **PCMCD Aztec with nozzle array mounted on starboard wing tip. Insert shows close-up of the 6-PJ20 HP nozzles**

Nozzle ID	$D_{v0.1}$	$D_{v0.5}$	$D_{v0.9}$
1	15	32	85
2	16	32	79
3	15	32	80
4	16	33	88
5	16	34	93
6	15	32	84

Table 3. Wind tunnel results for 6-PJ20 nozzles used on Aztec. Drop diameters (μm) corresponding to 10%, 50% and 90% of emitted volume are listed

3.3 Field Site

3.3.1 Ground

For the ground trials, a vacated sod farm in Manatee County, FL was chosen (Fig. 7). The site afforded nearly 500 m of low grass upwind fetch for the predominate easterlies that occurred during the early evening trials (Fig. 8). Ground samplers were located at 10 m intervals from the spray line (gravel road) to 500 m downwind. Collocated at every second sample station, a rotating 3 mm-slide impinger was mounted on a 1.4 m pole to provide measurements of drop density and size in the drifting cloud. The first sampler was placed 10 m downwind of the spray line. A 3 m tower located at the side of the spray line provided meteorology at the time of the sprays.

Each trial consisted of a single pass along the 700 m spray line. Truck speed was maintained at 15 kph maximum. Flow rate was adjusted automatically as speed varied away from the 15 kph. Sample collection commenced 20-30 min after the spray was completed, leaving sufficient time for the spray cloud to pass the furthest downwind sampler.

Figure 7. **Aerial view of grass farm where ground trials took place. Dashed line shows sample line location**

Figure 8. **Fetch upwind and sample line downwind of spray line along gravel road in sod farm**

3.3.2 Aerial

Aerial trials took place in a rural area of Manatee County, south and east of the grass farm site (Fig. 9). Local paved roads provided easy access for establishing a sampling grid to accommodate all wind directions. Deposit-sampling sites were established at 100 m intervals at the edge of the roadway (Fig. 10, 11) out to a distance of 5000 m from the flight line. Limited traffic occurred during the trials. Vegetation around each sampler site was cut to eliminate potential spray removal before depositing on the ground samplers. Cloud characterization sites (rotating impingers) were established at 200 m intervals starting at the flight line.

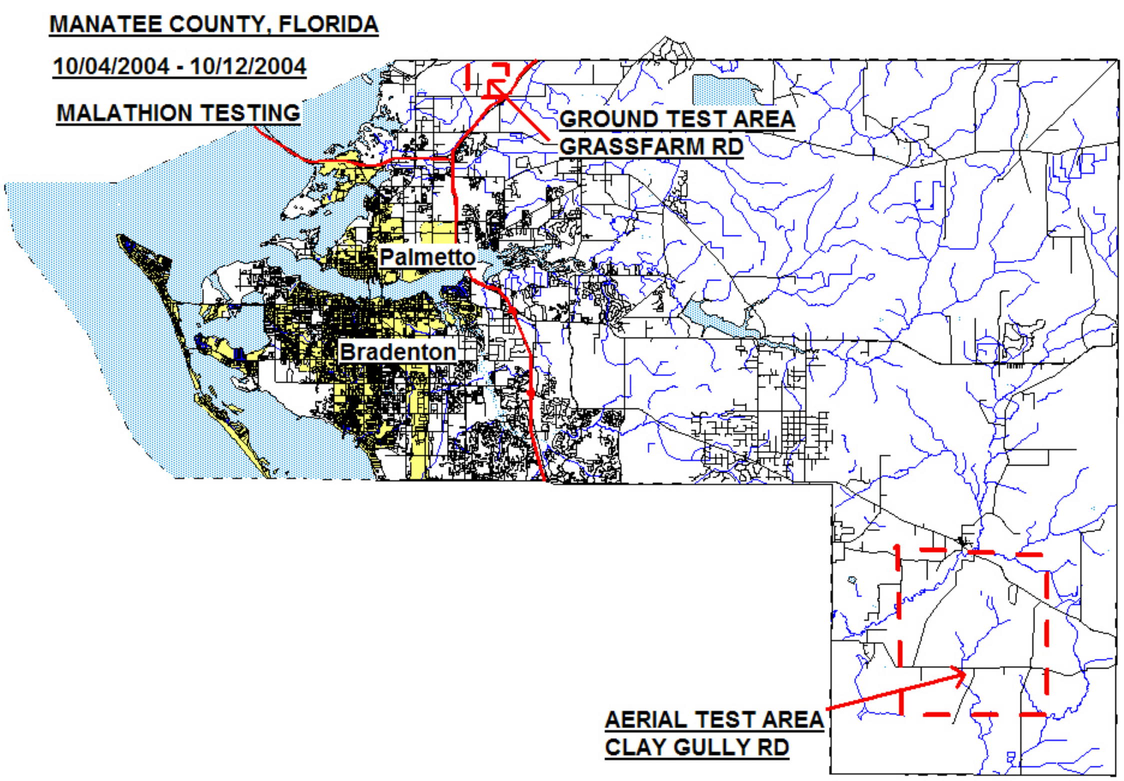

Figure 9. **Locations of experimental sites in Manatee County, FL**

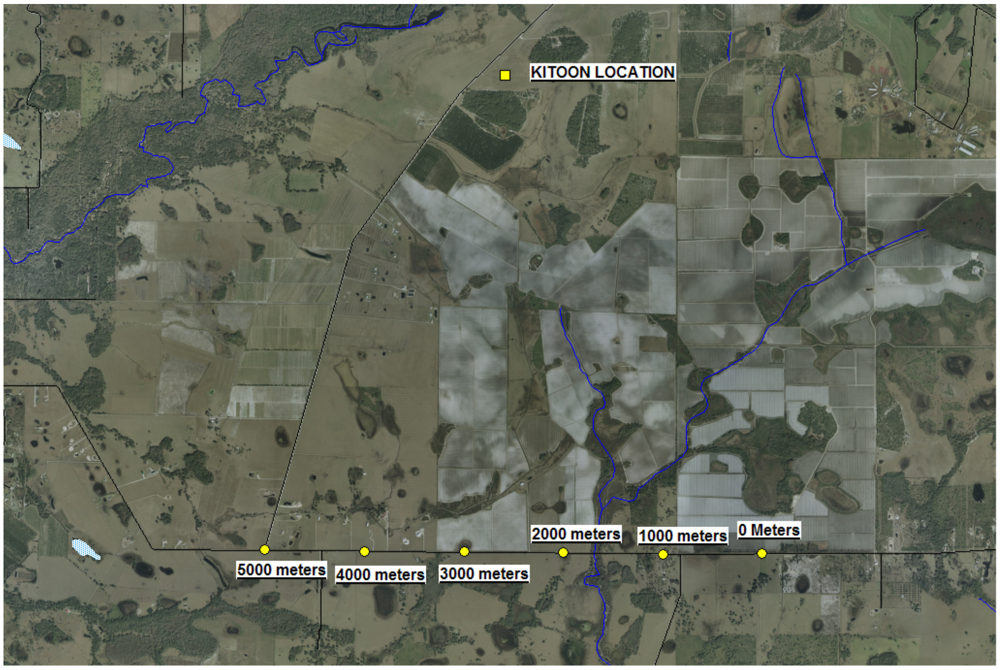

Figure 10. **Aerial photo showing sampling regime for easterly wind. Kitoon location is also noted**

Figure 11. **Aerial view of test area from 5000 m sample site looking East**

Each trial consisted of 4 passes in opposite directions along the same 10 km flight line. The flight-line length was set to ensure a representative deposition along the sample line despite a possible wind shift. The multiple-pass scenario was used to ensure differential vortex behavior due to mounting of nozzles on one side of the aircraft would be eliminated. Also the multi passes provided additional deposit out to downwind distances of 5 km thereby ensuring sufficient analysis sensitivity. Samples were retrieved 45-60 min after spraying was completed depending of the surface wind speed.

All aerial trials were supported with meteorology at the ground (tower), at aircraft height (Kitoon) and above spray height using the AIMMS-20 (Fig. 12) mounted on a separate aircraft. The AIMMS-20 and aircraft were supplied by Forest Protection Limited, Fredericton, New Brunswick. An evaluation of the AIMMS-20 (Mickle, 2005) indicated a 2 kph and 5^{o} accuracy could be expected.

Figure 12. Meteorological support for the aerial trials included a surface tower, Kitoon and AIMMS-20

Temperature, relative humidity, wind direction and wind speed were collected by each sampling device.

3.4 Sampling Devices and Analyses Protocol

3.4.1 Ground Samplers

Selection of sampling materials

In order to measure optimal deposit values in an actual environment, malathion concentrations were measured on inert receptive components (fiberglass filters). The use of these filters enables maximum recovery of deposit in realistic operational conditions, as the medium does not have any characteristics that contribute to furthering product degradation. Tests conducted in Murdochville, during the summer of 2003, by the Direction de la toxicologie humaine de l'Institut national de santé publique du Québec (INSPQ) and the Société de protection des forêts contre les insectes et les maladies (SOPFIM) showed that malathion deposited on soil could be very unstable depending on soil pH. These results were consistent with reported variability in data found in scientific literature on persistence of malathion in this matrix. For these reasons, using inert substrates was justified.

Many researchers have used filters or simply paper to evaluate residual pesticide deposits (Dukes *et al.*, 2004; Knepper *et al.*, 2003; Hester *et al.*, 2001; Tietze *et al.*, 1996 et 1994; Moore *et al.*, 1993; CDFA, 1991). This technique has also been used for the evaluation of deposits in studies on cutaneous exposure (Samuel *et al.*, 1996; Marty *et al.*, 1994; Brouwer *et al.*, 1992; Fenske, 1989; Turnbull, 1985). Most authors note the importance of respecting certain characteristics of the medium that should be used. It should be absorbent enough to retain the deposited product as well as being sufficiently inert as to not further the degradation of the pesticide. Moreover, the pesticide should be easily extracted without breaking the filter or the paper used. Some authors have used alpha cellulose filters, fiberglass filters or simple paper towels. In the summer of 2003, fiberglass filters were successfully used to measure malathion deposits in the course of the Murdochville project. Stability tests conducted by the toxicology laboratory of the INSPQ showed that malathion was slightly more stable on fiberglass filters that on alpha cellulose filters. However, fiberglass filters are slightly more fragile and must be manipulated with care.

3.4.2 Sampling protocol

The following protocol was followed for both ground and aerial trials:

1. Nine-centimeter (diameter) fiberglass filters were set on supports allowing samples to be taken directly at ground level. The filters were fastened with 2 paperclips on a circular piece of previously numbered metal (electrical junction box cover) approximately 10 cm in diameter (Fig. 13). For each test, sampling devices were set on a rigid piece of paper 15 X 15 cm with a metallic finish backing. This paper was placed directly on the ground and changed for every trial in order to avoid filter and support contamination. At selected locations, blank filters were placed on the ground and recovered prior to a spray in order to assess potential contamination from handling.

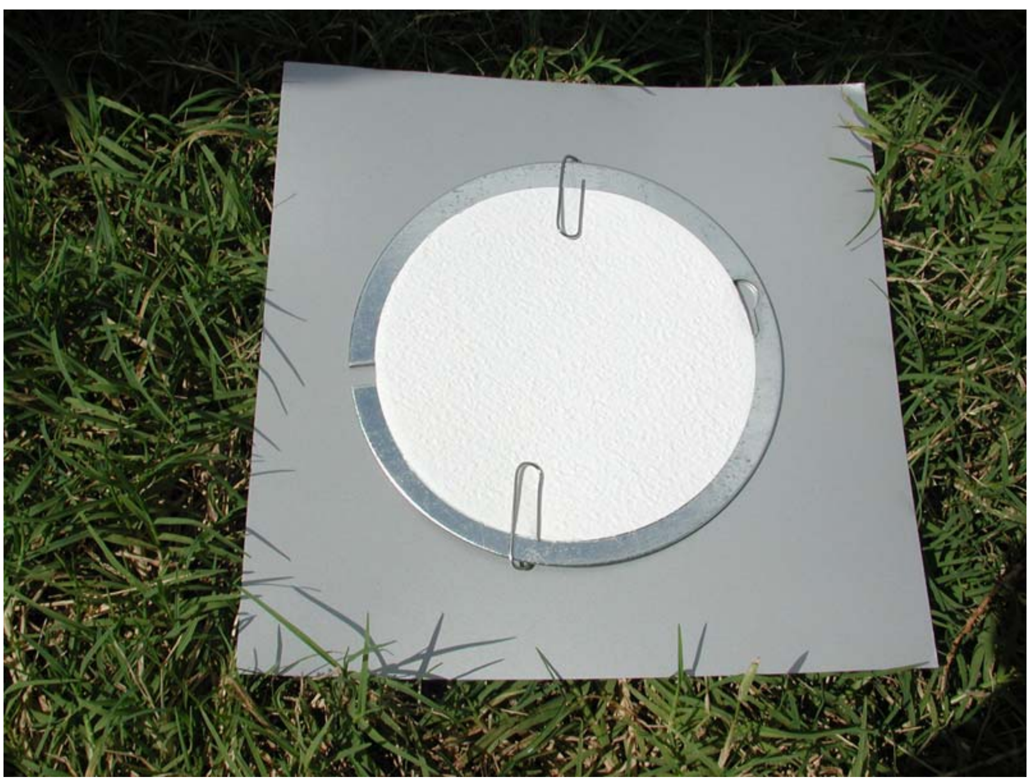

Figure 13. Sampler used to ground deposit

2. After each trial, sampler recovery was delayed until the pesticide cloud had cleared the sampling area. Surface winds were used to estimate residency time of the cloud. Filters and their supports were collected using fine long-nose tongs and put into a Petri dish (150 mm diameter X 15 mm) and identified with the same number as the sampling device. Samplers were handled only at the rim of the metal support in order to avoid filter contamination. Samples were immediately put into a container providing a cold temperature and absence of light in order to minimize sample degradation.

3. Each filter paper was transferred into a pre-washed 22 ml (Supelco cat. 27343) glass tube at the end of the sampling period. Paperclips were removed with micro-tongs and the filter was folded in two while ensuring that only the non-exposed surface touched the work surface. At this stage, the tongs were only in contact with a minuscule part of the filters' rim. Once folded, the filter was rolled lengthwise, then put in the glass bottle previously labelled with the same number as the sample. During the overall transfer operation, the exposed part of the filter was never touched and the non-exposed part was always manipulated while wearing latex gloves. The tongs were cleaned with solvent after each filter change.

4. In preparation for the field trials, stability tests were conducted to develop protocols for storage and transport of the samples. Pieces of cloth and cotton gloves spiked with malathion indicated that the pesticide should be stable for at least a few months if the samples were kept in the dark at 4°C. These results suggested that stability should be similar for the filters (Castro Cano *et al*., 2001). The INSPQ toxicology laboratory conducted persistency tests in order to verify different parameters that could affect the stability of the samples. The results of these tests served to finalize the conservation and transportation strategy for the samples. The protocol and the results from the stability tests are presented in Appendix 1. Also, during the field tests, reference filters were spiked with deuterated malathion and high purity malathion in order to ensure the absence of degradation during storage and transportation.

5. The filters were kept under optimal conditions until their arrival at the INSPQ laboratory. In Florida, the samples were kept at -20°C in a freezer. During transport between Florida and Québec, the samples were kept in the same freezer in which an appreciable amount of hermetic plastic containers containing ice, were added. Over the whole trip, the refrigeration content was verified and ensured.

6. At the laboratory, the filters were washed according to a recognized extraction procedure that had been validated by the toxicology laboratory in the summer of 2003. Finally, the extracts were analyzed according to the E-437 method developed in the same laboratory (Appendix 2).

7. Malathion extractions were divided by the sampling area (63.6 cm^2) with results presented as gm/ha in order to compare to application rate.

3.4.3 Spray cloud samplers

At alternate sampler sites, a rotating impinger, mounted atop a 1.4 m post (Fig. 14), was collocated with a ground sampler to provide a measure of drop density and drop sizes in the spray cloud. A 3 mm square rod was secured 8.9 cm from the axis of rotation and rotated at 640 rpm. Teflon tape applied to the leading surface of the rotating rod provided a stable surface to which the swept droplets could adhere. Previous studies in Florida had documented considerable aerosol background of droplets that were of similar size to those used during adulticide sprays. For this reason a fluorescent tracer (150 gm Uvitex OB) was dissolved in 3 L of toluene and added to 113 L of Fyfanon® tank mix. Earlier tests had been conducted to determine the optimal amount of tracer to use and to ensure no interference during malathion analysis.

Figure 14. Rotating impinger collocated with deposit sampler

Drops on rods were scanned by microscope under ultraviolet light to distinguish spray drops from background. Drop sizes and area scanned were documented in order to establish drop size and drop density variations along the sample line. Droplet counts on the sample rods were corrected for collection efficiency following May and Clifford's (1967) work using ribbons. Utilizing 3 mm rods spinning at 640 rpm, collection efficiencies varied from less than 10% for sub-6 μm drops to greater than 80% for drops greater than 25 μm (Fig. 15). VMD and drop density at each sample site were calculated using Slide Analysis, a freeware program from REMSpC Consulting.

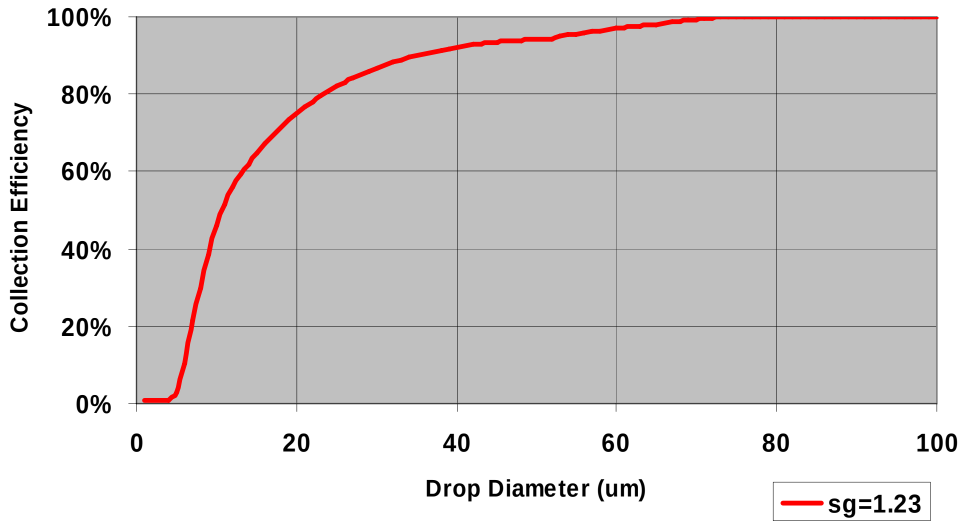

Figure 15. **Collection efficiency of 3 mm rods used during field trials (Specific gravity = 1.23)**

4. RESULTS AND DISCUSSION

4.1 Conservation and contamination

Analysis of samples containing deuterated malathion indicated no degradation during transport between field and laboratory. For the two tests made, the recovery was 100 ± 2 %. Moreover, analysis of blank samples for all the field trials indicated no contamination.

4.2 Field Results

Details from individual trials can be found in Appendices 3 and 4. Meteorological conditions during each trial as well as the resultant deposit and spray cloud characteristics are graphed.

Ground trials took place in significantly different wind regimes, winds that were around 12 kph and winds that were less than 6 kph. Generally, peak deposit levels in the higher wind sprays were lower than in the sub-6 kph sprays where deposit levels reached 20 gm/ha. Drop densities on the rotating slides maximized at locations ranging from 50-150 m further down range than the location of peak deposit. Maximum drop density ranged from 300-500 drops/cm^2. VMD of the drifting cloud was typically around 10 μm with a small but perceptible shift to smaller drops with distance away from the spray line. Number median diameter (NMD = 50% of drops measured had smaller diameters) was less than 4 μm highlighting the fact that the majority of measured drops were very small. Characterization of the spray cloud at the exit of the Grizzly nozzle produced a VMD near 11 μm, consistent with the rotating impinger results.

Integrated deposit to 500 m resulted in Malathion recoveries ranging from less than 10% to nearly 50% (Fig. 16) of the emitted spray. Integrated malathion to 500 m downwind decreased as wind speed increased (Fig. 17). Typically, evening ground ULV applications will occur in very light winds. Field results suggest that 30-50% of the spray would be lost to deposition within 500 m downwind.

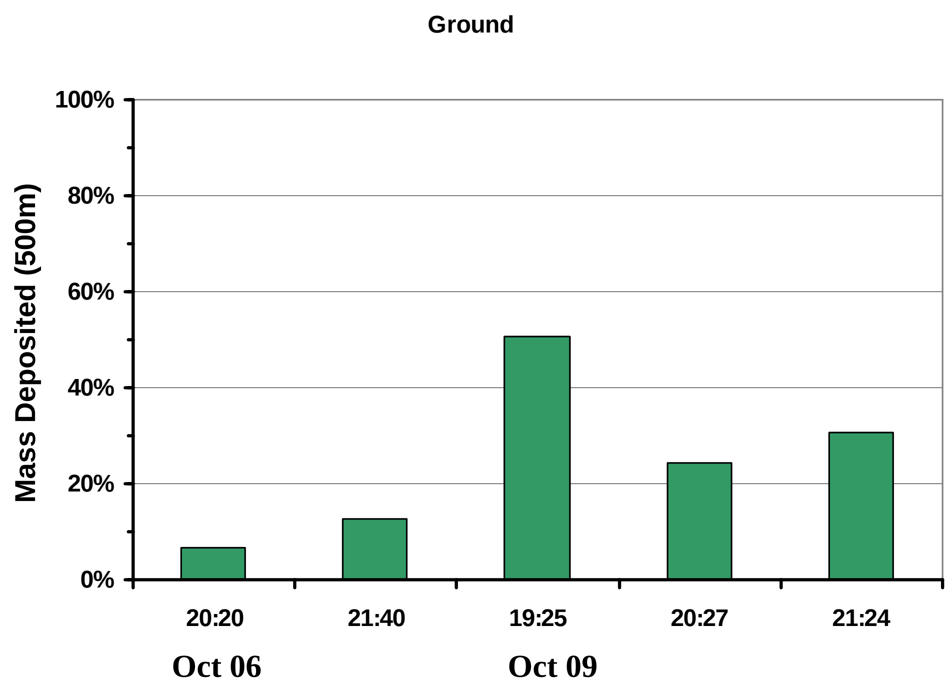

Figure 16. **Integrated ground deposit to 500 m as a percentage of emitted malathion**

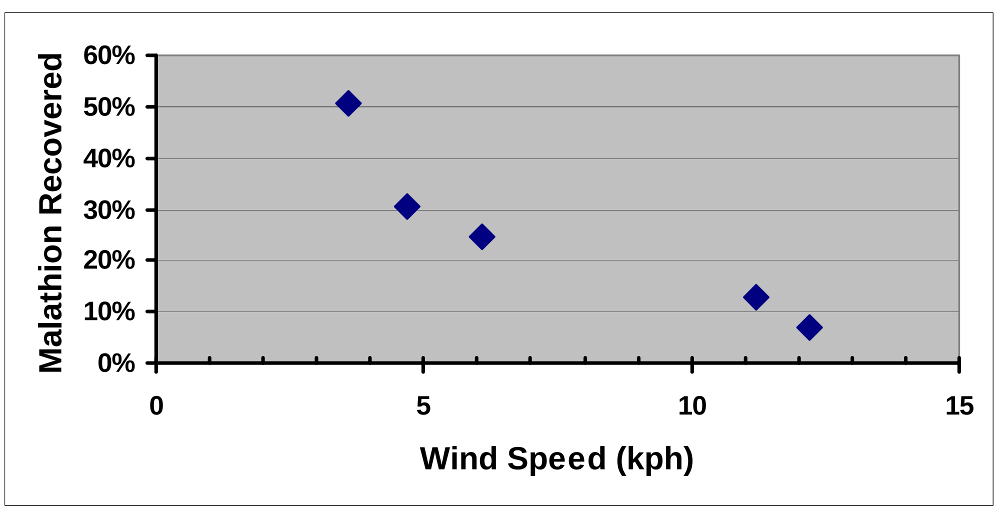

Figure 17. **Malathion recovered to 500 m as a function of wind speed**

Results from individual aerial trials can be found in Appendix 4. All data have been normalized to a single spray line. At the spray height (60 m), winds were relatively uniform ranging from 18-24 kph while surface winds were generally less than 4 kph. Meteorological profiles obtained from the tower-Kitoon -AIMMS20 combination showed a strong increase in winds with height within the nocturnal inversion. Over the layer, wind direction remained relatively uniform. Deviations noted in the surface layer were due to local topography that acted to channel the light winds. Peak malathion deposit ranged from 6-20 gm/ha similar to that for the ground application despite the fact that the application rate was 4 times greater (260 g a.i./ha vs 60.8 g a.i./ha for ground application). Maximum deposit was found 500-1000 m downwind of the flight line. Peak slide drop densities were 10-20% of those measured from ground applications. Generally peak drop density was found 1 km further downwind from the deposit peak. Measured drops produced VMDs that were 10-15 μm while NMD was around 5 μm. The winnowing effect of drop size with distance was especially noticeable on a couple of trials where the VMD and to a lesser extent NMD decreased with distance away from the flight line.

Integration of deposit to 5 km resulted in 30-55% of the emitted Malathion being recovered (Fig. 18). Recovered malathion decreased as wind speed at aircraft height increased (Fig. 19). When using meteorology to target small-drop adulticide sprays, winds at the height of the aircraft, being significantly different in speed and possibly direction than at the surface, are the most relevant to use.

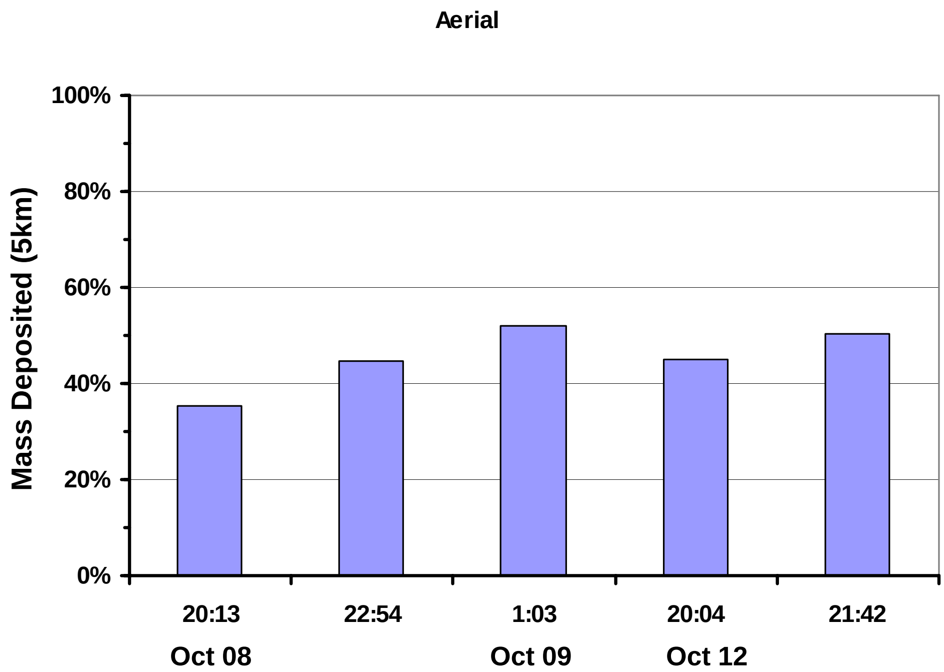

Figure 18. **Integrated ground deposit to 5 km as a percentage of emitted malathion**

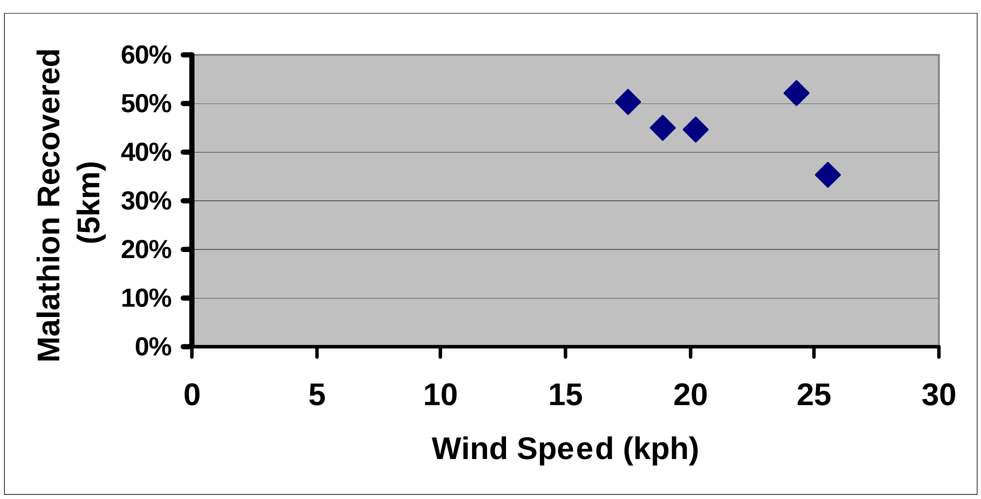

Figure 19. **Malathion recovered to 5 km as a function of wind speed at spray height (60 m)**

In figure 20, deposit (gm malathion/ha) has been summarized for the five ground and aerial sprays. Maximum, minimum and average deposit at each downwind sampling location has been graphed. For the ground ULV trials, peak average deposit occured approximately 150 m downwind of the spray truck. Over the first 93 m (swath) average deposit is less than 40% of peak deposit. Since the spray cloud is blasted up at 45^o from the nozzle at 1.85 m, negligible deposit was found over the first 10-30 m downwind of the truck. For the aerial sprays, peak malathion deposit was found nearly 800 m down range from the flight line beyond which deposit decay was typically Gaussian with distance. Negligible deposit was found within the immediate 93 m swath. Little difference in peak malathion deposit from the different application techniques was found despite the 4-fold increase in application rate during the aerial trials. Deposit variability was significantly higher for the ground trials than for the aerial trials.

Line source strength (LSS) is a measure of malathion released per unit length of spray line and takes into account not only the speed of the vehicle but also the flow rate. For the aerial spray, flow was limited by the capacity of the high pressure pump; the resultant operational swath being identical to the ground application at 4.3 times the label rate. This resulted in an aerial LSS that was 4.3 times that for ground application. Normalizing deposit by LSS removes differences associated with application rate so that the influence of application parameters (spray height, drop size distribution and meteorology) can be investigated (Fig. 21). Viewing normalized deposit from the two application strategies shows that in fact the peak average deposit from the ground applications was 3-4 fold greater than from an aerial application having the same LSS. Much of this difference can be related to differences in spray height. Drop densities on rotating slides indicated a significantly denser cloud from ground sprays (Fig. 22). While drop density peaked near 70 drops/cm^2 for aerial sprays, ground sprays produced drop densities that were nearly 4-fold greater. To achieve spray cloud densities equivalent to ground sprays, 3-4 passes would be required to build the cloud density to the same level. However, having built the cloud, the slide data suggest that the cloud densities would be maintained over distances of at least 2 km. Peak drop density from the aerial spray was nearly 2 km downwind of the flight line while it was 230 m for the ground spray. Swath offsets for aerial sprays approaching 2 km would be needed to target the small-drop adulticide cloud. Interestingly, the swath for ground spraying is 93 m while maximum drop density (mosquito kill) was 2 times further downwind

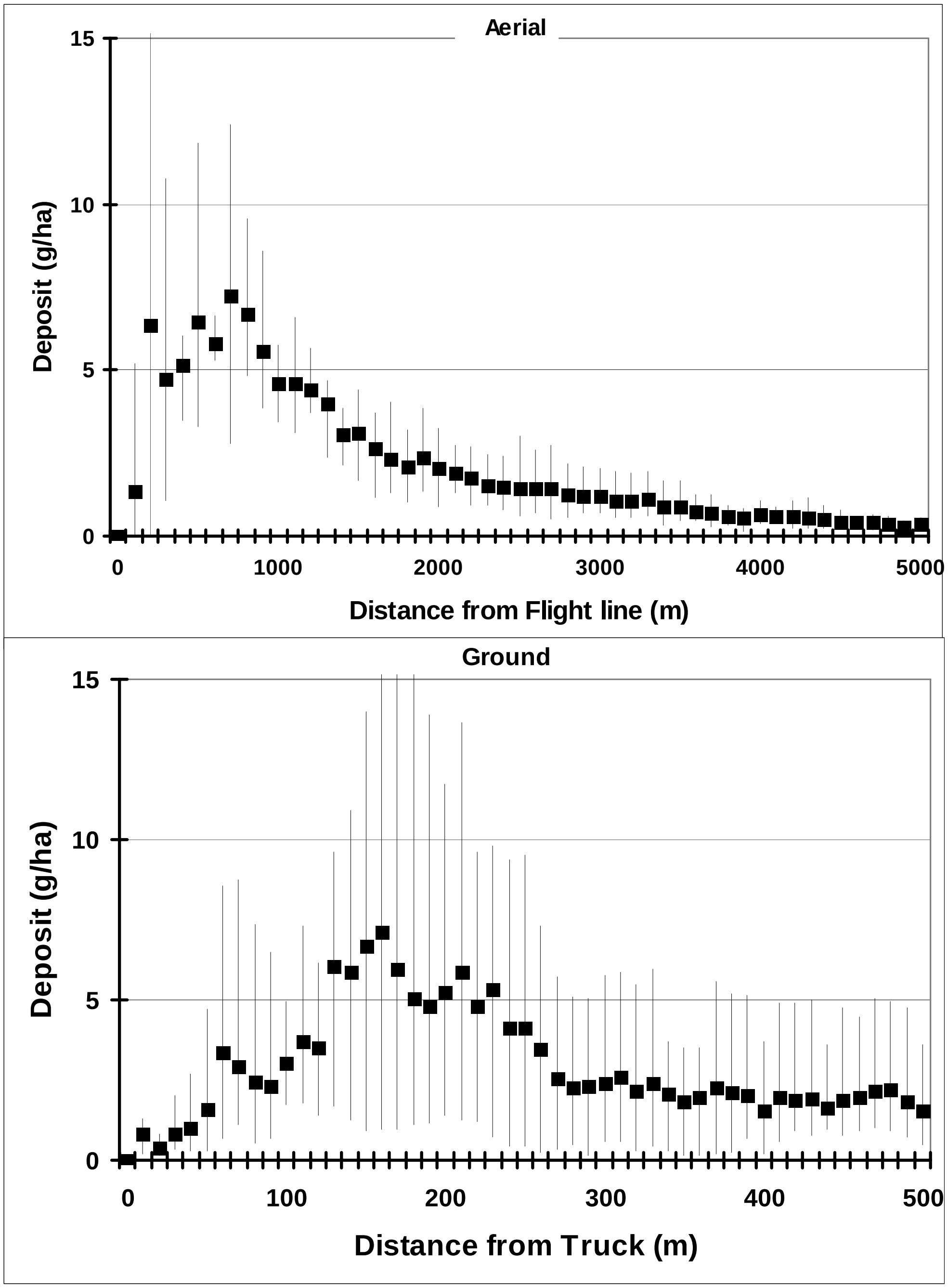

Figure 20. **Summary of measured deposit from aerial and ground trials**

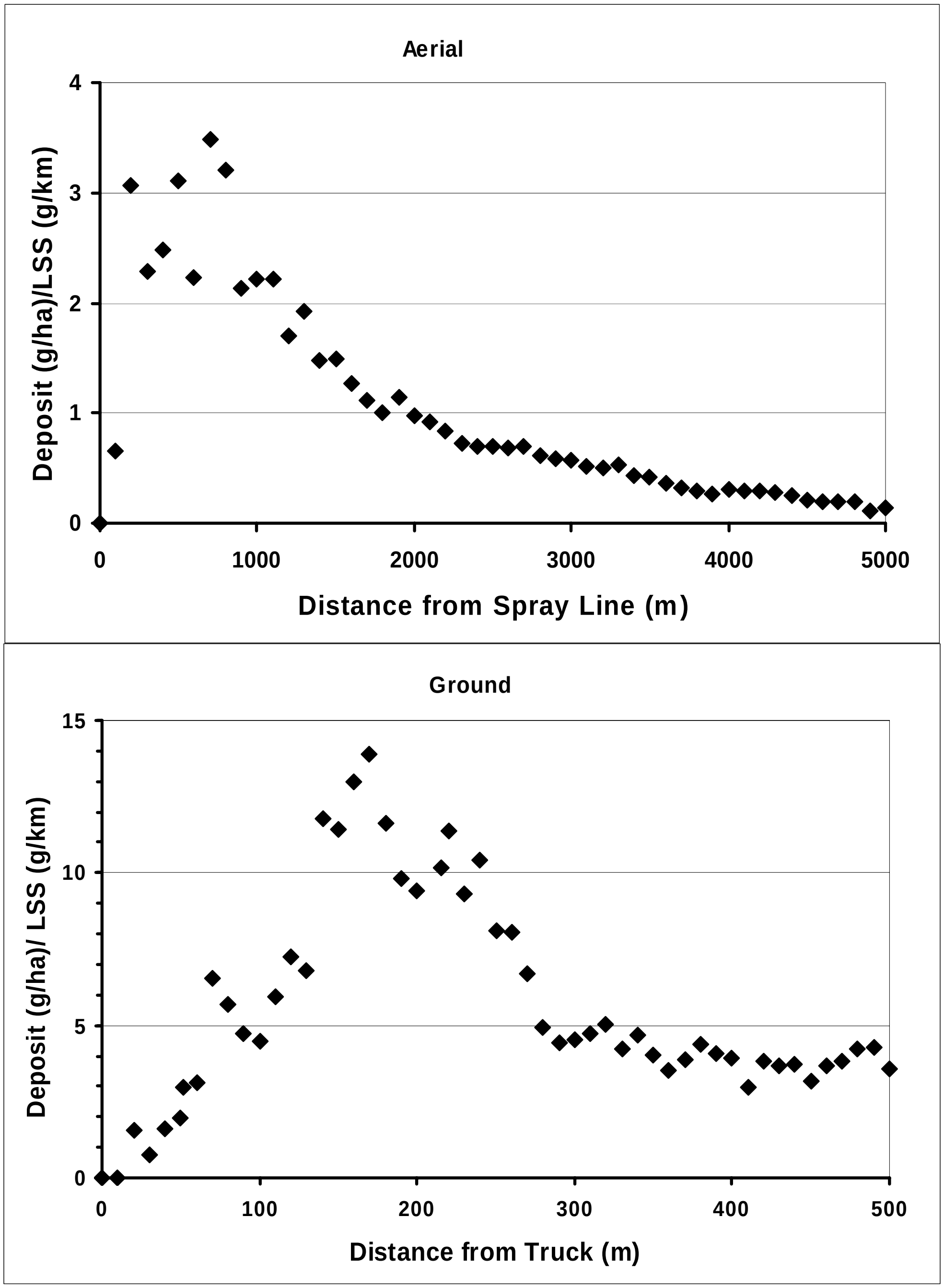

Figure 21. Average deposit normalized by LSS for ground and aerial applications.

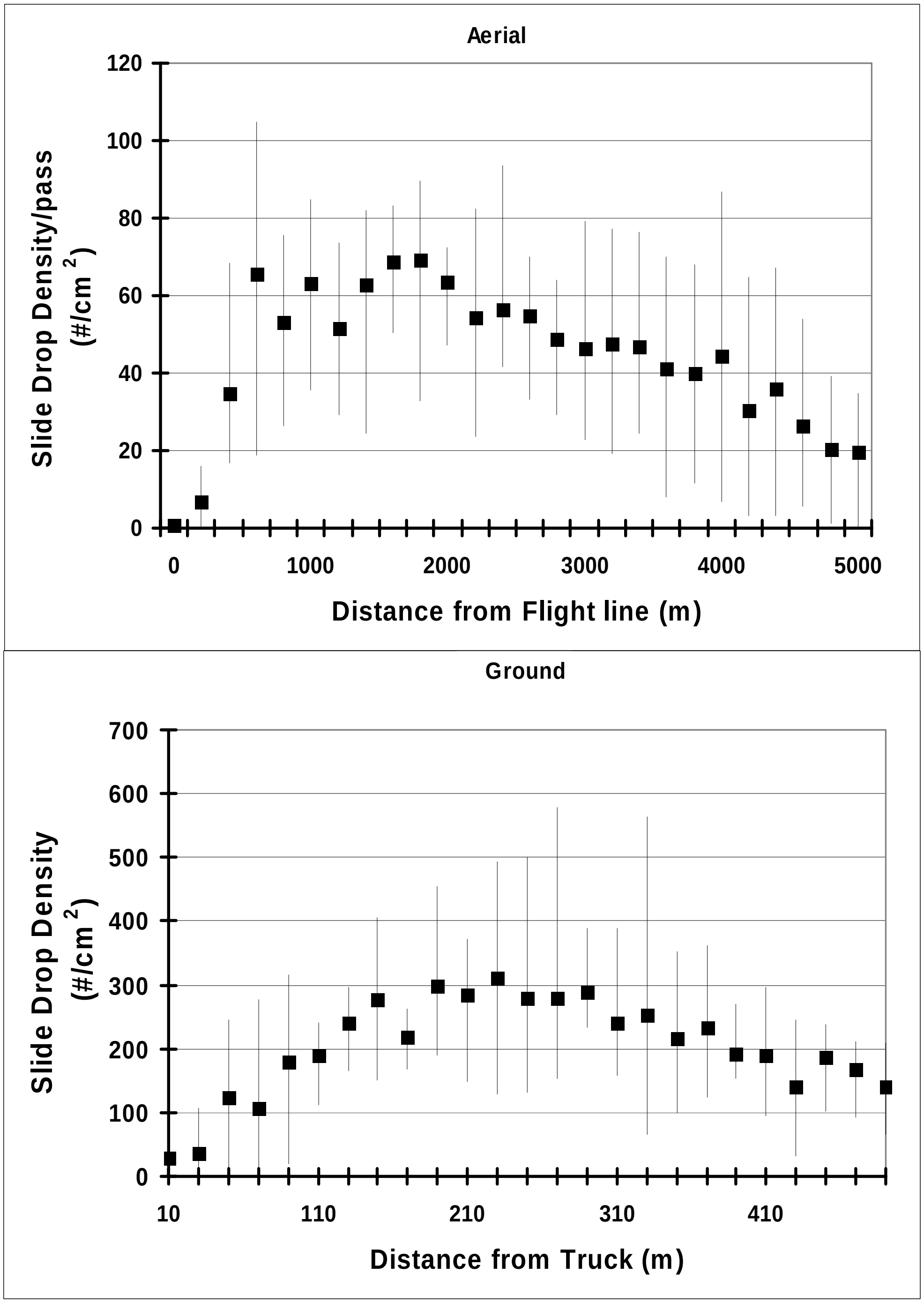

Figure 22. **Comparison on average drop density on slides for aerial and ground sprays**

While average deposit tended to maximize near 800 m during aerial sprays, drop density peaked nearly 1 km further down wind (Fig. 23). Drop sizes tended to decrease with sampling distance (Appendix 4) due to winnowing that led to deposition of the larger drops closer to the spray line. Typically, the VMD of the airborne cloud was sub-15 μm at distances beyond 800 m, the small drops being capable of sustained drift over long distances. A similar effect was also seen in the data set from the ground-based applications (Fig. 24). Although not as pronounced, peak drop densities were still displaced 100 m further down wind.

A swath analysis of measured drop density (Fig. 22) indicates a swath of 3.6 km could be sustained and provide a coefficient of variation (COV) of 0.3. However, pumping rates for the high-pressure system resulted in an operational swath of only 93 m in order to maintain a label rate of 260 g a.i. malathion/ha. Utilizing the maximum flow rates and a track space of 1 km could result in a uniform cloud peaking at 260 drops/cm^2 at 4 km downwind of the upwind line and having a COV of only 0.1. Predicted peak deposit would be 14 g a.i. malathion/ha near the same location as the peak cloud density. Over the same area maintaining an operational swath of 100 m would result in peak deposit levels closer to 100 g a.i./ha while drop densities would exceed 1100 drops/cm^2, i.e. resulting in a cloud far denser than from ground applications. Utilizing the field deposit and drift data, optimization schemes can be designed that would minimize environmental loading and still result in efficacious cloud densities.

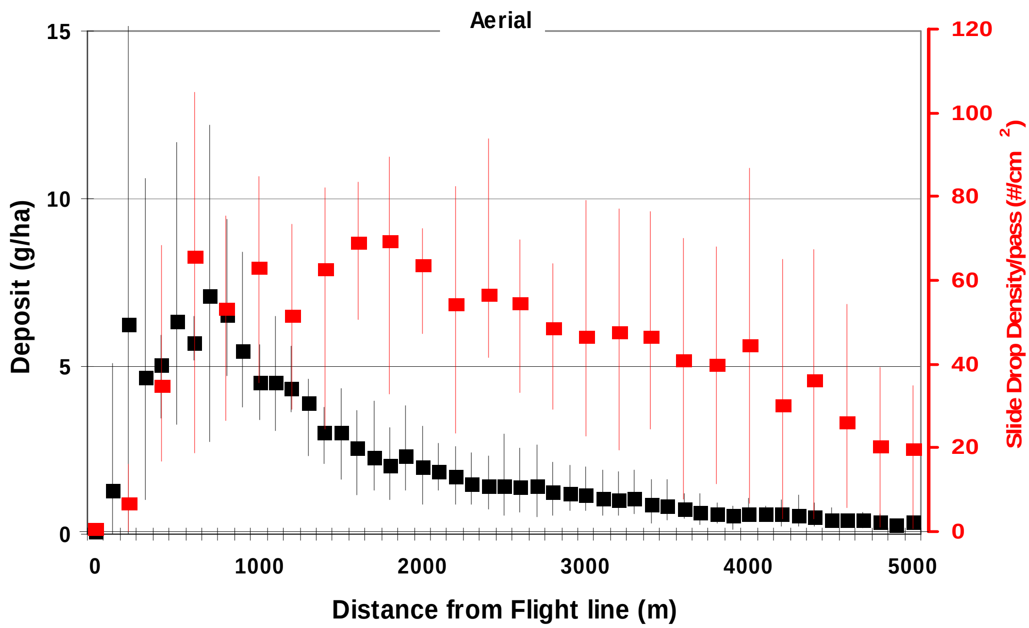

Figure 23. **Variation of average deposit and slide drop density downwind of the flight line**

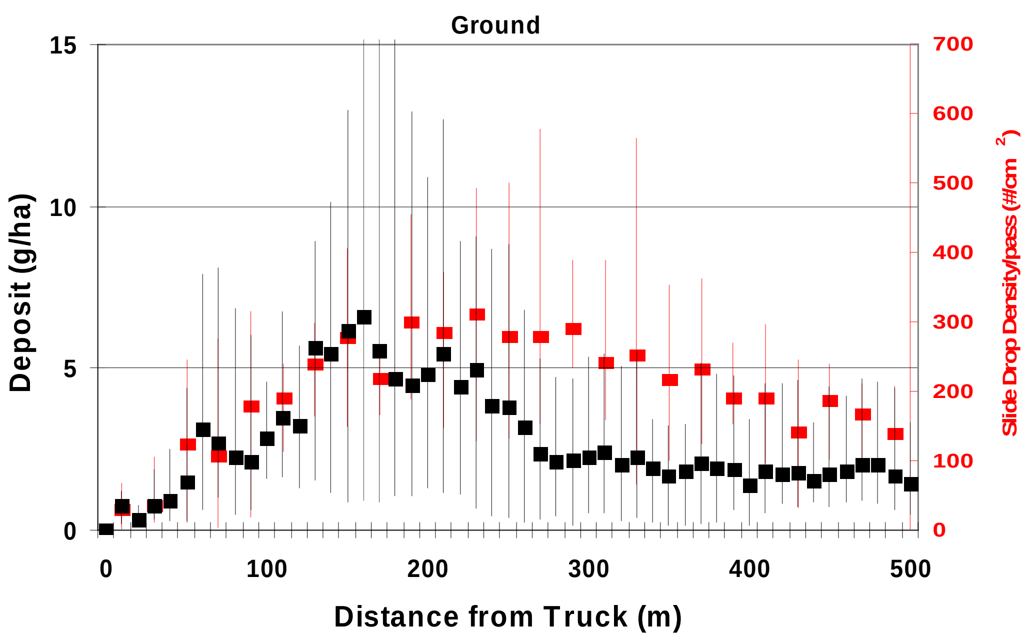

Figure 24. **Variation of ground deposit and slide drop density for ground sprays**

4.3 Model Predictions

The USDA Forest Service AGDISP model has been accepted both within the scientific and regulatory communities as one of the best spray-fate models available for aerial spraying. In the early 1990s, the AGDISP model was compared extensively to a series of field trials carried out by the Spray Drift Task Force (SDTF). Principally tested against agricultural spraying, the model utilizes operational parameters such as release height, drop size distribution and meteorology to calculate drop motion from the aircraft until deposit occurs. Although running the model for high spray heights and very small drop sizes is feasible, no comprehensive data set is available to test the model under these extreme conditions. The public version of AGDISP allows calculations to downwind distances of only 1500 m, far short of distances used during these aerial trials. A special version made available to REMSpC Consulting relaxed this restriction to 5 km.

With the recent release of Version 8.13 (used in this report), a ground module has been added to AGDISP. The ground model was specifically designed for agricultural row-crop spraying where nozzles are pointed down towards the crop and air entrainment assists movement of the very small drops into the canopy. For the ground-based adulticide simulations, pressure at the nozzle was reduced in order to ‘turn-off’ the entrainment model.

Inputs to AGDISP v8.13 for both aerial and ground simulations are listed in Appendices 6 and 7. For the aerial trials, nozzles were placed at the ends of both wings (only the starboard wing had nozzles on the Aztec) in order to alleviate vortex differences from the upwind and downwind wings. For the field trials, the Aztec was flown in both directions in order to resolve differences. Wind tunnel characterization of the PJ20 nozzles was used to initialize drop size distributions at the aircraft. Meteorological conditions at spray height (Kitoon) were used to evaluate the impacts of winds on spray cloud motion and ground deposit. Aircraft height remained fixed at 60 m. For ground trials, the height of the Grizzly nozzle was used as the release point of the spray. In-field drop-size distributions taken directly behind the truck using the ‘waved-slide’ technique established the initial cloud. Meteorology from the 3 m tower was used to evaluate deposit differences.

4.3.1 Ground Trials

Model runs were completed for field winds that ranged from 3.6 to 12.2 kph. Integration to 500 m of AGDISP-predicted deposit compared favorably to field measurements (Fig. 25). During higher wind sprays, most of the emitted spray (> 80%) was airborne beyond 500 m. During light-wind adult mosquito treatments (characteristic of operational programs within urban areas) nearly 50% of emitted spray would deposit within 500 m (5 swaths) downwind of the spray truck.

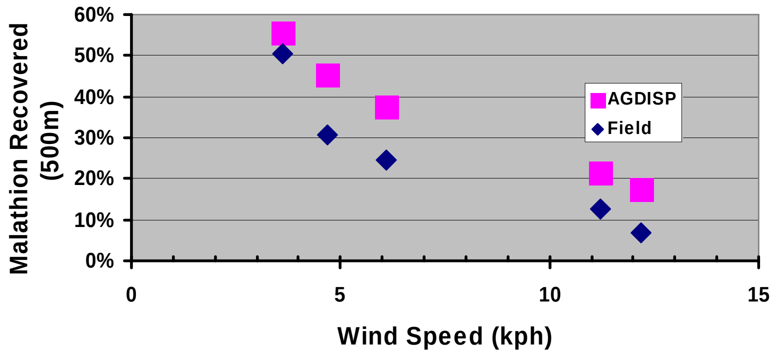

Figure 25. Comparison of integrated deposit to 500 m for AGDISP predictions and field data

Field trials were grouped into low wind (< 6 kph) and high wind (> 11 kph) conditions. Average winds (4.8 kph, 11.7 kph) were used in the AGDISP runs. Deposit during high wind conditions was significantly lower (2-3 fold) both in the field data and in the model runs (Fig. 26). In high winds, AGDISP predicted a shift in deposit further downwind than was actually observed although peak values were very similar to those measured in the field. Under low wind conditions, AGDISP predicted peak deposit near 100 m while field measurements placed the peak close to 180 m. As before, predicted maximum deposit was close to the observed average deposit peak. Beyond the peak deposit, AGDISP predictions fell within the deposit variation observed in the field.

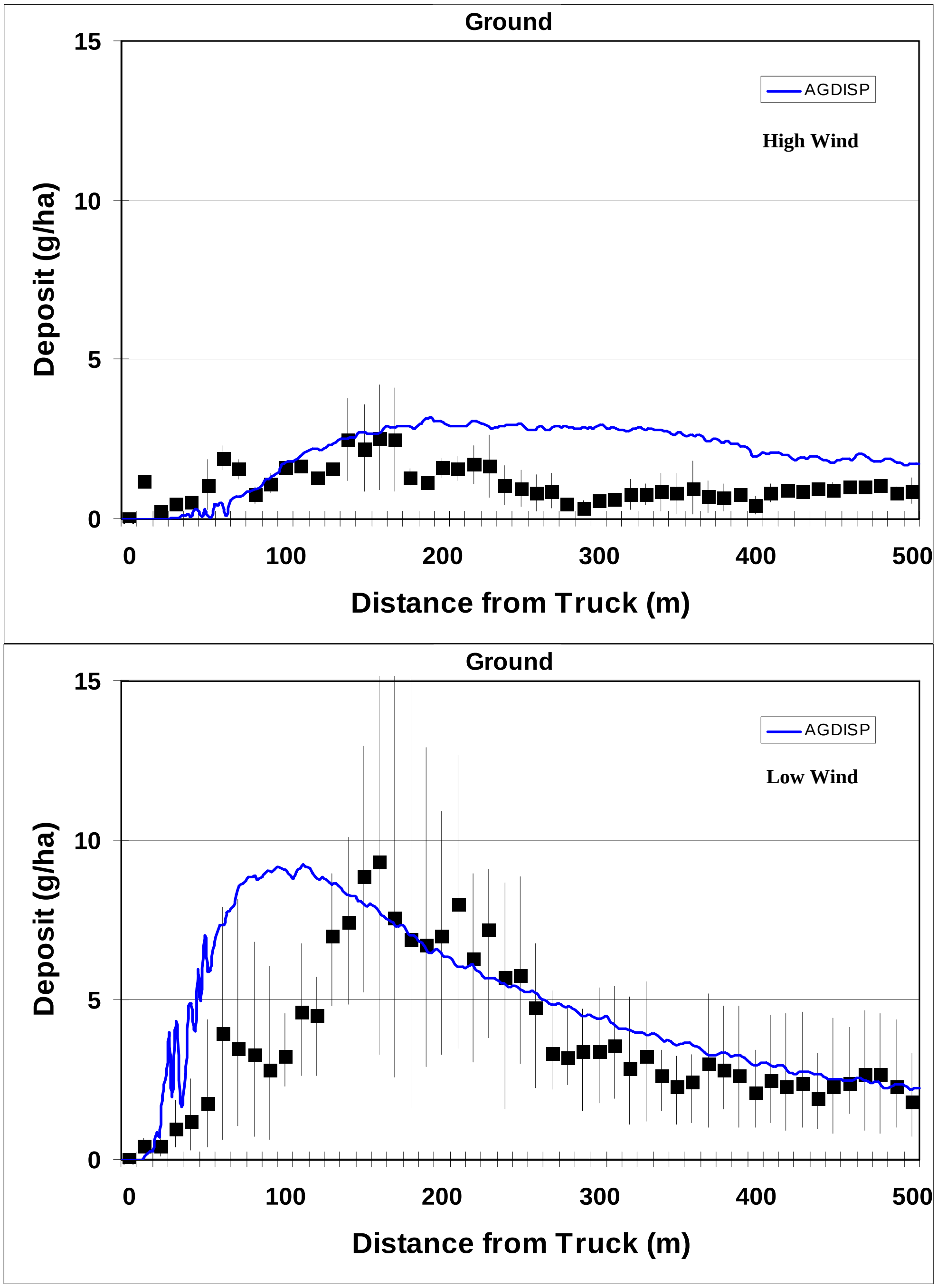

Figure 26. **Comparison of AGDISP deposit and field measurements for high and low wind cases during ground trials**

AGDISP predicted air concentrations (1 hr average) at 1.5 m show a pattern (Fig. 27) similar to deposit differences for high and low wind cases. Differences of 4-fold are predicted in the two wind regimes. While air concentrations in high winds remain nearly constant beyond 200 m, air concentrations in low winds tend to drop off nearly 25% over the same distance due to deposition.

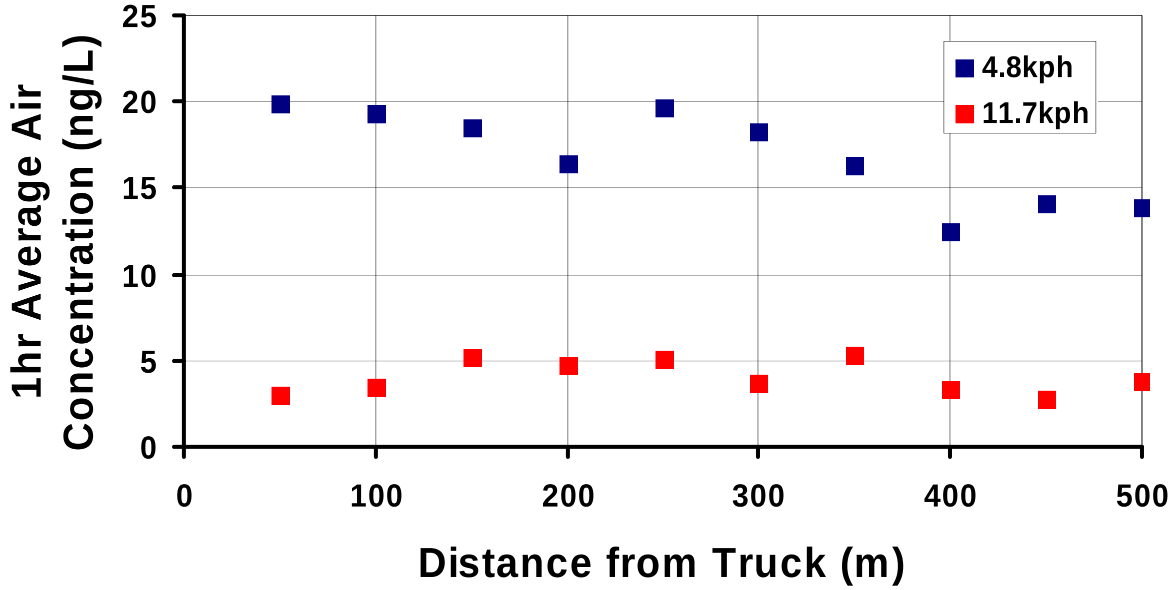

Figure 27. AGDISP predicted air concentrations during ground spraying in low and high winds

Comparing measured slide drop densities (Fig. 28) for high and low wind cases shows differences of only 60-70%, not 4-fold. Wind speed had little impact on the position of maximum drop density. At higher winds, drop densities beyond 200 m, were consistently lower than for the low-wind trials.

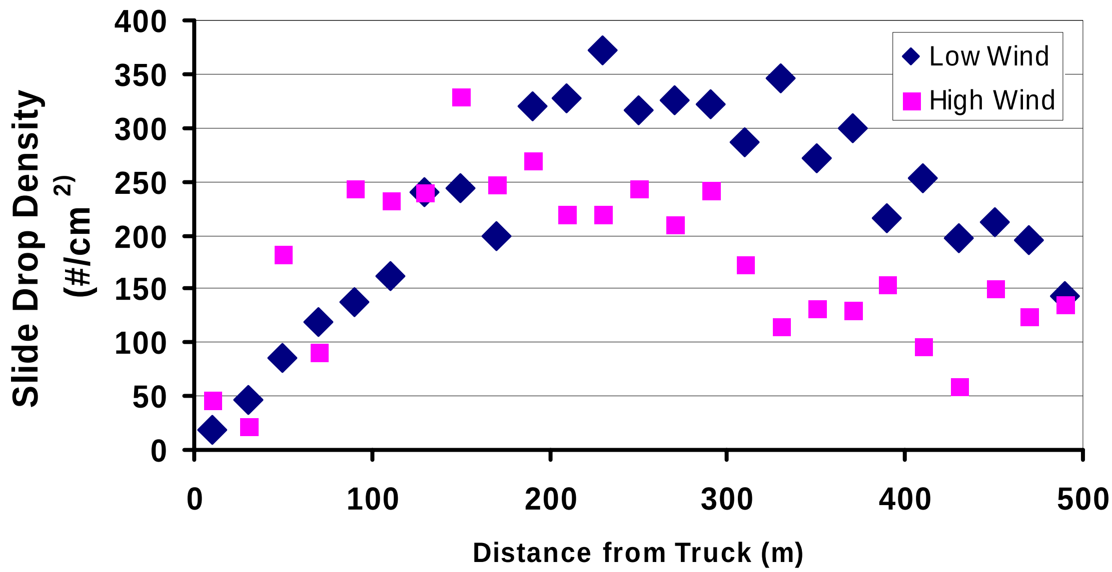

Figure 28. Comparison of average slide drop density (#/cm^2) during high and low-wind ground sprays

4.3.2 Aerial Trials

For the aerial trials, integrated deposit to 5 km was very similar between AGDISP predictions and field measurement (Fig. 29). Winds at spray height ranged from 17.5 to 25.5 kph resulting in a 16% decrease in integrated deposit (57% to 41%).

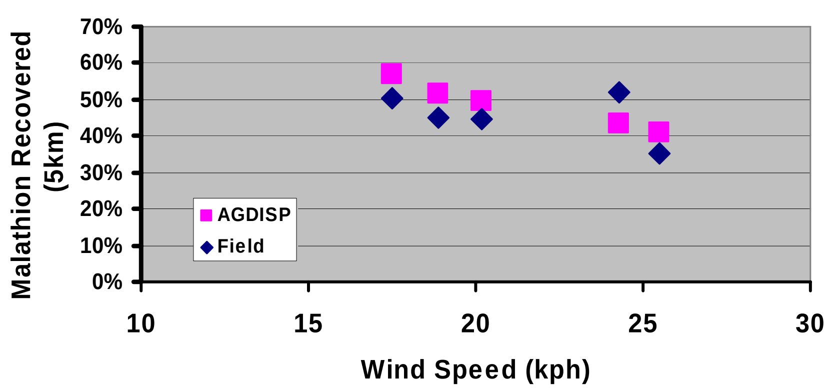

Figure 29. Comparison of integrated deposit to 5 km for AGDISP and field aerial trials

Although integrated deposits were similar, AGDISP tended to predict a deposit peak shifted 300-400 m further downwind (Fig. 30). Predicted maximum deposit in lighter winds was equivalent to average field deposit. Beyond the maxima the rate and shape of deposit fall-off were very similar (Fig. 31). Offsetting the AGDISP data by 400 m to match peak-deposit locations produces near identical results to 3.5 km beyond which the data sets begin to diverge.

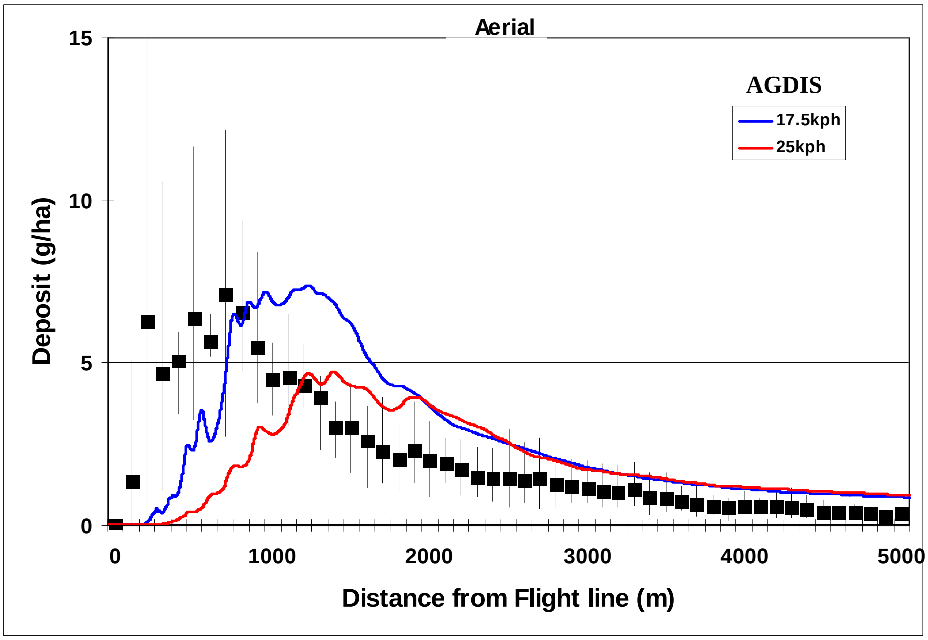

Figure 30. Comparison of measured and AGDISP predicted deposit for aerial sprays in winds from 17.5-25 kph

Average air concentration (Fig. 32) is significantly lower than for ground spraying due largely to the increased distance away from the spray aircraft. With time and distance, the spray cloud disperses vertically leaving low air concentrations near the surface. Peak air concentrations (AGDISP) are significantly further downwind than peak deposit (Fig. 30) similar to the differences measured between deposit and slide drop density (Fig. 23). Air concentration is predicted to fall off much slower with distance than deposit reflecting the long distances that the small drops travel before depositing. Beyond 4 km downwind, the impacts of wind speed at aircraft height are negligible.

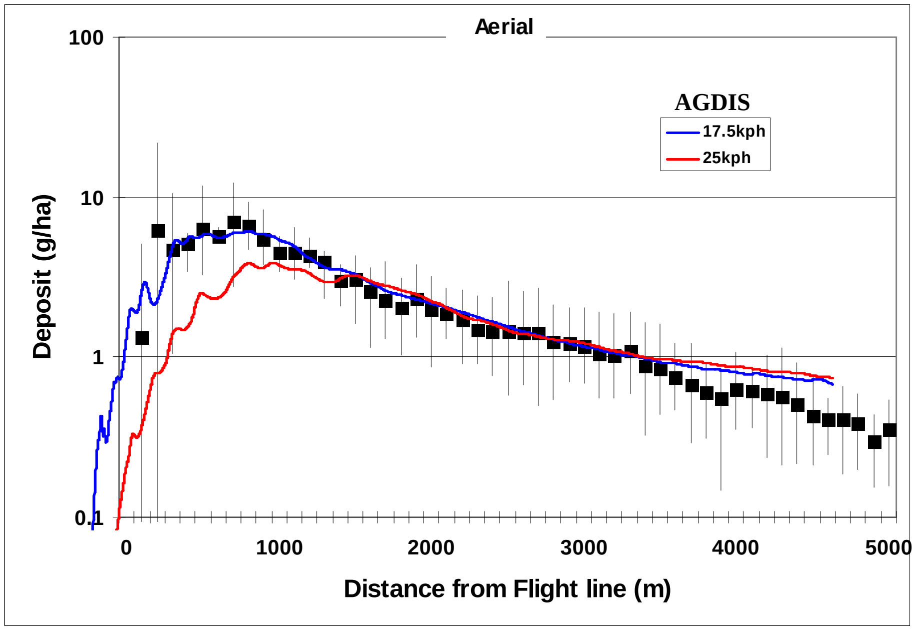

Figure 31. **Comparison of deposit fall-off in far field. AGDISP data have been shifted 400 m to match peak location of field data**

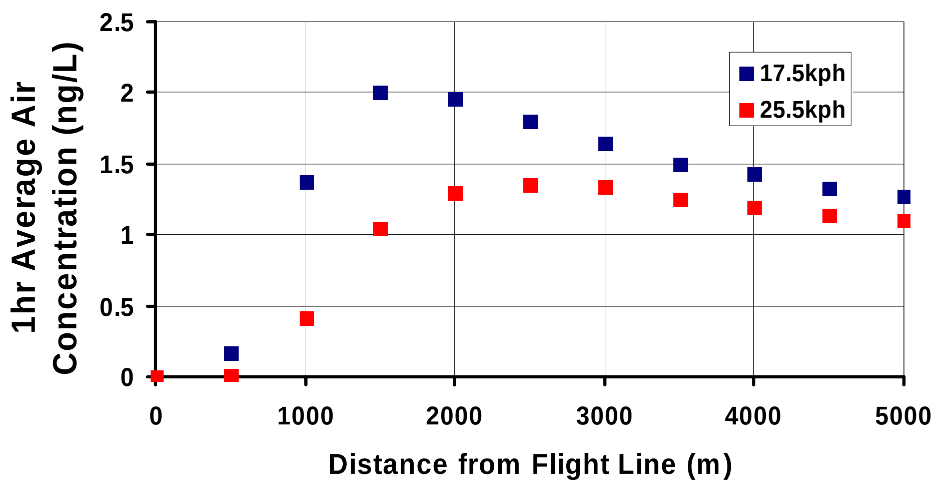

Figure 32. **Predicted average air concentration at 1.5 m height for aerial sprays in 17.5 and 25.5 kph winds**

5. CONCLUSIONS

This is the first complete study comparing aerial and ground deposit of malathion when new optimal ULV spray techniques were used. Of the 10 aerial and ground spray tests (5 of each), all were completed under conditions that were typical of operational conditions. Experiments were conducted in open field conditions.

Analysis of samples containing deuterated malathion indicated no degradation during transport between field and laboratory. Earlier tests to determine the optimal conditions for the conservation of malathion deposits on inert components revealed good stability of the pesticide when kept at -20 or 4 ^{o}C. These conditions were always maintained during the study. Moreover, analysis of field blank samples indicated insignificant contamination.

Under the meteorological conditions during the field trials, peak deposition from ground (11 μm VMD) and aerial (32 μm VMD, 60 m height) were equivalent despite the 4-fold application rate increase for aerial spraying. However, drop densities from the ground application were 4-fold greater than for the aerial application. At spray heights of 60 m, peak deposit was observed 800 m downwind of the flight line while drop density peaked nearly 1 km further down range. For ground application, average deposit peaked nearly 150 m from the spray line and drop density about 100 m further down range. Wind speed had a significant impact on deposit level from ground sprays. Malathion recovery to 500 m indicated between 10-50% of the spray was deposited depending on wind speed. For aerial sprays, 35-50% of emitted malathion deposited within 5 km as winds at spray height ranged from 17-25 kph.

Integrated deposition to the end of the sampling grid was accurately predicted by AGDISP. AGDISP also predicted maximum deposits that were equivalent to those that were measured in the field. For ground trials in high winds, the AGDISP peak deposit was beyond the location of field measurement while in light winds it was closer. For aerial trials, the predicted peak was beyond the location measured in the field. Predicted peak 1-hr average air concentrations from aerial trials were significantly lower than for ground sprays being less than 2 ng/L (1-hr average) compared with 5 ng/L for high wind ground sprays and 20 ng/L for low wind ground sprays.

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APPENDIX 1

Assessment of malathion stability on inert materials

Assessment of malathion stability on inert materials

Goal: In order to determine the best conditions for the conservation of malathion deposits on inert components, assessment of malathion stability will be performed on 9 cm diameter Whatman 934AH fiberglass filters (cat. no. 1827090) for various parameters such as time of conservation, temperature and exposure to light. One additional set will be made on 9 cm diameter Whatman No. 1 alpha cellulose filter (cat. no. 1001090) to compare the efficiency of the different type of filter at 4°C condition.

Filter preparation: The study will be carried out on fiberglass filters spiked with 200 ng of malathion, enrichment being done with a 1 mg/L solution of malathion in hexane. Of this solution, 200 µL will be applied on each of the 40 filters suspended in the air to allow the solvent to evaporate quickly.

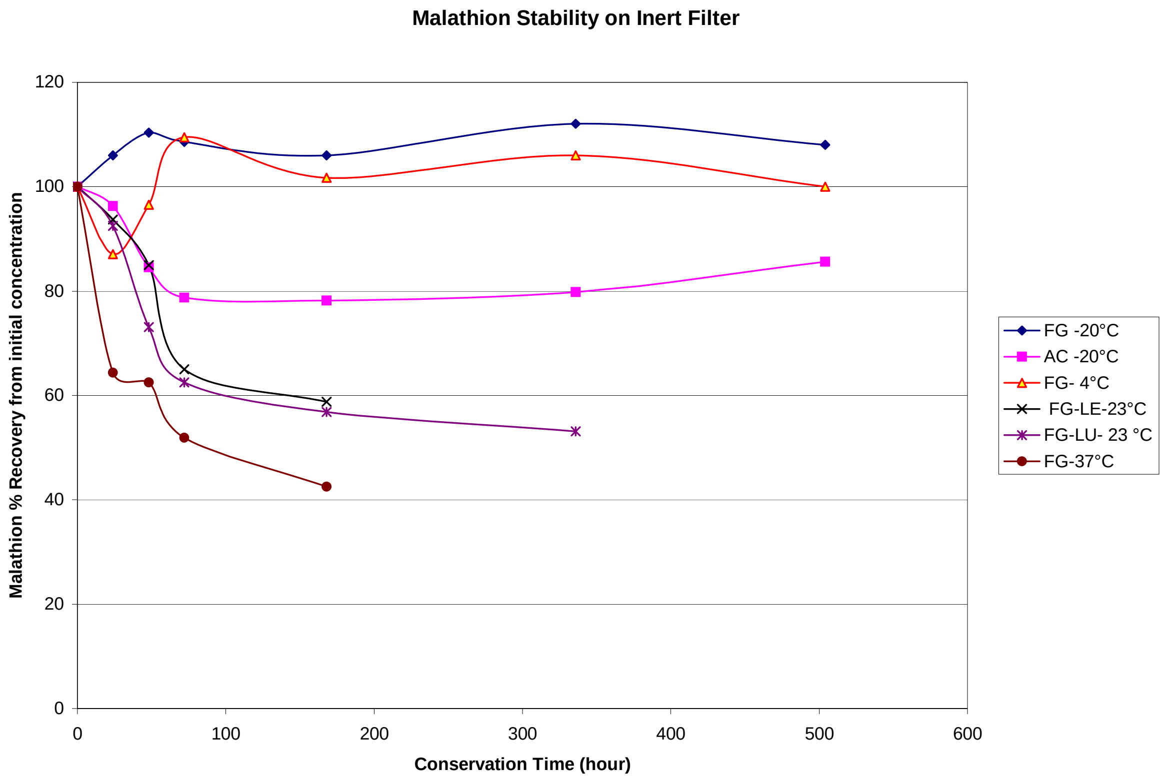
Filter analysis: Once prepared, filters will be introduced into Sarstedt 50 ml test tubes and will be preserved according to the parameters showed in the table below until to be analysed. Filter analysis will be achieved using the E437A laboratory method.

Filter type	**Preservation temperature**	**Preservation time (hour)**							
		0	12	24	48	72	168	336	504
FG-Standard	-20°C	---	*	*	*	*	*	*	*
AC-Standard	-20°C	---	*	*	*	*	*	*	*
FG-Standard	4°C	*	*	*	*	*	*	*	*
FG-Light exposure[1]	23°C	*	*	*	*	*	*	---	---
FG-Unexposed to light[2]	23°C	---	*	*	*	*	*	*	---
FG-Standard	37°C	---	*	*	*	---	---	---	---

[1] Exposure to light will be done by placing filters on the counter of the laboratory close to the unshaded windows.

[2] The filters will be protected from light by wrapping the tubes with aluminium foil and storing in a drawer.

FG = Fiberglass filter AC = Alpha cellulose Filter


Malathion Stability on Inert Filter
Malathion % Recovery from initial concentration
Conservation Time (hour)
0
20
40
60
80
100
120
0
100
200
300
400
500
600
FG -20°C
AC -20°C
FG- 4°C
FG-LE-23°C
FG-LU- 23 °C
FG-37°C

APPENDIX 2

Analytical method for the determination of malathion on fiber glass filter by GC-MS (E-437)

ANALYTICAL METHOD FOR THE DETERMINATION OF MALATHION ON FIBER GLASS FILTER BY GC-MS (E-437)

-Condensed version-

1. Type of method

Gas chromatography coupled with mass spectrometry (GC-MS)

2. Application range

1 ng/filter to 2000 ng/filter

Higher concentration may be quantified with appropriated dilution of the filter extract.

3. Instrument

Chromatograph 5890 from Agilent with mass detector 5989B (Engine).

4. Description

The filter is first spiked with 100 ng of deuterated malathion analogue and extracted with ethyl acetate. The extract is centrifuged to separate the remaining filter fibres before evaporation near dryness and finally reconstituted of 1 ml in isooctane-dichloromethane mixture. The malathion is quantified on gas chromatography coupled with mass spectrometry (GC-MS) operating in electron capture negative ionisation (ECNI) where concentration are corrected according to the recovery of the deuterated malathion in each sample.

5. Analytical performance

The method gave the following performance during the validation process.

Analyte(s)	Detection limit (ng/filter)	Quantitation limit (ng/filter)	Linearity (ng/filter)	Biais (%)	Same day reproducibility (%)	Day to day reproducibility (%)	Recovery (%)
Malathion	1	3	1 – 2000	N.A.	3.5 (n=10)	5.1 (n=10)	80 (n=3)

Routine checks of accuracy and precision are accomplished by including in each analytical series a spiked filter containing 100 ng of malathion from a different source than the one used for calibration.

Approved by	*Date*	*Date of first revision*	*Page*
	2005/01/20		53 de 97

ANALYTICAL METHOD FOR THE DETERMINATION OF MALATHION ON FIBER GLASS FILTER BY GC-MS (E-437)

-Condensed version-

6. Reference range and occupational exposure levels

Not available

7. Interlaboratory comparison programs

Not available

8. References

1. Beeson MD, Driskell WJ, Barr DB. Isotope Dilution High-Performance Liquid Chromatography/Tandem Mass Spectrometry Method for quantifying Urinary Metabolites of Atrazine, Malathion, and 2,4-Dichlorophenoxyacetic acid. 1999; Anal. Chem. 71:3526-3530.

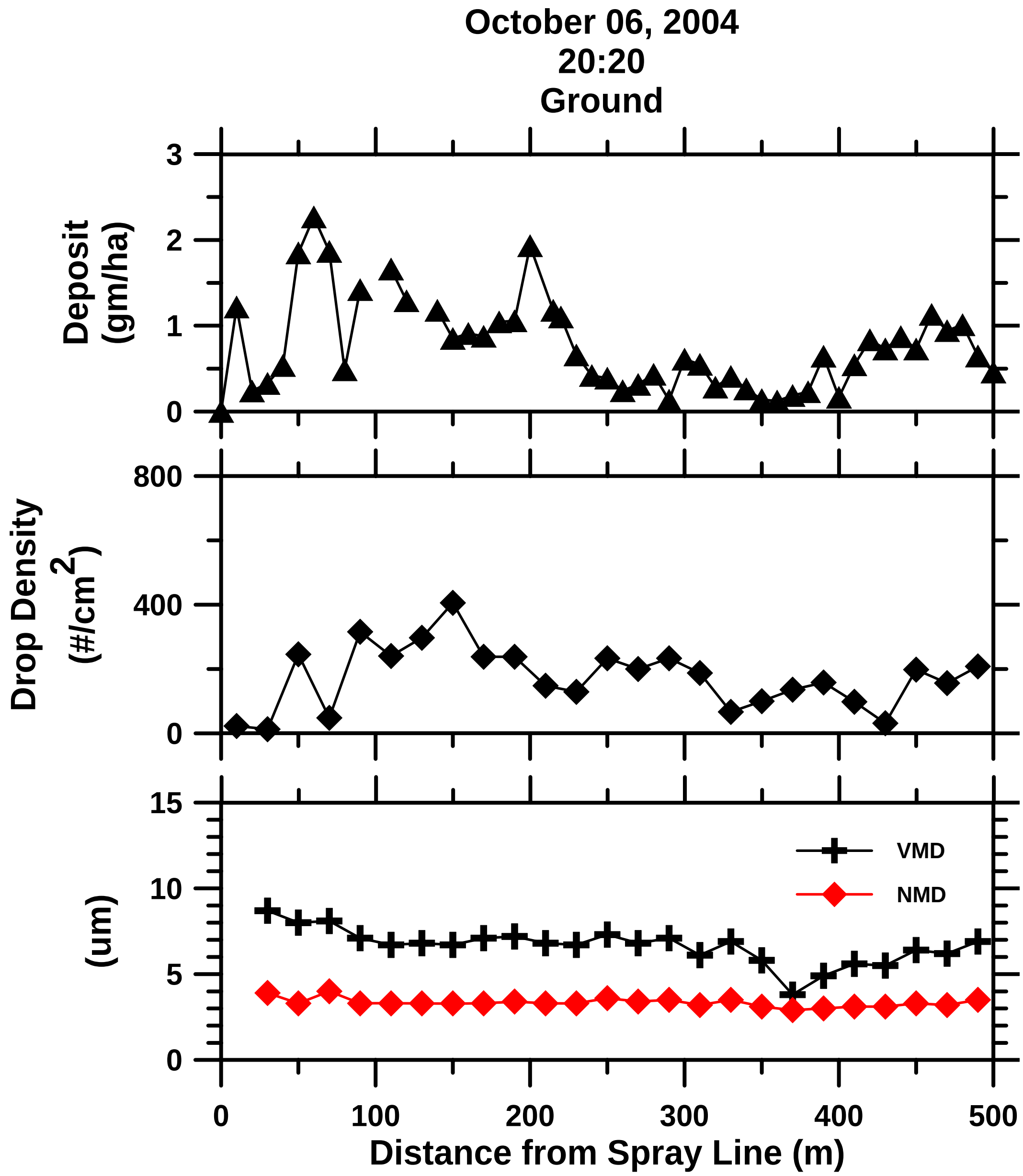
2. Lioy PJ, Edwards RD, Freeman N, Gurunathan S, Pellizzari E, Adgate JL, Quackenboss J, Sexton K. House dust levels of selected insecticides and an herbicide measured by the EL and LWW samplers and comparisons to hand rinses and urine metabolites. J. Exposure Anal. And Env. Epidemiology. 2000;10 :327-340.

3. AOAC Official Method 979.05 Malathion in Pesticide Formulations. Gas Chromatographic Method.

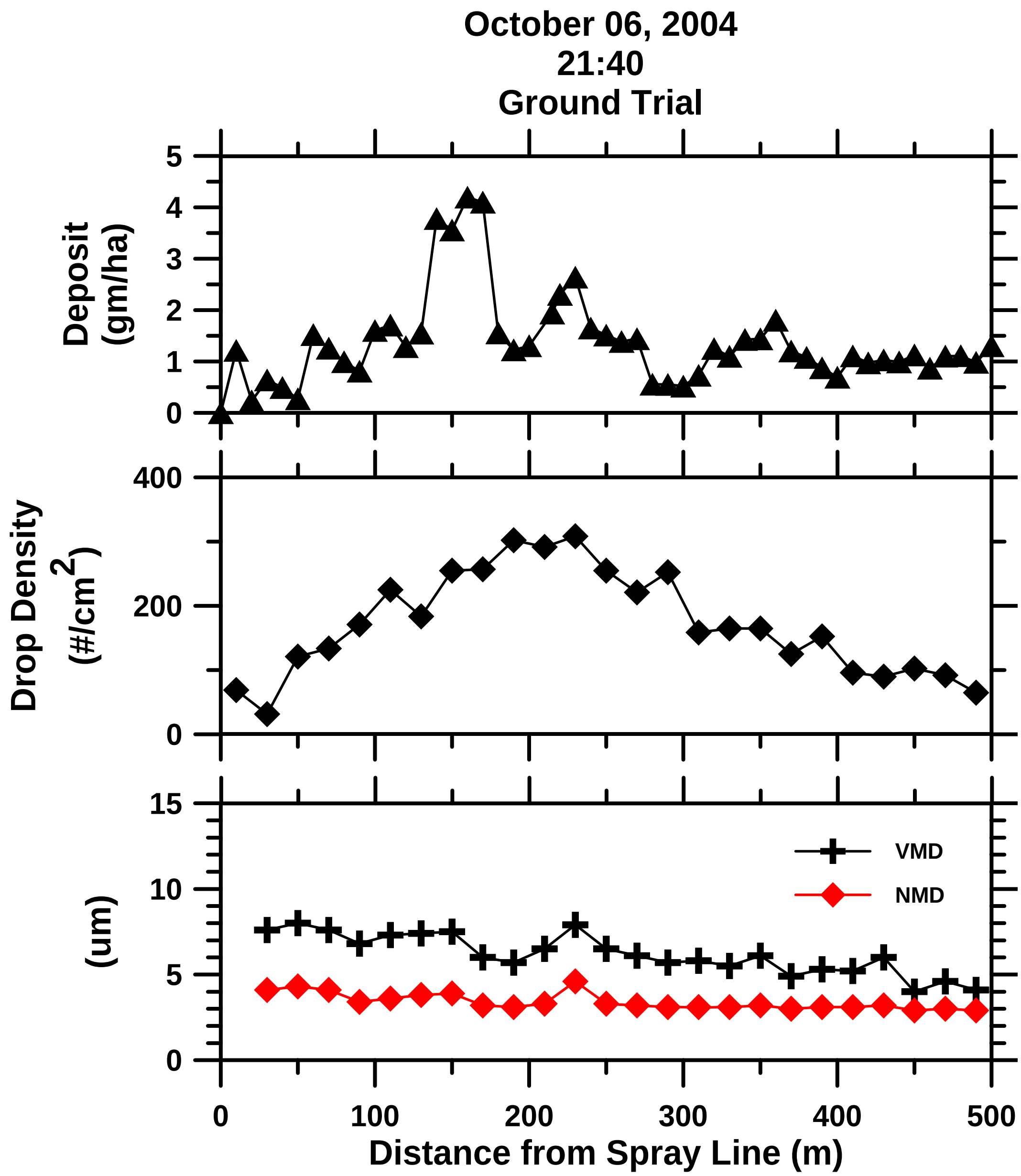
Approved by	*Date*	*Date of first revision*	*Page*
	2005/01/20		54 de 97

APPENDIX 3

Results of Ground Trials



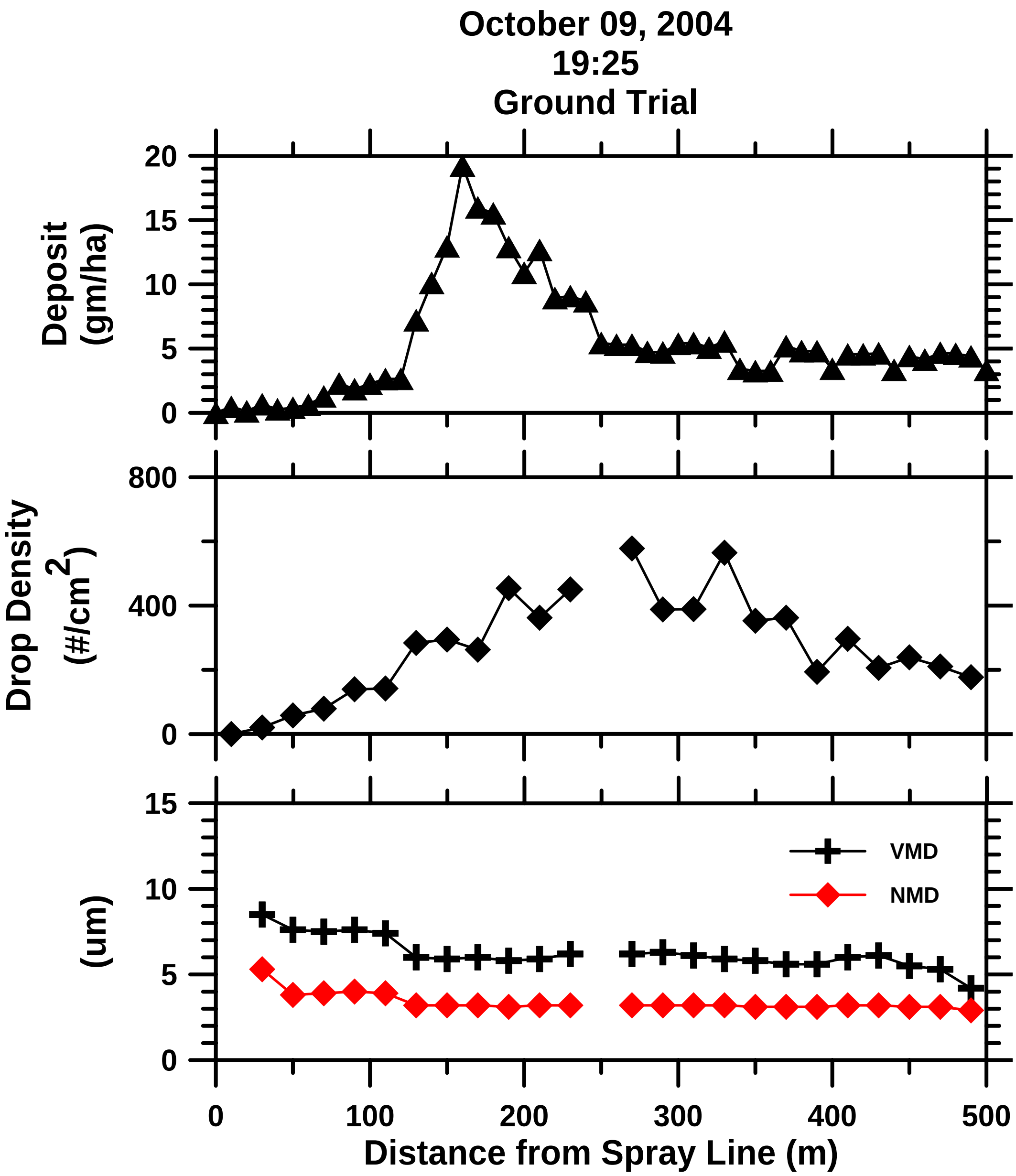
Winds	**12.2kph**
	86°
Ta	**25.7C**
RH	**79%**
Spray Line	**90°**



Winds 11.2kph

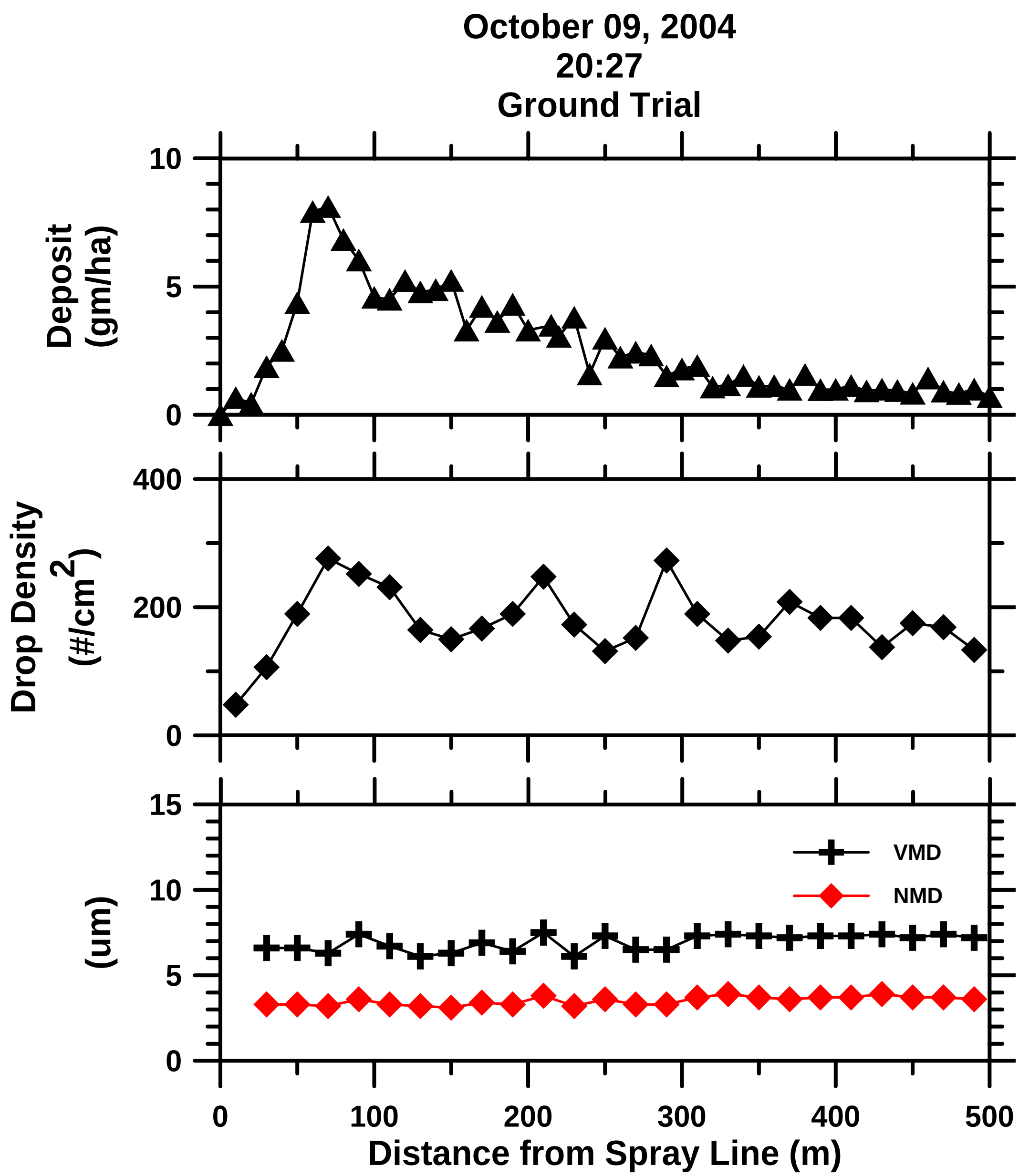
73°

Ta	**24.4C**
RH	**85%**
Spray Line	**90°**

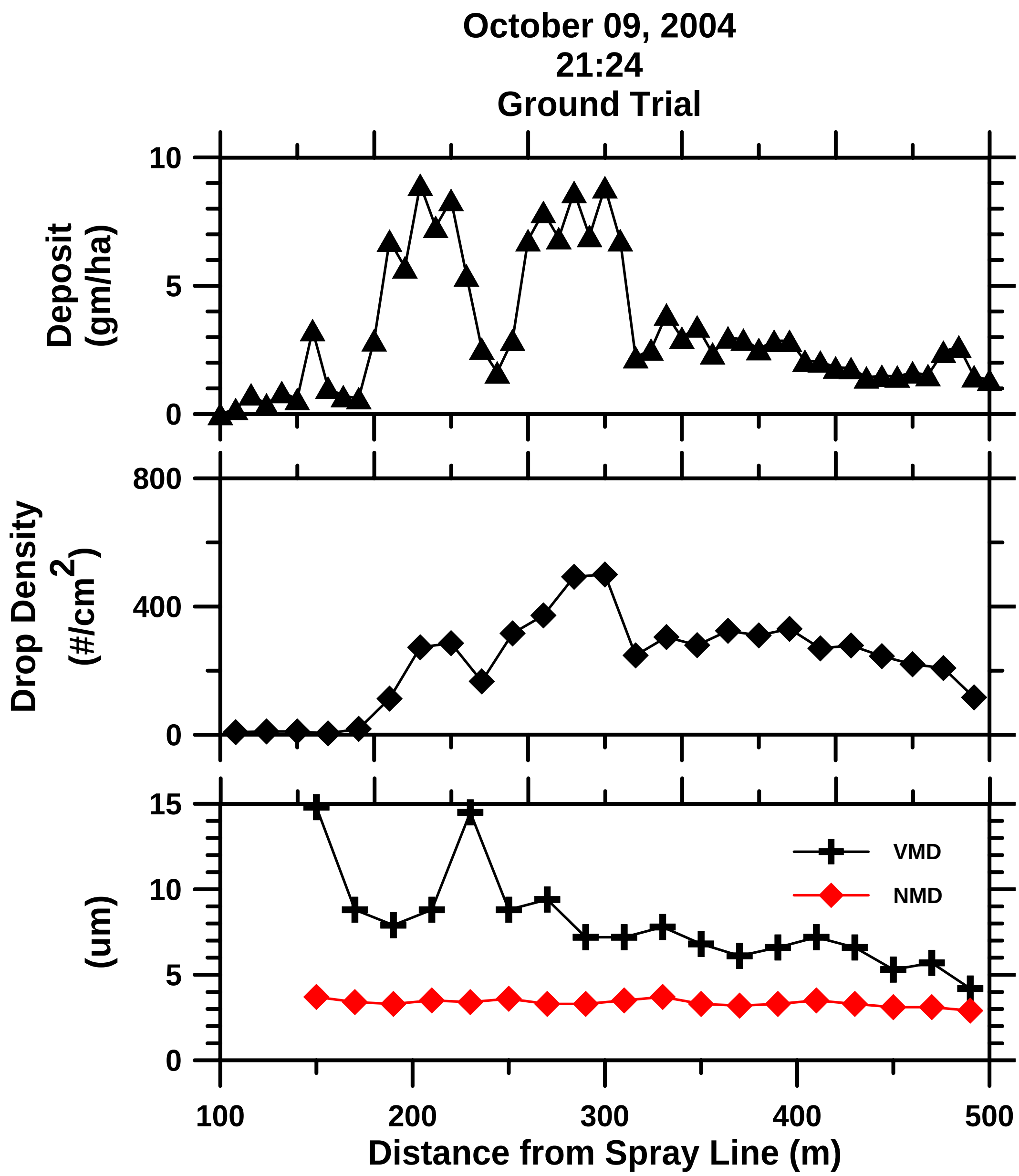


Winds **3.6kph**

	86^o
Ta	**25.2C**
RH	**79%**
Spray Line	**90^o**



Winds	**6.1kph**
	96°
Ta	**24.6C**
RH	**78%**
Spray Line	**90°**



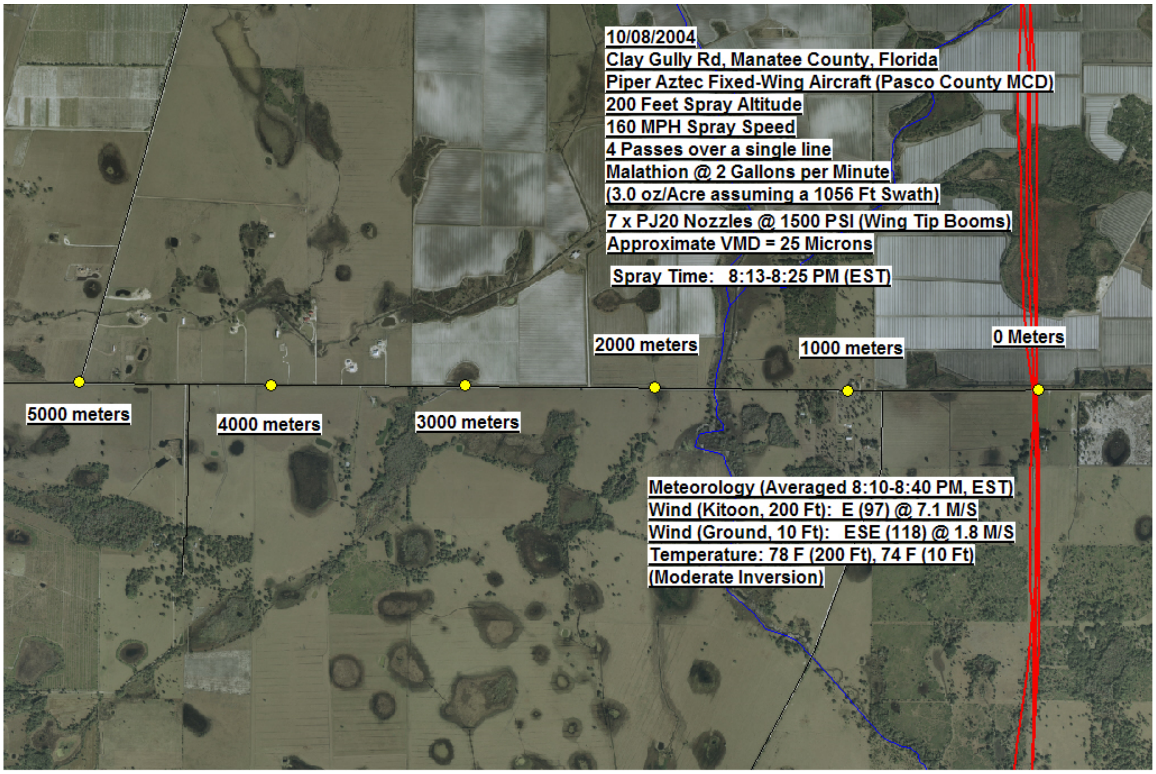
Winds 4.7kph

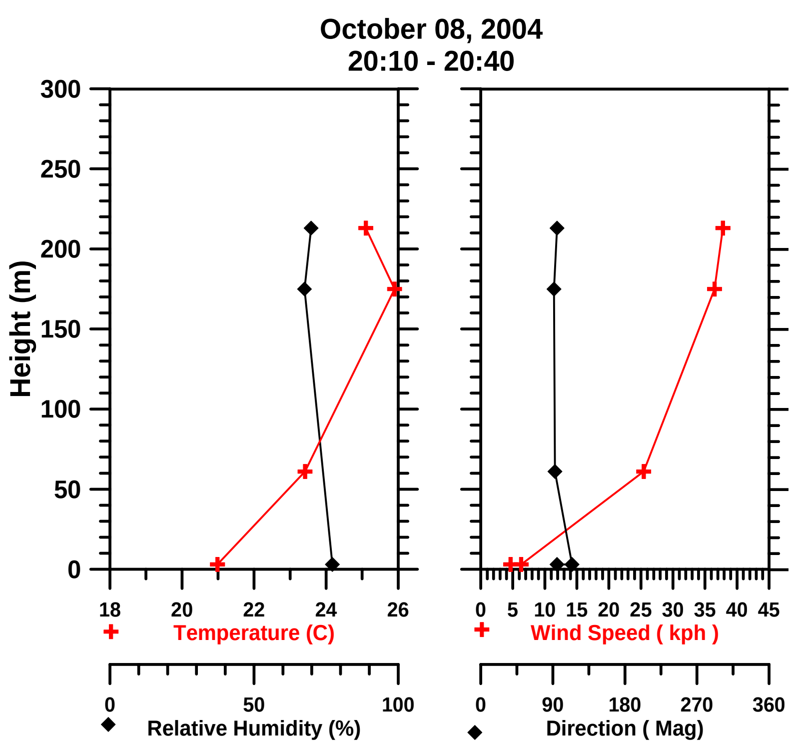
86°

Ta	**23.6C**
RH	**83%**
Spray Line	**90°**

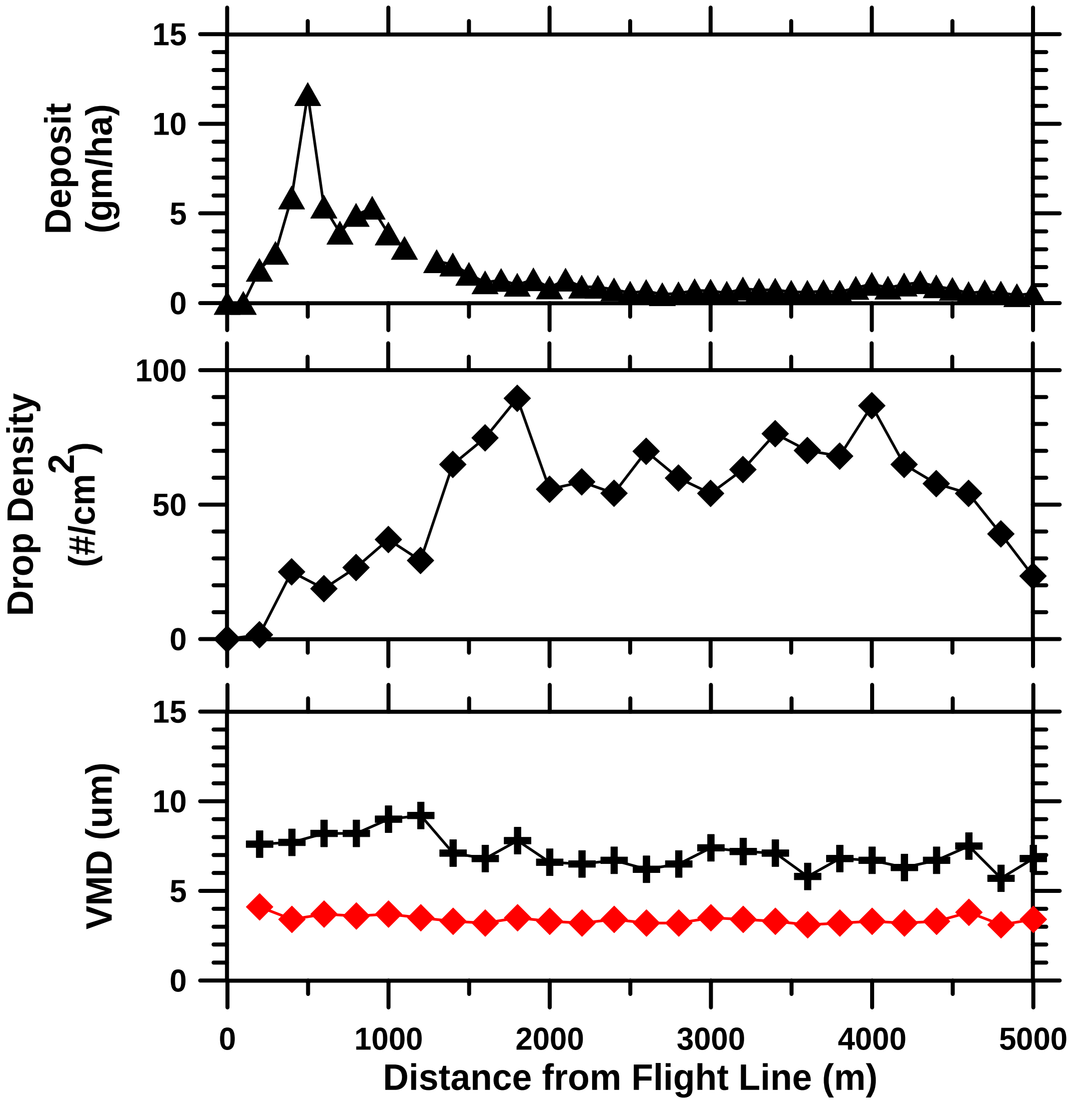
APPENDIX 4

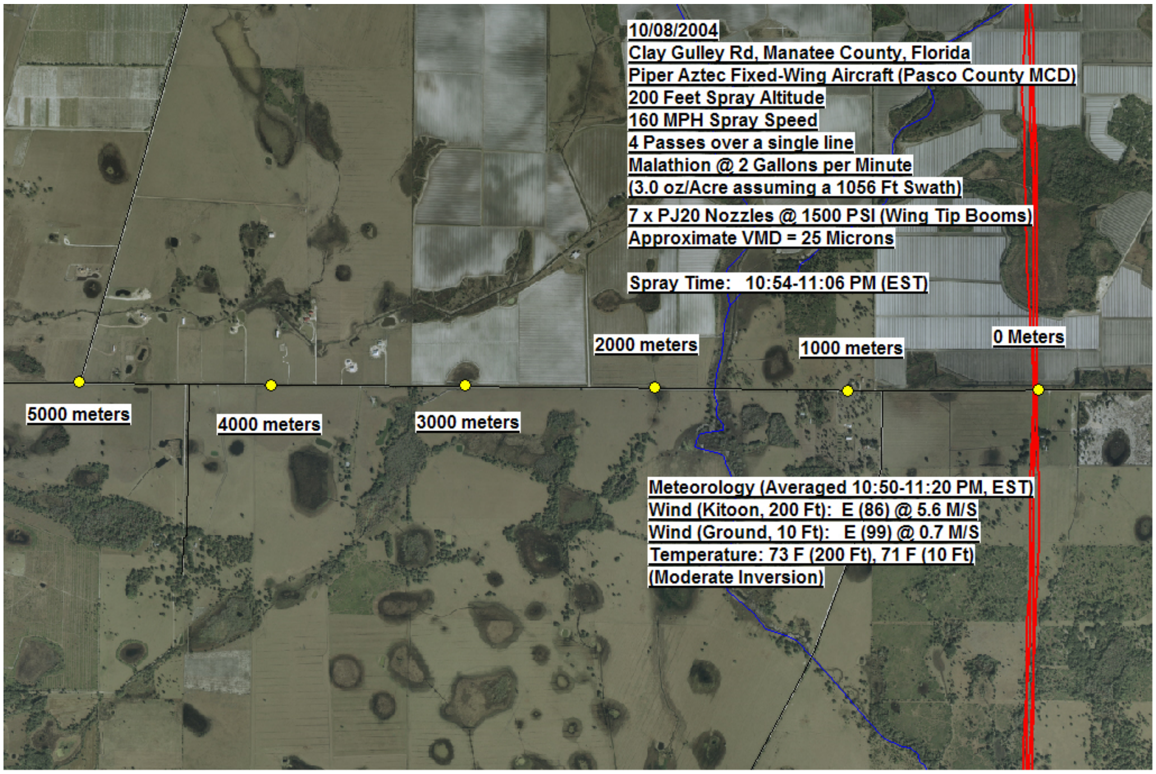
Results of Aerial Trials

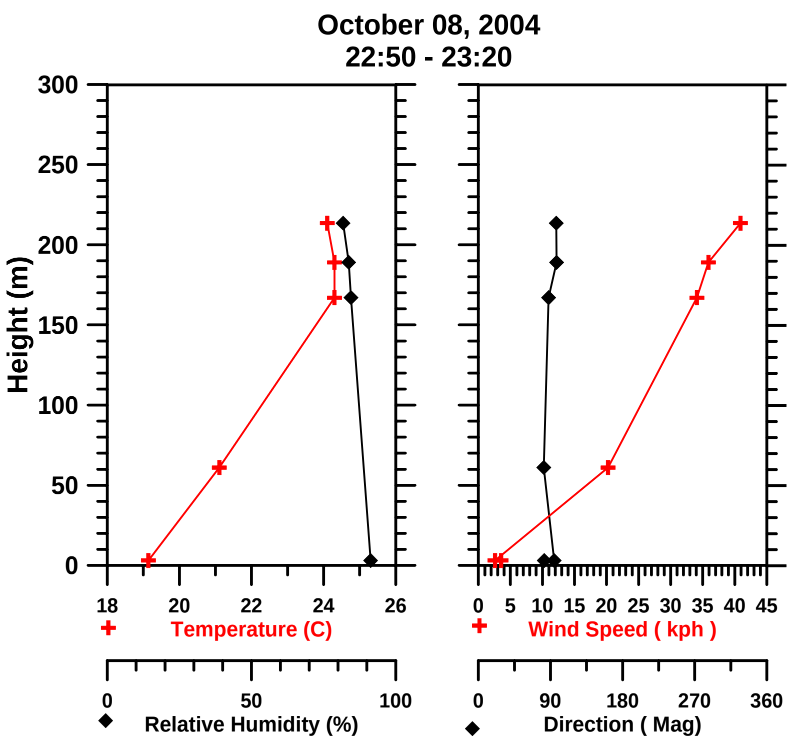

10/08/2004
Clay Gully Rd, Manatee County, Florida
Piper Aztec Fixed-Wing Aircraft (Pasco County MCD)
200 Feet Spray Altitude
160 MPH Spray Speed
4 Passes over a single line
Malathion @ 2 Gallons per Minute
(3.0 oz/Acre assuming a 1056 Ft Swath)
7 x PJ20 Nozzles @ 1500 PSI (Wing Tip Booms)
Approximate VMD = 25 Microns
Spray Time: 8:13-8:25 PM (EST)
2000 meters
1000 meters
0 Meters
5000 meters
4000 meters
3000 meters
Meteorology (Averaged 8:10-8:40 PM, EST)
Wind (Kitoon, 200 Ft): E (97) @ 7.1 M/S
Wind (Ground, 10 Ft): ESE (118) @ 1.8 M/S
Temperature: 78 F (200 Ft), 74 F (10 Ft)
(Moderate Inversion)

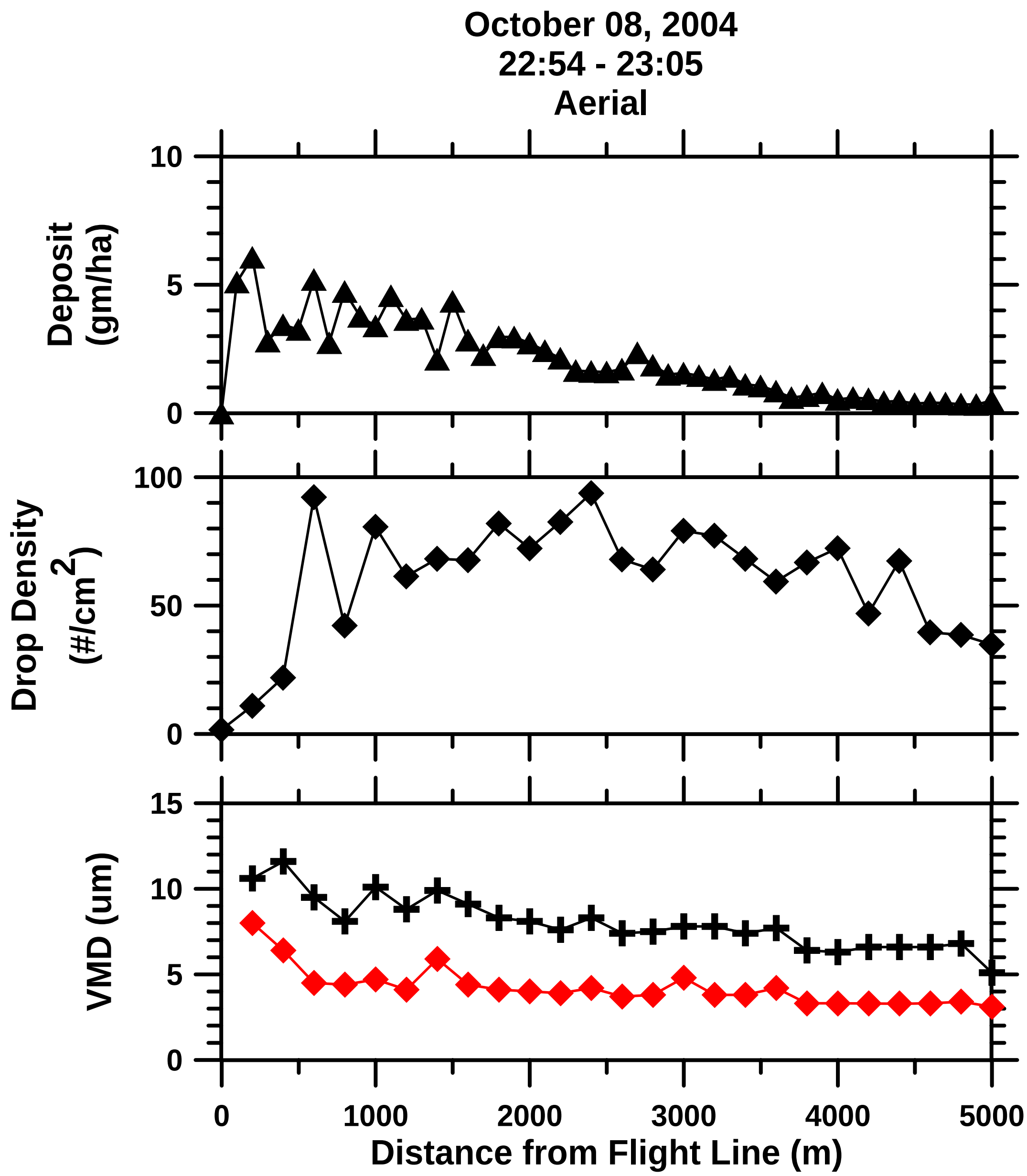

October 08, 2004
20:10 - 20:40
Height (m)
300
250
200
150
100
50
0
18 20 22 24 26
Temperature (C)
0 50 100
Relative Humidity (%)
0 5 10 15 20 25 30 35 40 45
Wind Speed (kph)
0 90 180 270 360
Direction (Mag)

October 08, 2004
20:13 - 20:24
Aerial

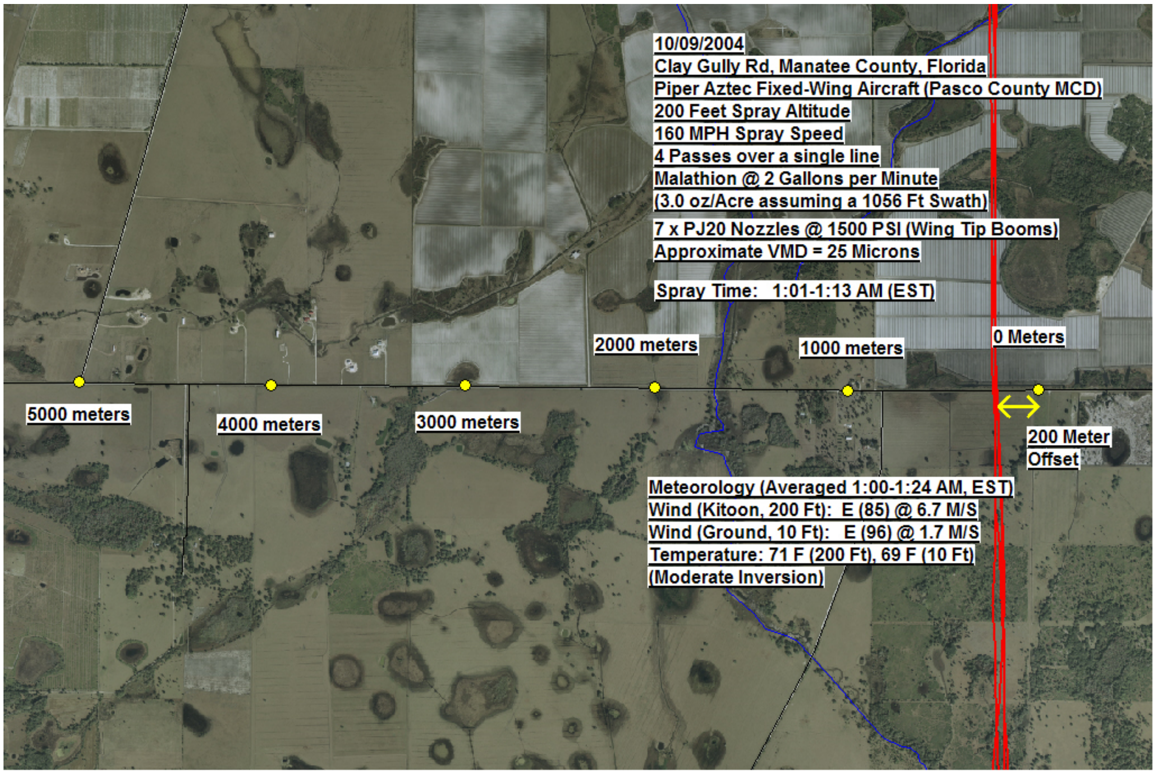



10/08/2004
Clay Gulley Rd, Manatee County, Florida
Piper Aztec Fixed-Wing Aircraft (Pasco County MCD)
200 Feet Spray Altitude
160 MPH Spray Speed
4 Passes over a single line
Malathion @ 2 Gallons per Minute
(3.0 oz/Acre assuming a 1056 Ft Swath)
7 x PJ20 Nozzles @ 1500 PSI (Wing Tip Booms)
Approximate VMD = 25 Microns
Spray Time: 10:54-11:06 PM (EST)
2000 meters
1000 meters
0 Meters
5000 meters
4000 meters
3000 meters
Meteorology (Averaged 10:50-11:20 PM, EST)
Wind (Kitoon, 200 Ft): E (86) @ 5.6 M/S
Wind (Ground, 10 Ft): E (99) @ 0.7 M/S
Temperature: 73 F (200 Ft), 71 F (10 Ft)
(Moderate Inversion)

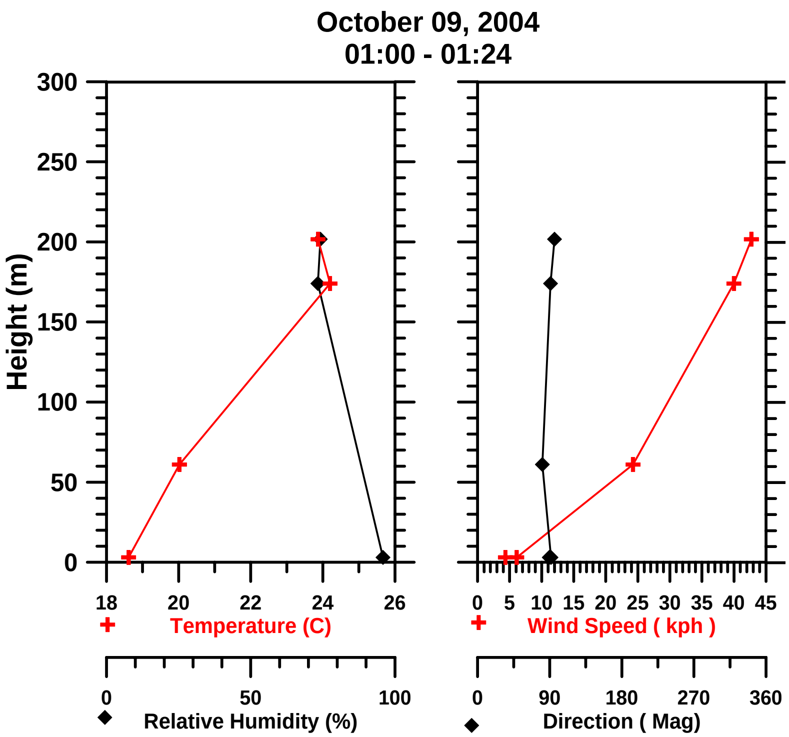

October 08, 2004
22:50 - 23:20
Height (m)
300
250
200
150
100
50
0
18 20 22 24 26
Temperature (C)
0 50 100
Relative Humidity (%)
0 5 10 15 20 25 30 35 40 45
Wind Speed (kph)
0 90 180 270 360
Direction (Mag)



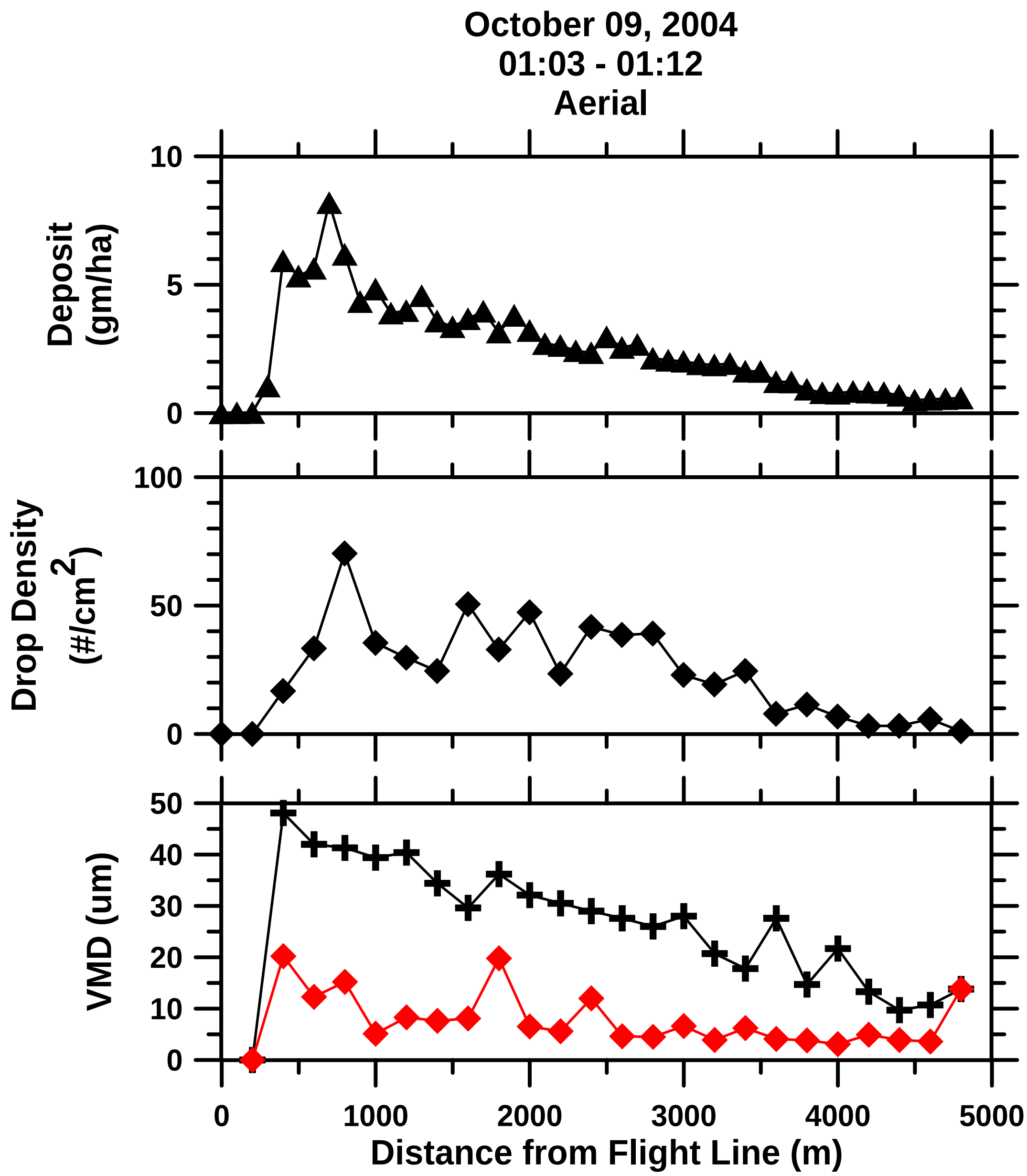
October 08, 2004
22:54 - 23:05
Aerial
Deposit (gm/ha)
10
5
0
Drop Density (#/cm2)
100
50
0
VMD (um)
15
10
5
0
0
1000
2000
3000
4000
5000
Distance from Flight Line (m)

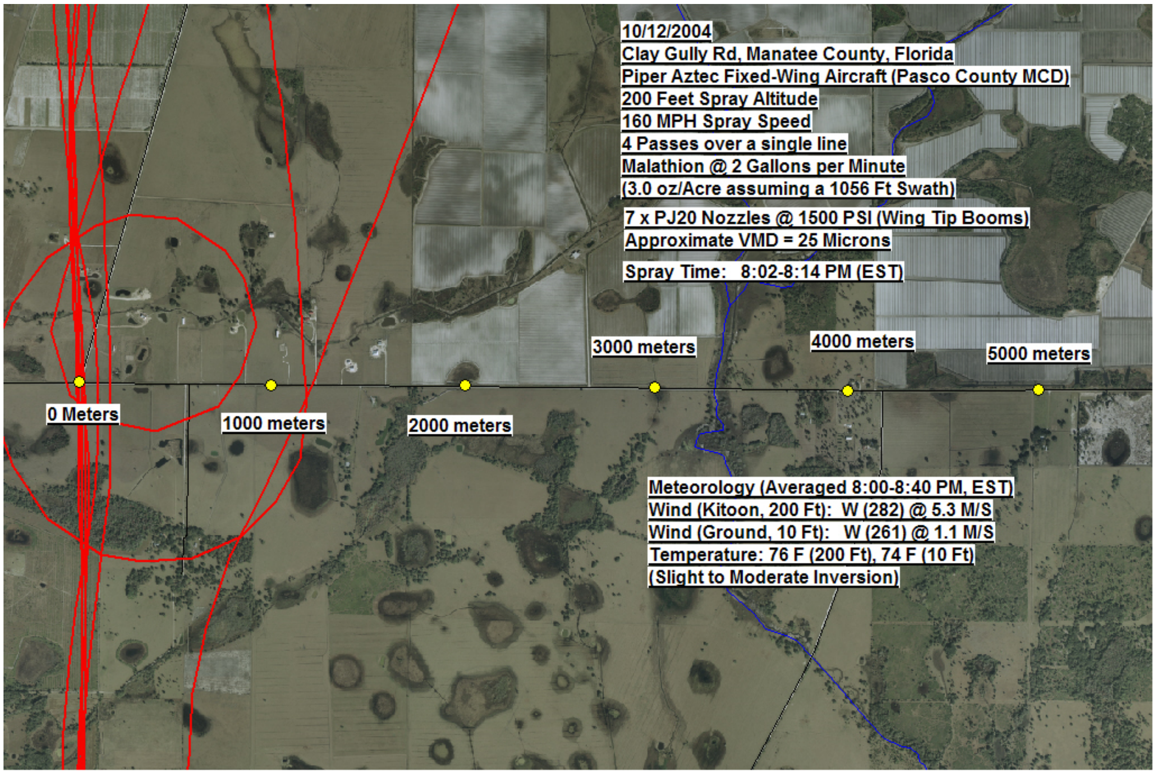


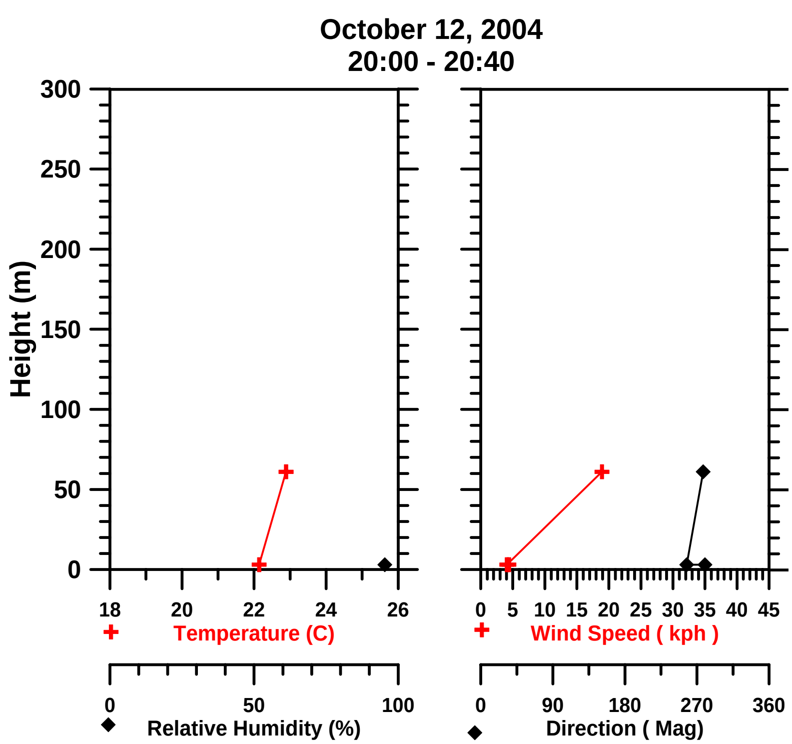
10/09/2004
Clay Gully Rd, Manatee County, Florida
Piper Aztec Fixed-Wing Aircraft (Pasco County MCD)
200 Feet Spray Altitude
160 MPH Spray Speed
4 Passes over a single line
Malathion @ 2 Gallons per Minute
(3.0 oz/Acre assuming a 1056 Ft Swath)
7 x PJ20 Nozzles @ 1500 PSI (Wing Tip Booms)
Approximate VMD = 25 Microns
Spray Time: 1:01-1:13 AM (EST)
2000 meters
1000 meters
0 Meters
5000 meters
4000 meters
3000 meters
200 Meter Offset
Meteorology (Averaged 1:00-1:24 AM, EST)
Wind (Kitoon, 200 Ft): E (85) @ 6.7 M/S
Wind (Ground, 10 Ft): E (96) @ 1.7 M/S
Temperature: 71 F (200 Ft), 69 F (10 Ft)
(Moderate Inversion)

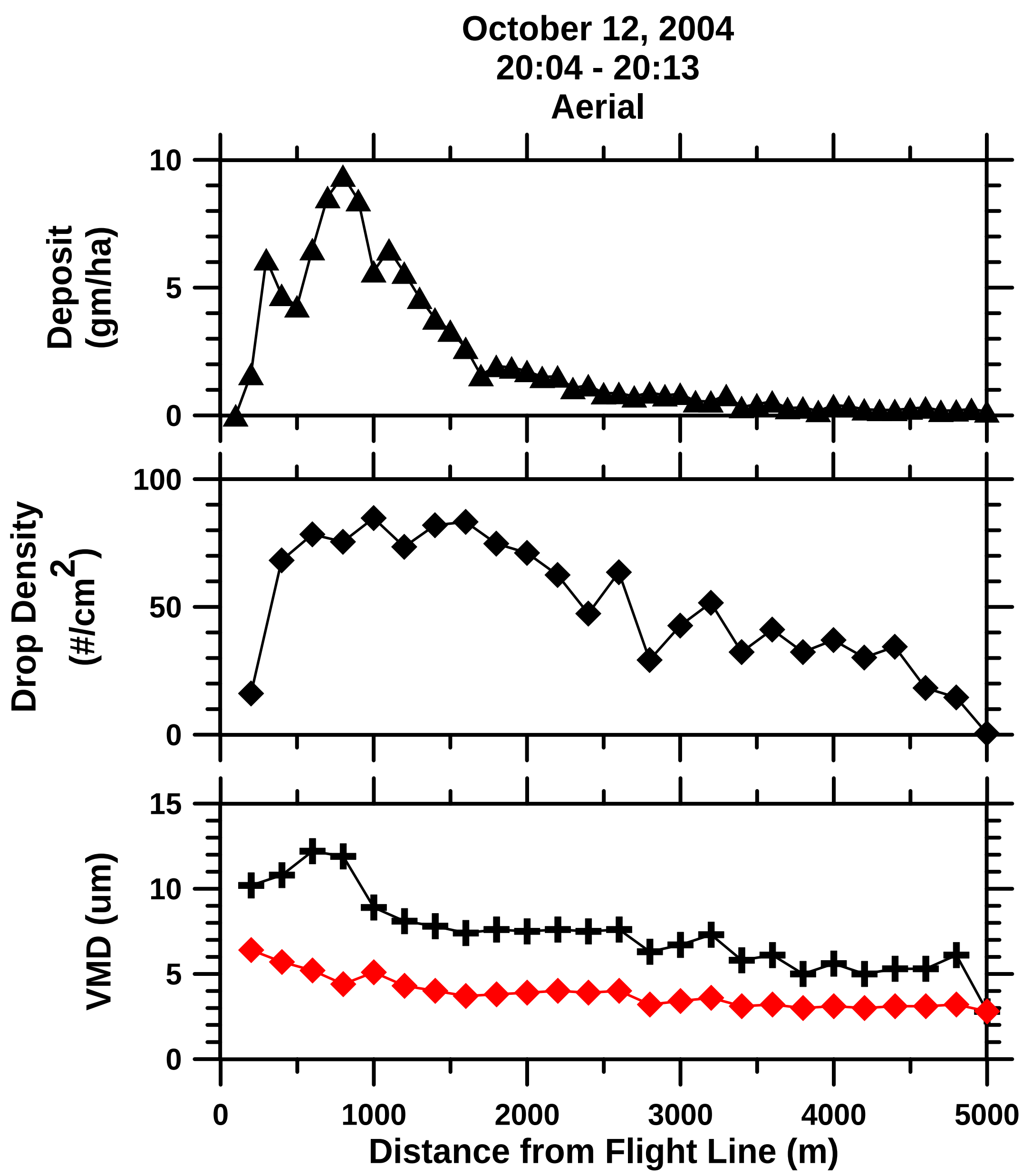


October 09, 2004
01:00 - 01:24
Height (m)
300
250
200
150
100
50
0
18 20 22 24 26
Temperature (C)
0 50 100
Relative Humidity (%)
0 5 10 15 20 25 30 35 40 45
Wind Speed (kph)
0 90 180 270 360
Direction (Mag)

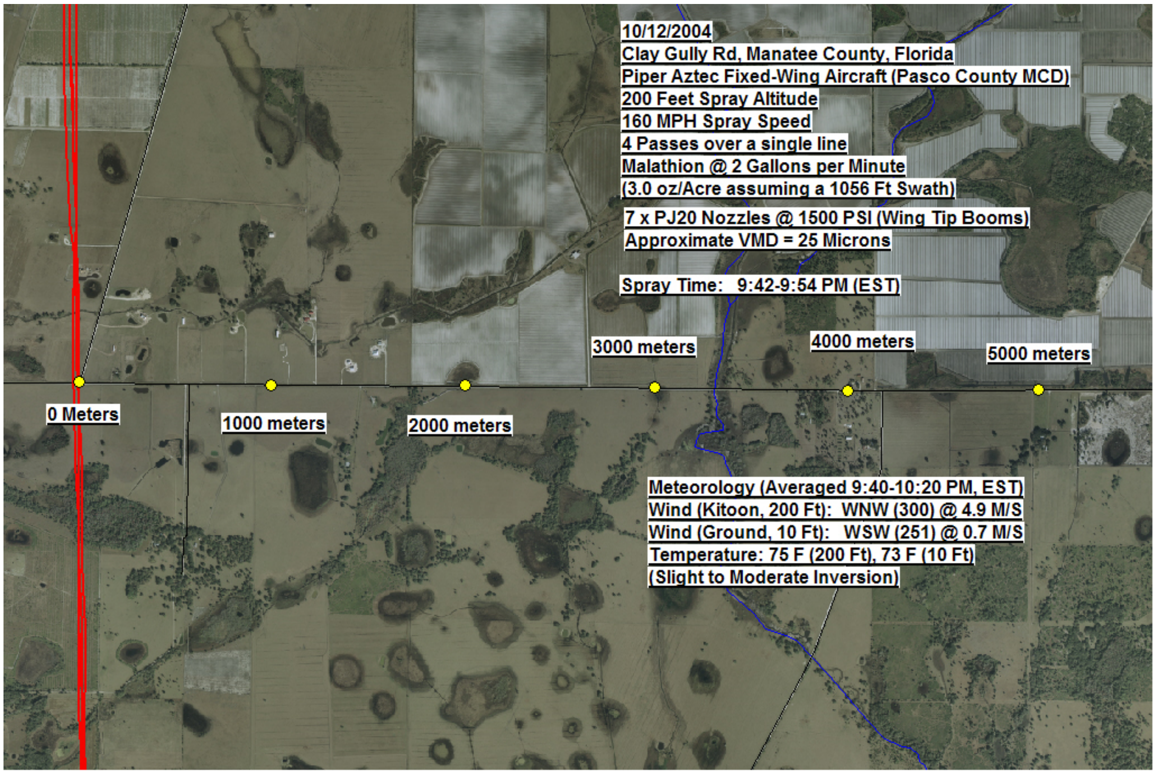

October 09, 2004
01:03 - 01:12
Aerial
Deposit (gm/ha)
0
5
10
Drop Density (#/cm2)
0
50
100
VMD (um)
0
10
20
30
40
50
0
1000
2000
3000
4000
5000
Distance from Flight Line (m)

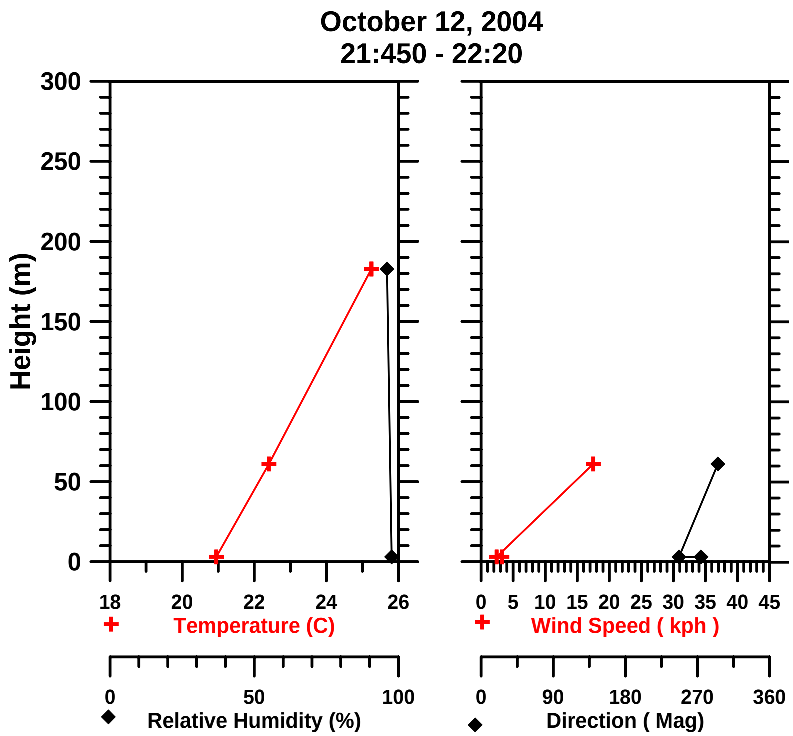

10/12/2004
Clay Gully Rd, Manatee County, Florida
Piper Aztec Fixed-Wing Aircraft (Pasco County MCD)
200 Feet Spray Altitude
160 MPH Spray Speed
4 Passes over a single line
Malathion @ 2 Gallons per Minute
(3.0 oz/Acre assuming a 1056 Ft Swath)
7 x PJ20 Nozzles @ 1500 PSI (Wing Tip Booms)
Approximate VMD = 25 Microns
Spray Time: 8:02-8:14 PM (EST)
0 Meters
1000 meters
2000 meters
3000 meters
4000 meters
5000 meters
Meteorology (Averaged 8:00-8:40 PM, EST)
Wind (Kitoon, 200 Ft): W (282) @ 5.3 M/S
Wind (Ground, 10 Ft): W (261) @ 1.1 M/S
Temperature: 76 F (200 Ft), 74 F (10 Ft)
(Slight to Moderate Inversion)

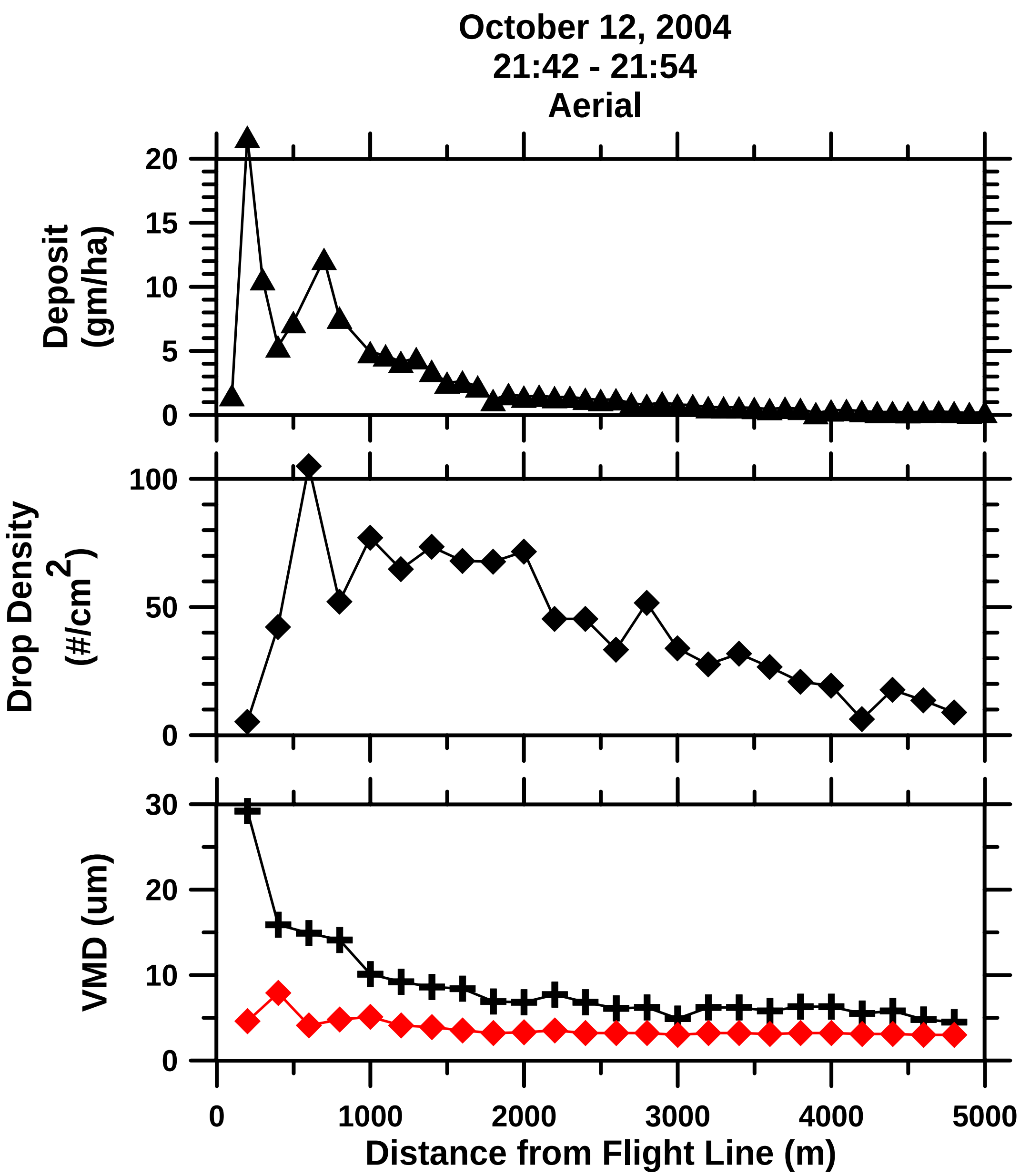

October 12, 2004
20:00 - 20:40
Height (m)
0
50
100
150
200
250
300
18 20 22 24 26
Temperature (C)
0 50 100
Relative Humidity (%)
0 5 10 15 20 25 30 35 40 45
Wind Speed (kph)
0 90 180 270 360
Direction (Mag)



October 12, 2004
20:04 - 20:13
Aerial
Deposit (gm/ha)
10
5
0
Drop Density (#/cm2)
100
50
0
VMD (um)
15
10
5
0
0
1000
2000
3000
4000
5000
Distance from Flight Line (m)


10/12/2004
Clay Gully Rd, Manatee County, Florida
Piper Aztec Fixed-Wing Aircraft (Pasco County MCD)
200 Feet Spray Altitude
160 MPH Spray Speed
4 Passes over a single line
Malathion @ 2 Gallons per Minute
(3.0 oz/Acre assuming a 1056 Ft Swath)
7 x PJ20 Nozzles @ 1500 PSI (Wing Tip Booms)
Approximate VMD = 25 Microns
Spray Time: 9:42-9:54 PM (EST)
3000 meters
4000 meters
5000 meters
0 Meters
1000 meters
2000 meters
Meteorology (Averaged 9:40-10:20 PM, EST)
Wind (Kitoon, 200 Ft): WNW (300) @ 4.9 M/S
Wind (Ground, 10 Ft): WSW (251) @ 0.7 M/S
Temperature: 75 F (200 Ft), 73 F (10 Ft)
(Slight to Moderate Inversion)


October 12, 2004
21:450 - 22:20
Height (m)
300
250
200
150
100
50
0
18 20 22 24 26
Temperature (C)
0 50 100
Relative Humidity (%)
0 5 10 15 20 25 30 35 40 45
Wind Speed (kph)
0 90 180 270 360
Direction (Mag)


October 12, 2004
21:42 - 21:54
Aerial
Deposit (gm/ha)
20
15
10
5
0
Drop Density (#/cm2)
100
50
0
VMD (um)
30
20
10
0
0
1000
2000
3000
4000
5000
Distance from Flight Line (m)

APPENDIX 5

Field parameters for Input to AGDISP

Reference Document: PMRA Re-evaluation of Malathion (PARC2003-10)

Regulatory Conclusions: Maximum rates

Ground ULV application 60.8 g a.i./ha

Aerial application 260 g a.i./ha

Aztec

Max Cdn Label Rate = 260gai/ha

Product

Field experiment used US Fyfanon which contained

9.9 lb malathion/gal = 1.18627 Kg/L at 96.5% (US Fyfanon label)

therefore, Spray Volume Rate 0.2191L/ha (US Fyfanon)

Specific gravity (sg) of malathion 1.23

Flight parameters:

AC speed 150mph = 240kph

Flow 2.16 gal/min=276.48 oz/min = 8.1756 L/min

Line Source Strength (LSS) = 2.0439L/km

Swath = 93.3m (required to provide Spray Volume Rate)

Ground ULV Sprayer

Max Cdn Label 60.8gai/ha

therefore, Spray Volume Rate = 0.05125L/ha (US Fyfanon)

Ground Speed = 15kph

Ground ULV Parameters

Flow set to 4.3oz/min at 10mph=16kph (flow regulated based on speed)

Flow=4.3oz/min = 0.12715 L/min (1US oz=0.02957L)

LSS (L/km) = 0.4768 L/km

Swath = 93.0m (Required to provide Spray Volume Rate)

Notes:

$LSS_{Aztec} = 4.28 \times LSS_{Ground}$

APPENDIX 6

AGDISP 8.13 Input Parameters for Ground Model Run

AGDISP Input Data Summary

--General--
Title: PCMCD Ground Trials
Notes:

Calculations Done: Yes
Run ID: AGDISP PCMCD Grnd.ag 8.13 02-19-2005 20:51:26

--Aircraft--	**---------------------------**	
Name		**Clarke Grizzly**
Type		**Library**
Boom Height (m)		**0**
Spray Lines		**1**
Optimize Spray Lines		**No**
Spray Line Reps	**#**	**Reps**
	1	**1**

--Ground Application Type--	**---------------------------**
Ground Application Type	**Liquid**

--Drop Size Distribution--	**---------------------------**
Name	**PCMCD Waved Slide**
Type	**User-defined**
Drop Categories	

#	**Diam (um)**	**Frac**
1	**1.01**	**0.0181**
2	**1.30**	**0.0061**
3	**1.61**	**0.0078**
4	**1.97**	**0.0099**
5	**2.37**	**0.0125**
6	**2.82**	**0.0157**
7	**3.32**	**0.0197**
8	**3.89**	**0.0244**
9	**4.52**	**0.0298**
10	**5.24**	**0.0362**
11	**6.04**	**0.0433**
12	**6.94**	**0.0510**
13	**7.94**	**0.0592**
14	**9.08**	**0.0672**
15	**10.35**	**0.0738**
16	**11.77**	**0.0779**
17	**13.37**	**0.0806**
18	**15.17**	**0.0787**
19	**17.19**	**0.0729**
20	**19.45**	**0.0638**
21	**21.99**	**0.0524**
22	**24.84**	**0.0396**
23	**28.04**	**0.0271**
24	**31.64**	**0.0165**
25	**35.67**	**0.0089**
26	**40.20**	**0.0042**
27	**45.28**	**0.0018**
28	**50.99**	**0.0010**

--Nozzle Distribution--	**----------------------------**				
Boom Length (%)	**0**				
Nozzle Locations	**#**	**Hor(m)**	**Ver(m)**	**Fwd(m)**	
	1	**0**	**-0.1**	**0**	
--Swath--	**----------------------------**				
Swath Width	**93.0 m**				
Swath Displacement	**0 m**				
--Spray Material--	**----------------------------**				
Name	**Fyfanon**				
Type	**Reference**				
Nonvolatile Fraction	**1**				
Active Fraction	**0.965**				
Spray Volume Rate (L/ha)	**0.0513**				
--Meteorology--	**----------------------------**				
Wind Speed (m/s)	**1.32**				
Wind Direction (deg)	**-90**				
Temperature (deg C)	**18.33**				
Relative Humidity (%)	**50**				
--Atmospheric Stability--	**----------------------------**				
Atmospheric Stability	**Less Than 3/8ths Overcast**				
--Transport--	**----------------------------**				
Flux Plane Distance (m)	**0**				
--Canopy--	**----------------------------**				
Type	**None**				
--Advanced--	**----------------------------**				
Wind Speed Height (m)	**2**				
Max Compute Time (sec)	**6000**				
Max Downwind Dist (m)	**502**				
Ambient Pressure (mb)	**1013**				
Save Trajectory Files	**No**				
Half Boom	**No**				
Default Swath Offset	**0 Swath**				
Specific Gravity (Carrier)	**1.23**				
Specific Gravity (Nonvolatile)	**1.23**				
Evaporation Rate (µm²/deg C/sec)	**84.76**				

APPENDIX 7

AGDISP 8.13 Input Parameters for Aerial Model Run

AGDISP Input Data Summary

--General--
Title: PCMCD Aztec with PJ20 Nozzles
Notes:

Calculations Done: No
Run ID: AGDISP PCMCD Aztec.ag 8.13 00-00-0000 00:00:00

--Aircraft--	**---------------------------**	
Name		**Piper Aztec E**
Type		**Library**
Boom Height (m)		**60**
Spray Lines		**1**
Optimize Spray Lines		**No**
Spray Line Reps	**#**	**Reps**
	1	**1**
Wing Type		**Fixed-Wing**
Semispan (m)		**5.67**
Typical Speed (m/s)		**66.7**
Biplane Separation (m)		**0**
Weight (kg)		**1912.02**
Planform Area (m²)		**32.89**
Propeller RPM		**2575**
Propeller Radius (m)		**1.1**
Engine Vert Distance (m)		**0**
Engine Fwd Distance (m)		**3.6**

--Aerial Application Type--	**---------------------------**
Aerial Application Type	**Liquid**

--Drop Size Distribution--		**---------------------------**	
Name		**LCMCD Wind Tunnel**	
Type		**User-defined**	
Drop Categories	**#**	**Diam (um)**	**Frac**
	1	**1.11**	**0.0250**
	2	**1.61**	**0.0057**
	3	**2.17**	**0.0066**
	4	**2.82**	**0.0078**
	5	**3.58**	**0.0093**
	6	**4.44**	**0.0111**
	7	**5.44**	**0.0132**
	8	**6.60**	**0.0159**
	9	**7.93**	**0.0190**
	10	**9.46**	**0.0228**
	11	**11.23**	**0.0272**
	12	**13.27**	**0.0324**
	13	**15.63**	**0.0383**
	14	**18.34**	**0.0450**
	15	**21.47**	**0.0522**
	16	**25.08**	**0.0598**
	17	**29.24**	**0.0668**
	18	**34.04**	**0.0719**
	19	**39.57**	**0.0764**
	20	**45.95**	**0.0774**
	21	**53.31**	**0.0743**

22	61.80	0.0676
23	71.58	0.0577
24	82.86	0.0454
25	95.88	0.0322
26	110.88	0.0201
27	128.18	0.0109
28	148.14	0.0050
29	171.15	0.0020
30	197.68	0.0010

--Nozzle Distribution-- ----------------------------

Boom Length (%) 98.59

Nozzle Locations

#	Hor(m)	Ver(m)	Fwd(m)
1	-5.59	0.0035	0
2	-5.39	0.0035	0
3	-5.19	0.0035	0
4	-4.99	0.0035	0
5	-4.79	0.0035	0
6	-4.59	0.0035	0
7	4.59	0.0035	0
8	4.79	0.0035	0
9	4.99	0.0035	0
10	5.19	0.0035	0
11	5.39	0.0035	0
12	5.59	0.0035	0

--Swath-- ----------------------------

Swath Width 93.3 m

Swath Displacement 0 m

--Spray Material-- ----------------------------

Name Fyfanon

Type Reference

Nonvolatile Fraction 1

Active Fraction 0.965

Spray Volume Rate (L/ha) 0.2191

--Meteorology-- ----------------------------

Wind Speed (m/s) 4.85

Wind Direction (deg) -90

Temperature (deg C) 18.33

Relative Humidity (%) 90

--Atmospheric Stability-- ----------------------------

Atmospheric Stability Less Than 3/8ths Overcast

--Transport-- ----------------------------

Flux Plane Distance (m) 1000

--Canopy-- ----------------------------

Type None

--Terrain-- ----------------------------

Surface Roughness (m) 0.0075

Upslope Angle (deg) 0

Sideslope Angle (deg) 0

--Advanced--	**----------------------------**
Wind Speed Height (m)	**60**
Max Compute Time (sec)	**60000**
Max Downwind Dist (m)	**5000**
Vortex Decay Rate (IGE) (m/s)	**0.56**
Vortex Decay Rate (OGE) (m/s)	**0.15**
Aircraft Drag Coeff	**0.1**
Propeller Efficiency	**0.8**
Ambient Pressure (mb)	**1013**
Save Trajectory Files	**No**
Half Boom	**No**
Default Swath Offset	**0 Swath**
Specific Gravity (Carrier)	**1.23**
Specific Gravity (Nonvolatile)	**1.23**
Evaporation Rate (μm²/deg C/sec)	**84.76**