Assessment of aerosol deposition and movement in open field conditions

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Abstract: The overall objective of this study was to evaluate the dispersion of aerosol plumes generated by a truck-mounted ultra low-volume (ULV) applicator and a hand-held thermal fogger under open field conditions. Experiments were also planned to determine the relative capture efficiencies of various sampling techniques in such applications. The ULV applicator was used at three travel speeds (8.5 km/h, 16.8 km/h, and 24.8 km/h) and the thermal fogger at two release heights (0.6 m and 1.1 m above ground) to investigate the effects of speed or release height on deposition at 6 m, 12 m, 24 m, and 48 m downwind. High volume air samplers (HVS), low volume air samplers (LVS), spinning cotton ribbon (CR) samplers, polypropylene green plastic cards (GC), acetate cards (AC), and water-sensitive papers (WSP) were used to collect deposits. The ULV applicator was tested with water and oil sprays while the thermal fogger was tested with the latter tracer only. Using water- and oil-based tracers, all deposition targets were analyzed by fluorometry. Results showed decreased tracer deposition with increase in sampling distance. Overall, travel speed affected deposition at the near sample locations only, but in most sample locations, normalized deposits were comparable at all speeds. Spray release height did not affect deposition of active samplers but had significant effect on deposition of passive samplers at 6 m location only. Overall, the higher release height resulted in more deposition in most downwind locations. There were good correlations between depositions on active and passive samplers. The HVS, CR, GC, and AC samplers were effective in sampling aerosol plume dispersion under open field conditions. The paper includes relationships among capture efficiencies of various samplers.
Keywords: ULV applicator, thermal fogger, deposition samplers, Yellow 131SC dye, Pyranine 10G, fluorometry

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1 Introduction

Sand flies transmit perilous diseases including Leishmaniasis which affect human health in 88 countries (Desjeux, 2001; Alexander and Maroli, 2003). These small insects have silent non-hovering flight up to several hundred meters. They are predominant in desert and semi-desert areas of Middle East and parts of Asia (Sirak-wizeman et al., 2008). Over the years, efforts have been made to control sand flies around houses, and animal shelters by treating walls and surrounding open areas up to several hundred meters with insecticides (Alexander and Maroli, 2003). In a pilot study, Chaniotis et al. (1982) achieved only about 30% reduction in sand flies with bimonthly ULV applications. This low level of efficacy might be due to the insect flight close to the ground and its high activity during the night (USACHPPM Technical, 2005). Thus, some of the techniques used for mosquito control in open field conditions may also be applicable for sand flies control.

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Pant et al. (1974) evaluated mist blower ULV applications of fernitrothion for field control of dengue fever vector. Although useful for immediate insect control, Pant et al. (1974) reported that equipment and application methods needed further improvements for long term control of immature vector population (e.g., eggs, larvae, and pupae). Tietze, Hester and Shaffer (1994) determined insecticide depositions at 5 m, 25 m, 100 m, and 500 m, using a truck-mounted cold ULV aerosol applicator. They observed that deposition rate decreased with increasing distance from the applicator; however, droplet size with mass median diameter in the range of 8.8 - 11.0 μm, was unchanged up to 100 m. Mount (1998) reported that, for efficient mosquito control, ULV aerosol applications should be performed after sunset at travel speed of 4-8 km/h and with aerosol volume mean diameter (VMD) in the ranges of 8 - 15 μm. Another recommendation by Mount (1998) was to increase the daytime application rates to compensate for intensified vertical lift of the spray plume, and also to maintain the optimal VMD size range. Recently, Britch et al. (2010) tested thermal foggers and ULV applicators in temperate and desert environment and concluded that the thermal foggers had higher efficacy in mosquito control than ULV applicators. Therefore, further understanding of the ULV and thermal fog plume dispersions, in optimal and suboptimal metrological conditions, could be helpful in improving the efficiency and efficacy of the aerosol applications.

The spread of released aerosol droplets may be characterized by a variety of active and passive samplers that are commonly used in spray drift assessment. Active sampling techniques involve using spinning devices with different catching surfaces (Cooper et al., 1996; Farooq et al., 2009; Bonds (Barber) et al., 2009) or high- and low-volume air samplers (Salyani and Cromwell, 1992; Bui et al., 1998; Hayward, Gouin and Wania, 2010). Passive samplers include paper/plastic cards, water-/oil-sensitive papers, synthetic wool yarn, alpha cellulose sheets, cotton/paper tapes, polyurethane foam disks, etc. (Salyani and Whitney, 1991; Salyani and Hoffman, 1996; Cooper et al., 1996; Bui et al., 1998; Salyani, 2000; Jaward et al., 2004; Biugstad and Hermansen, 2009). These samplers have different capture efficiencies and their measured deposits are not readily comparable. Therefore, this study was also designed to evaluate various deposition samplers under the same application conditions. Specific objectives of the study were:

a) To evaluate aerosol dispersion and deposition at three travel speeds of a ULV applicator and two release heights of a thermal fogger at several downwind sampling locations;

b) To determine the relative capture efficiencies of various sampling techniques in such applications.

2 Materials and methods

Field experiments were conducted during April, 2010, in a site located at Camp Blanding Joint Training Center, Starke, FL. The test site included a dirt runway surrounded by grassy flat terrain and pine trees at the boundaries (Figure 1). Application equipment included: a truck-mounted ULV applicator (Grizzly; Clarke Engineering Technology Inc., Roselle, IL), and a hand-held thermal fogger (Golden Eagle® 2610; Curtis Dyna-Fog Ltd., Westfield, IN). The ULV applicator was operated at three travel speeds of 8.5 km/h, 16.8 km/h, and 24.8 km/h (S1, S2, S3), with both oil and water sprays. The spray was released at about 1.4 m height above ground in the horizontal direction to the back of the truck. The fogger was mounted on a custom built trolley with an adjustable height platform which was pulled by a pickup truck at 8.5 km/h during the applications. It was operated at two aerosol release heights of about 0.6 m and 1.1 m (H1, H2) above ground using oil spray only.

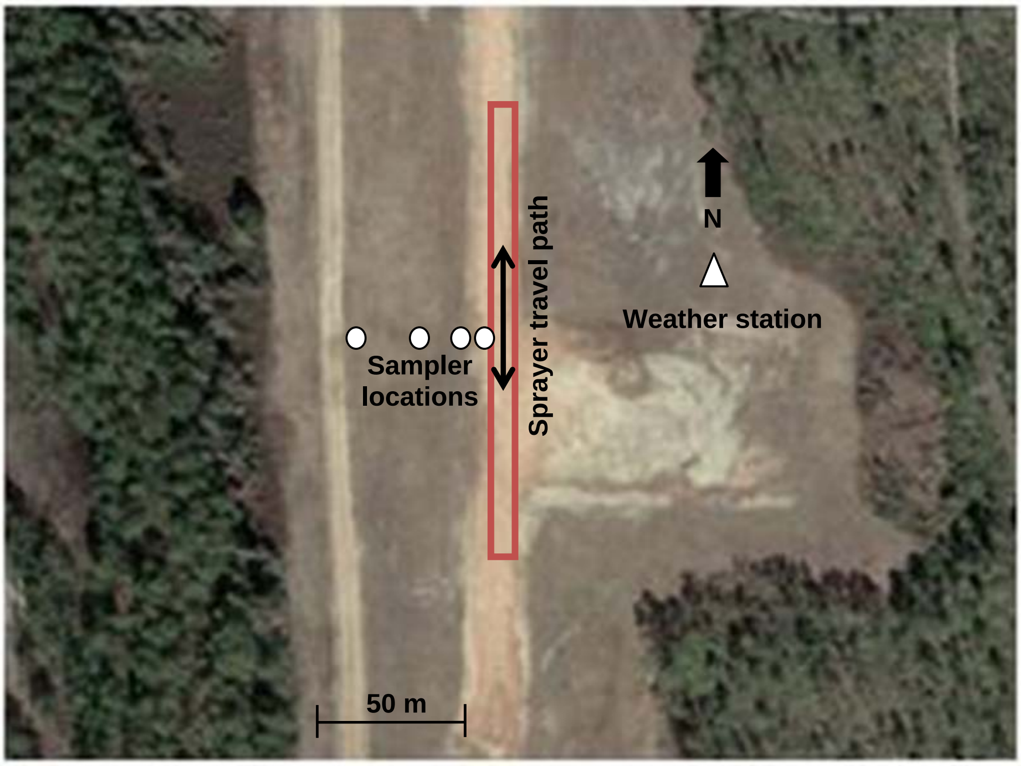

Figure 1 Aerial view of the test site at Camp Blanding Joint Training Center, Starke, FL

2.1 Droplet size characterization

A droplet sizing instrument (DC-III; KLD Labs Inc., New York, NY) was used to characterize the spectra of droplets generated by the applicators under field conditions. The measurements with the ULV applicator were made with both BVA-13® mineral oil (BVA Inc., Wixom, MI) and de-ionized (DI) water as the spray solutions. Droplet size spectra of the thermal fogger were measured using mineral oil only. The measurements were made in four replications (Table 1).

Droplet size distribution depends on the physical properties of the spray mix such as surface tension and extension viscosity (Miller and Butler Ellis, 2000; SDTF, 2001). Therefore, droplet spectra of the actual pesticide mixes may be somewhat different from those obtained with the test solutions.

Table 1 Droplet size spectra generated by the test equipment

Spray equipment	Spray solution	Flow rate /L • min^{-1}	Droplet diameter (Mean ± SD)			Relative span†
			$Dv_{0.1}$/μm	$Dv_{0.5}$/μm	$Dv_{0.9}$/μm	
ULV applicator	Mineral oil	0.2	3.0 ± 0.3	18.8 ± 1.8	33.1 ± 2.8	1.6 ± 0.1
ULV applicator	DI water	0.2	9.1 ± 5.2	36.8 ± 4.5	83.6 ± 25.8	2.0 ± 0.5
Thermal fogger	Mineral oil	0.2	4.4 ± 0.3	22.4 ± 1.3	38.8 ± 1.0	1.5 ± 0.1

Note: † Relative span = $(Dv_{0.9}-Dv_{0.1})/Dv_{0.5}$.

2.2 Spray deposition

Two fluorescent tracer dyes were used to quantify spray droplets deposited on the active and passive samplers at 6 m (A), 12 m (B), 24 m (C), and 48 m (D) downwind locations (Figure 2). The tracers were oil-soluble Yellow 131SC® (Rohm and Haas Co., Philadelphia, PA) and water-soluble Pyranine 10G® (Keystone Aniline Co., Chicago, IL). The former was dissolved in BVA-13® mineral oil at about 53 mL/L and was used as a spray mixture for testing both applicators. Pyranine 10G, dissolved in DI water at about 26 g/L, was used with the ULV applicator only. Khot, Salyani and Sweeb (2011a) have reported on the degradation characteristics of these dyes under similar application conditions. Based on preliminary tests, the prepared dye concentrations were expected to give detectable deposits on all samplers.

Within each equipment and tracer combination, the treatments were applied in a randomized block design in four replications. Each replication consisted of four spray runs on the runway. The ULV applicator was tested with the oil and water spray mixtures at three speeds. Oil sprays were applied, from late afternoon (unstable) through nighttime (stable) atmospheric conditions while the water sprays were applied during nighttime only. The fogger was tested in the afternoon.

Schematic of the test setup and locations of the active and passive samplers are shown in Figure 2. Active samplers included: 1) high volume air sampler (HVS) (model TFIA, Staplex Co., Brooklyn, NY) with 89 mm OD paper filters, 2) low volume air samplers (LVS) (model P-4000, DuPont DE Nemours and Co., Wilmington, DE) with 35-45 mm OD foam filters (Dispo Plugs Bouchons, Apico Inc., Baltimore, MN), and 3) spinning cotton ribbon (CR) samplers (model 212, John W. Hock Company, Gainesville, FL) with 25×460 mm bio-degradable white cotton ribbons (Lab Safety Supply Inc., Janesville, WI). The air intake rates of the HVS and LVS were about 0.517 and 0.003 m^3/min, respectively. Passive samplers included polypropylene green plastic cards (GC), acetate cards (AC), and water-sensitive papers (WSP). They were positioned vertically and horizontally to sample downwind droplet movement and ground deposit, respectively. Both GC and AC cards were 89 × 54 mm. They were used during oil sprays while WSP were used with water sprays. HVS, GC, and WSP samplers were positioned parallel to the sprayer path and facing spray plume while cotton ribbon samplers rotated in horizontal planes.

During each application, when spray plume appeared to have moved out of the sampling area, the targets were collected. Each target was placed in a re-sealable plastic bag and stored in a cooler. All samples of a replication were collected within about 5 min after stopping the sprayer.

2.3 Fluorometry

Fluorometric analysis was conducted with a Turner fluorometer (Model: 111, Sequoia Scientific Inc., Mountain View, CA) following the standard procedures outlined in Salyani (2000). Yellow 131SC dye solution had maximum excitation at 494 ± 5 nm and maximum emission at 535 ± 5 nm in hexane solvent (Rohm and Haas Co., Philadelphia, PA). Based on the information above and preliminary tests with hexane and ethyl alcohol as wash solutions along with filters available, an excitation (primary) filter with 365-nm cutoff and emission (secondary) filter with >535-nm were selected for fluorometric analysis. For Pyranine 10G dye deposits, fluorometry was performed with the excitation and emission filters of 365-nm and >570-nm, respectively. The samples of oil-soluble tracer deposits were washed with ethyl alcohol while those of water-soluble tracer were washed with de-ionized water. For each target, two samples of the wash solution were collected in matching cuvettes (12 × 75 mm). Each cuvette was read twice at different exposure angles to obtain four readings per sample. Before analyzing the samples, background fluorescence of each target type was determined. The background fluorescence values (mostly negligible) were used in adjusting the sample fluorescence. The fluorescence data were then normalized for wash volume and dilution factor. Based on tank samples of known concentrations, the data were expressed in μg/cm^2.

2.4 Weather data

A 3-axis sonic anemometer (Model CSAT3; Campbell Scientific, Inc., Logan, UT) was used to record wind velocity (U), wind direction (θ), and air temperature (T_a) at a rate of 4 Hz during the spray applications. The sensors were mounted at 9 m above the ground level. An infrared thermometer (model Minitemp, Raytek Corporation, Santa Cruz, CA) was used to record ground temperature (T_g). The ranges of micro-metrological parameters recorded during the field experiment are reported in Table 2.

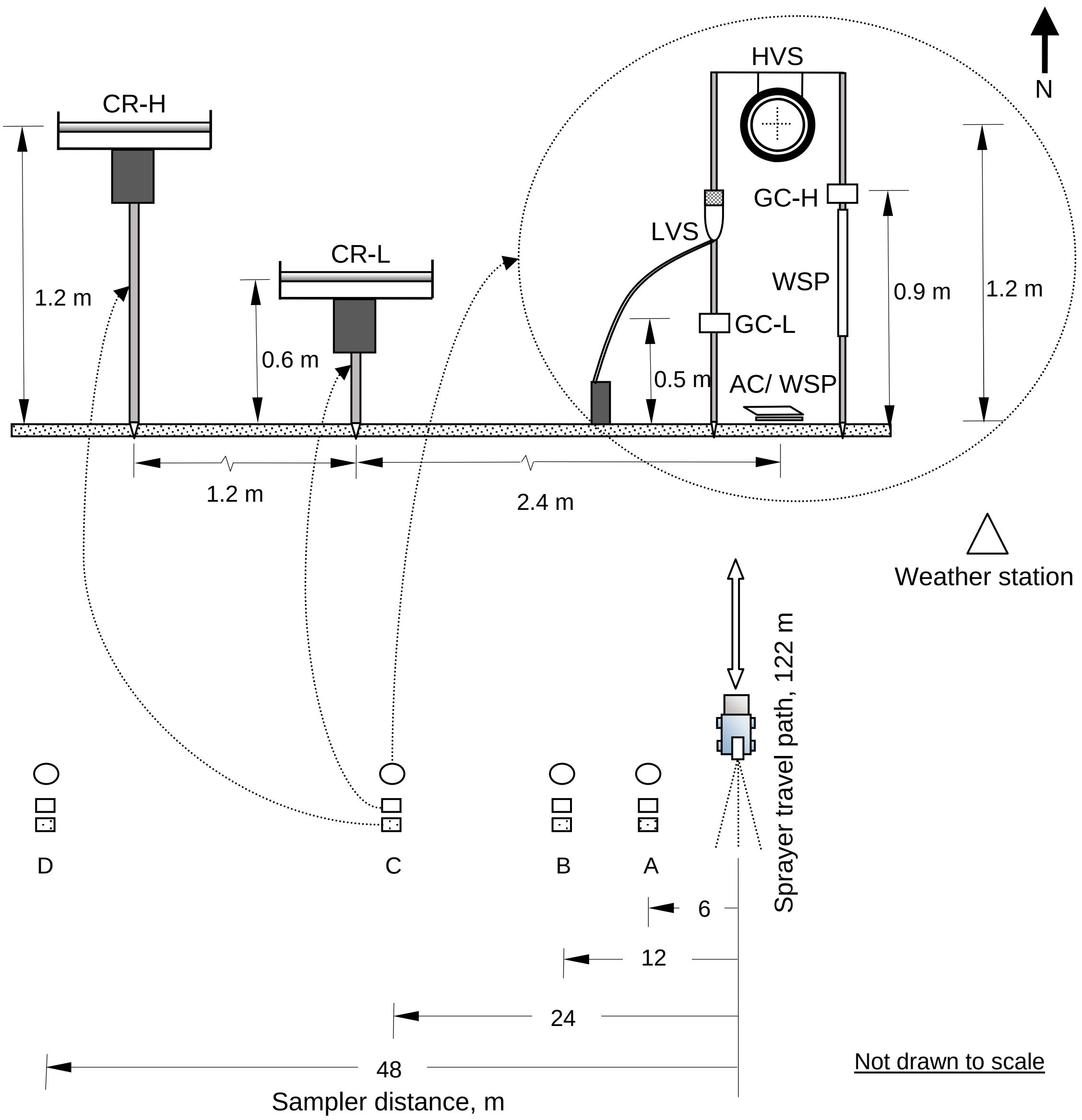

Figure 2 Schematic of the aerosol applicator and deposition sampling setup. The samplers were: high volume air sampler (HVS), low volume air sampler (LVS), spinning cotton ribbons (CR-H, CR-L), green plastic cards (GC-H, GC-L), acetate cards (AC), and water-sensitive papers (WSP).

Table 2 The ranges of metrological parameters measured during the spray applications

Spray equipment	Spray mixture	Treatment*	Wind velocity/m · $s^{-1\dagger}$	Wind direction N = 0º	T_a/℃†	T_g/℃†
ULV applicator	Mineral oil	S1	0.4-8.4 (3.0)	16-162	19-25 (21)	15-31 (21)
		S2	0.6-8.4 (3.4)	11-153	19-24 (22)	13-28 (20)
		S3	0.6-6.4 (3.0)	0-154	19-24 (21)	13-29 (20)
ULV applicator	DI water	S1	0.4-4.6 (1.6)	50-154	15-19 (17)	8-14 (10)
		S2	0.5-3.6 (1.6)	8-129	15-20 (17)	7-17 (11)
		S3	0.5-3.4 (1.7)	12-115	14-19 (17)	8-13 (11)
Thermal fogger	Mineral oil	H1	0.0-7.1 (3.1)	5-176	22-26 (23)	29-41 (34)
		H2	0.5-7.3 (3.3)	19-179	21-26 (23)	29-41 (35)

Note: *Travel speeds S1, S2, S3 = 8.5, 16.8, 24.8 km/h; Release heights H1, H2 = 0.6, 1.1 m above ground; †values in parentheses are averages.

2.5 Data analysis

For the ULV treatments, the tracer depositions on active and passive targets were normalized for sprayer travel speed (of 8.5 km/h). The low volume air sampler data were not reported here due to very low deposition at farther locations. Also, water-sensitive cards (vertical and horizontal) did not show detectable deposits at any location due to small size of impinged droplets.

The *SAS*® statistical analysis software Ver.9.2 (SAS Institute Inc., Cary, NC) was used to obtain descriptive statistics (mean and standard deviation) and perform correlation analysis (on the normalized deposit data). Pearson correlation coefficient (PCC) was obtained for tracer deposition data of all active and passive samplers. The mixed model procedure (PROC MIXED) with split/plot model (Littell et al., 1996) was used to analyze the effects of speed/ height treatments on tracer deposition at each of the fixed downwind locations. Least square mean difference (LSMEANS/PDIFF) option was used to compare the means separated by t-test at 5% level of significance. The means were plotted using SigmaPlot® Ver. 11.0 (Systat Software Inc., San Jose, CA). In reporting the PCC values, the significances of the correlations were indicated by either "*" or "**" for 5 and 1% levels, respectively.

To compare the capture efficiencies of the active and passive samplers, the ratios of their deposits were computed. Data from all aerosol treatments, i.e., ULV applications and thermal fogging treatments were combined for this computation. Also, deposits of samplers were regressed to obtain the relationship between each contrasted pair. For example, deposits of the AC sampler were plotted against deposits of the CR-H, CR-L, GC-H, GC-L, and HVS samplers to obtain the relationships between each pair.

3 Results and discussion

3.1 Effect of speed

Figure 3 displays the amount and variability of aerosol deposition on HVS filters and CR (CR-L, CR-H) targets at each sample location. Clearly, the tracer deposition on HVS filters at 6 m, and 12 m were considerably higher than those captured at farther locations. This was due to the dilution of aerosol as it dispersed farther downwind from the sprayer travel path. Normalized depositions on HVS filters were not significantly different for three speeds at any sample location; however, CR-H and CR-L samples showed significantly different deposition at 6 m location (Figure 3). There were no significant effects of speed at other locations. Figure 4 shows the deposition on the vertical (GC) and ground (AC) passive samplers. Overall, travel speed appeared to affect deposition at the near locations only.

Similar to oil spray treatments, for water spray treatments using ULV applicator, the travel speed significantly affected tracer deposition at 6 and 12 m but the effect was not significant at farther locations (Figure 5). Meteorological stability ratios, expressed as $SR = (T_a - T_g)/U^2$), ranged from -0.56 to 1.81 °C(m/s)$^{-2}$ during the ULV oil applications and from 0.70 to 7.46 °C(m/s)$^{-2}$ during water sprays. Thus, the ULV oil sprays were applied during both unstable and stable weather conditions while all ULV water sprays were discharged during stable conditions. Therefore, some variation of the tracer deposit might be attributed to variability in metrological conditions. At 6 m and 12 m locations, the air turbulence created by the sprayer travel might also have elevated the deposit variation.

Our previous study on evaluation of aerosol applicators in open field conditions revealed that the amount of aerosol per unit area fluxing downwind decreases to some extent linearly as the travel distance increases (Khot et al., 2011b). It was also reported that during daytime unstable atmospheric conditions, aerosol plume has wider spread as it travels downwind than during nighttime stable conditions. Decrease in deposition on both active and passive samplers with downwind distance agrees with such trend.

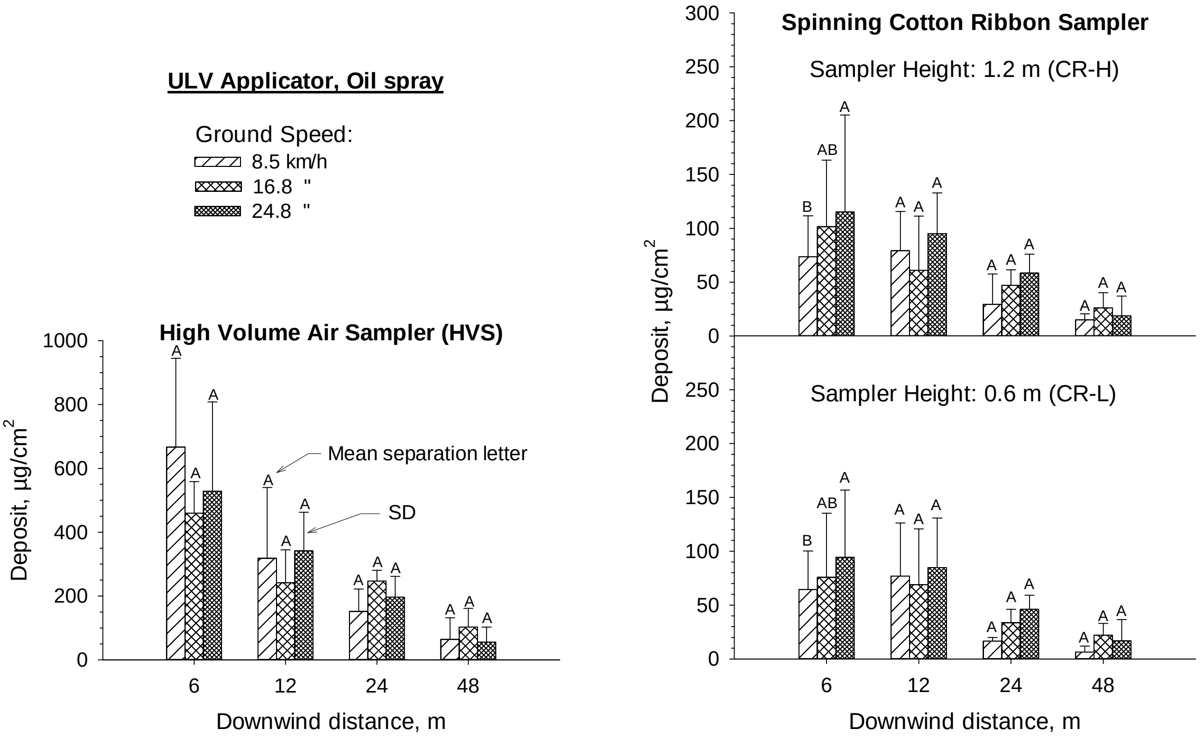

Figure 3 Oil-soluble tracer collected by high volume air samplers and spinning cotton ribbons at different travel speeds of the ULV applicator. Within each plot/downwind location, different mean separation letters indicate significant effect at the 5% level.

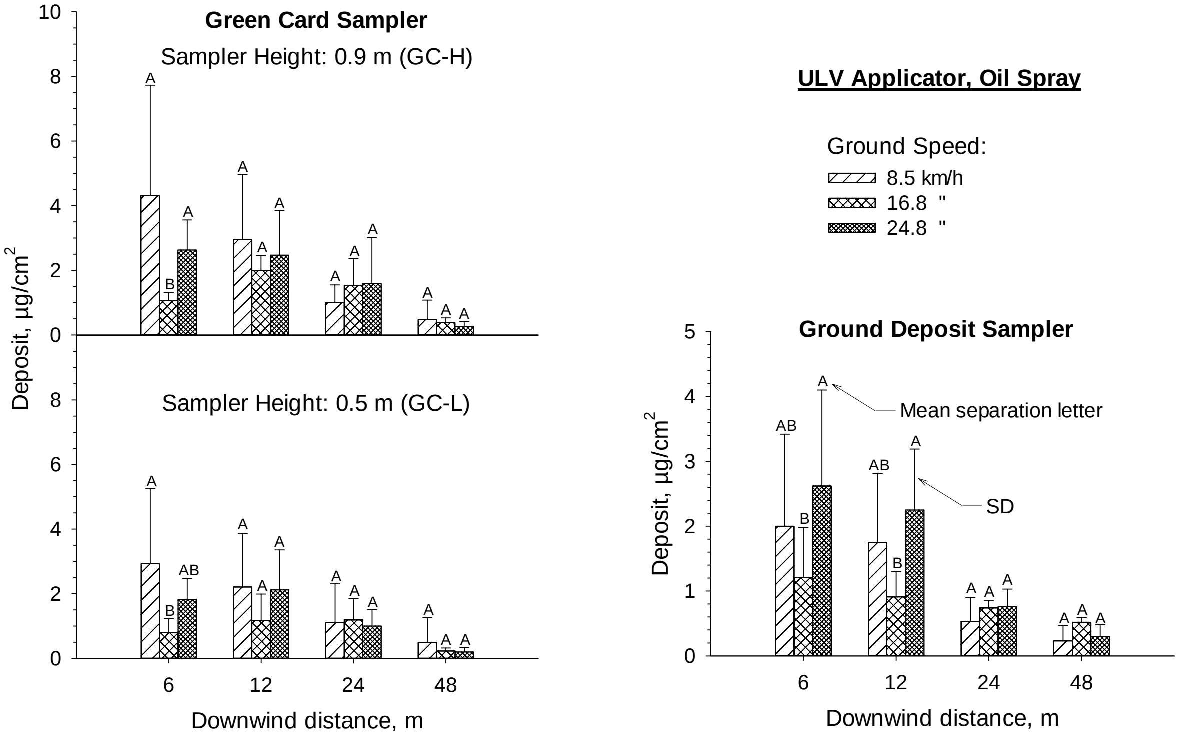

Figure 4 Oil-soluble tracer deposited on passive samplers at different travel speeds of the ULV applicator. Within each plot/downwind location, different mean separation letters indicate significant effect at the 5% level.

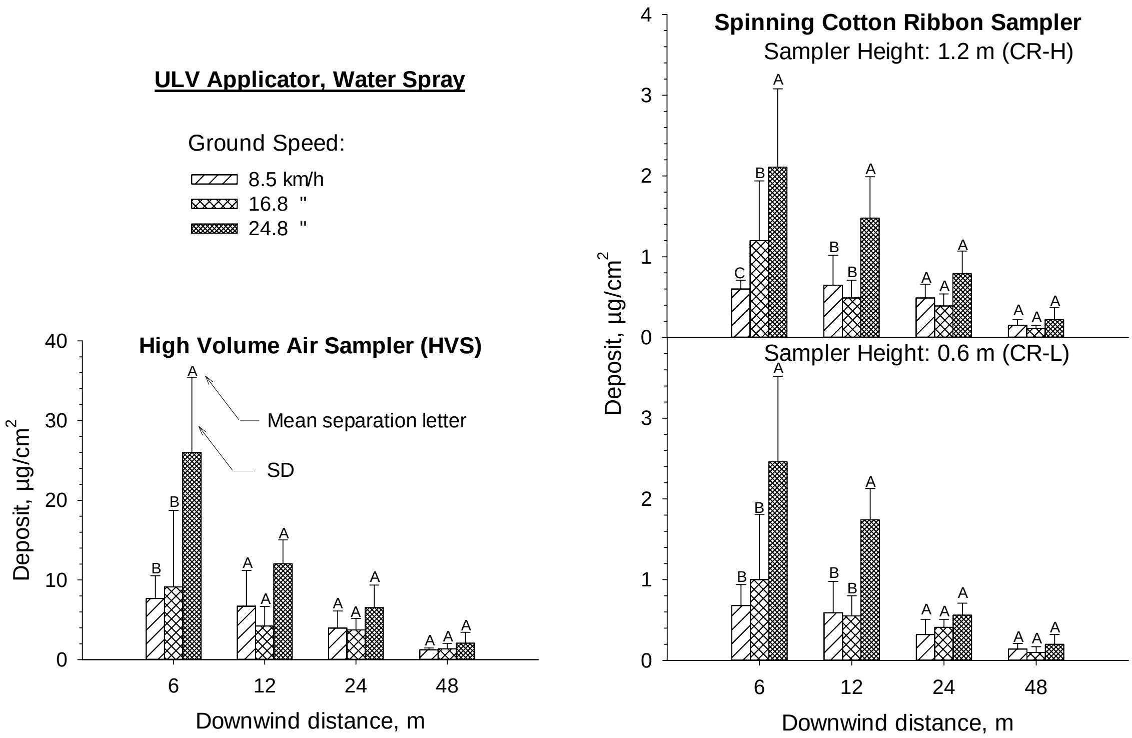

Figure 5 Water-soluble tracer collected by high volume air samplers and spinning cotton ribbons at different travel speeds of the ULV applicator. Within each plot/downwind location, different mean separation letters indicate significant effect at the 5% level.

3.2 Effect of release height

Figure 6 and Figure 7 respectively show aerosol deposition on active and passive samplers during thermal fogging treatments. Spray release height did not affect active sampler deposition at each of the sampler location but had significant effect on passive samplers' deposition at 6-m location. Overall, the higher release height resulted in more deposition at most downwind locations. During thermal fogger application treatments, weather was unstable (*SR*: -1.16 to -1.60 ℃$(m/s)^{-2}$) with average wind speed of about 3.2 m/s. Thus, air turbulence might have had a more pronounced effect on aerosol dispersion and dilution resulting in higher variation among the replicates. The lesser depositions from the lower fog release height may be attributed to the stronger thermal lift near the ground level that has resulted in relatively quicker plume lift during unstable conditions. Also, lower wind speeds close to the ground could have resulted in slower plume movement along the sampling lines.

Unstable atmospheric conditions during the fogging could have resulted in higher vertical mixing and more dilution of the aerosol as it traveled downwind. This effect might not have been as pronounced during some of the ULV oil sprays that were discharged in relatively stable weather conditions.

3.3 Relationship between samplers

During ULV oil spray application treatments, the HVS filters collected considerably higher amounts of tracer material than CR samplers. However, correlation analysis showed good correlations between depositions on HVS filters and cotton ribbons at the low (CR-L) and high sampling heights (CR-H). The respective PCCs were 0.69^{**} and 0.70^{**}. Depositions on green cards at low and high sampling heights (GC-L and GC-H) were strongly correlated with each other (PCC = 0.91^{**}) and moderately to the ground deposit (PCC of 0.45^{**} and 0.41^{**}, respectively). Ground

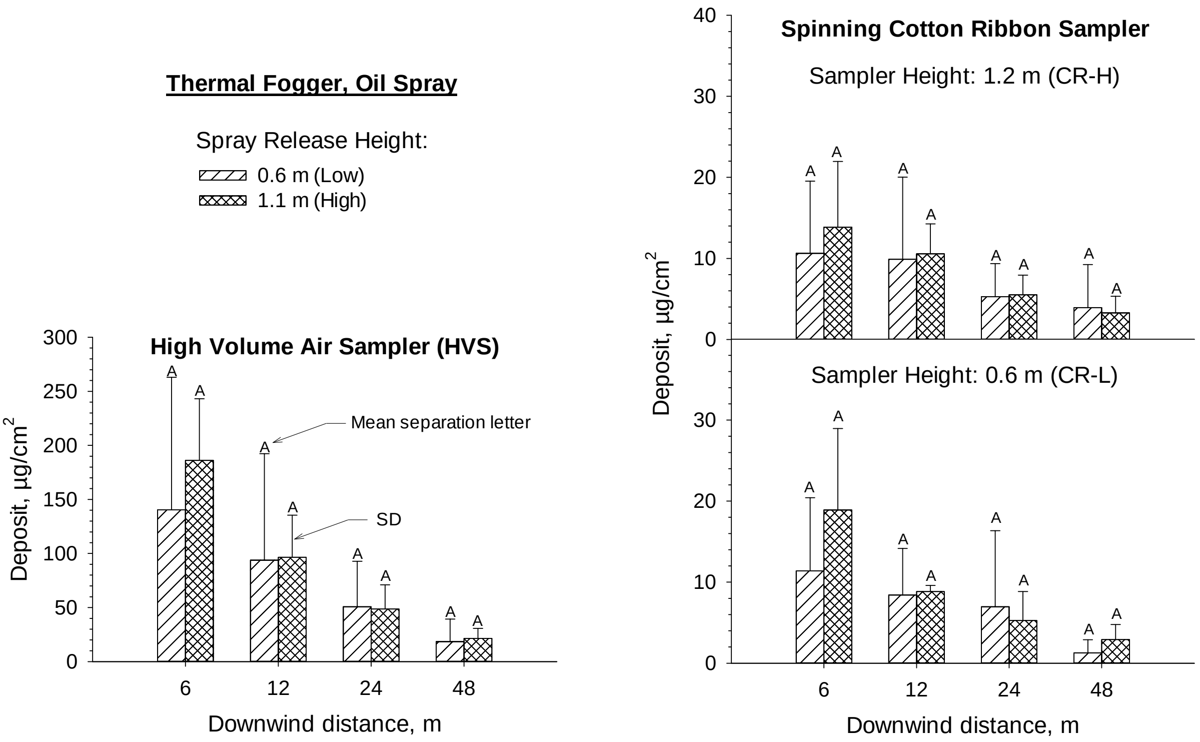

Figure 6 Oil-soluble tracer collected by high volume air samplers and spinning cotton ribbons at two release heights of the thermal fogger. Within each plot/downwind location, different mean separation letters indicate significant effect at the 5% level.

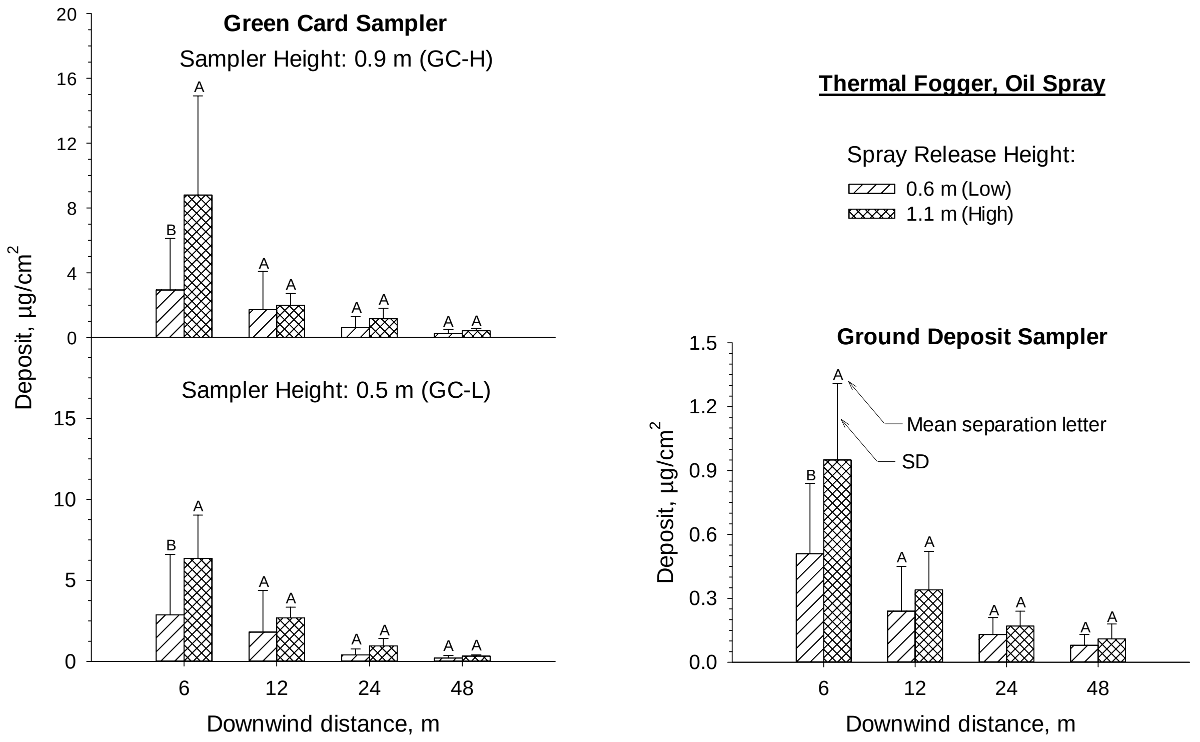

Figure 7 Oil-soluble tracer deposited on passive samplers at two release heights of the thermal fogger. Within each plot/downwind location, different mean separation letters indicate significant effect at the 5% level.

deposition was also strongly correlated with depositions on cotton ribbons (PCC = 0.78**) and HVS filters (PCC = 0.72**). Similar to ULV oil spray treatments, depositions of HVS and CR for ULV water spray treatments were also strongly correlated (PCC = 0.93**). For hand-held thermal fogger treatments, depositions on active samplers (HVS and CR) showed good correlation with each other (PCC = 0.72**); however, the latter was moderately correlated with green card deposits (PCC = 0.49** – 0.62**).

The high volume air samplers, spinning cotton ribbons, and green/acetate cards were effective in sampling of aerosol plume dispersion under open field conditions. Though the active samplers captured considerably higher tracer deposit compared to the passive samplers; overall, correlation between various samplers was moderate to strong. Therefore, capture efficiencies of studied samplers and their relationships among each other were examined in this study (Table 3 and Table 4). These regression relationships between the samplers (Table 4) can be helpful in converting and comparing the depositions from various samplers. These tables can also assist researchers in deciding upon which sampling technique best suits for their field studies.

Table 3 Ratios of the captured deposits (mean (CV, %)) among aerosol samplers (row/column).

Samplers*	AC	CR-H	CR-L	GC-H	GC-L	HVS
AC	1	0.02 (29)	0.03 (33)	0.61 (52)	0.78 (53)	0.01 (21)
CR-H	44.34 (27)	1	1.13 (12)	28.71 (66)	37.00 (66)	0.19 (22)
CR-L	37.18 (32)	0.90 (11)	1	21.41 (63)	26.71 (69)	0.17 (19)
GC-H	2.12 (51)	0.05 (65)	0.071 (63)	1	1.30 (15)	0.01 (43)
GC-L	1.74 (57)	0.04 (68)	0.063 (75)	0.79 (16)	1	0.01 (50)
HVS	259.40 (19)	5.41 (22)	6.011 (19)	121.33 (47)	150.05 (45)	1

Note: * Samplers: AC - acetate card (ground deposit), CR-L & CR-H - cotton ribbon samplers at 0.6 and 1.2 m above ground, GC-L & GC-H – vertical green card samplers at 0.5 and 0.9 m above ground, HVS - high volume sampler at 1.2 m above ground.

Table 4 Relationships among pairs of deposit samplers (row/column)

Samplers*	AC	CR-H	CR-L	GC-H	GC-L	HVS
AC	1	$Y = 0.02X$, ($R^2 = 0.89$)	$Y = 0.03X$, ($R^2 = 0.89$)	$Y = 0.45X$, ($R^2 = 0.53$)	$Y = 0.57X$, ($R^2 = 0.58$)	$Y = 0.01X$, ($R^2 = 0.90$)
CR-H	$Y = 44.23X$, ($R^2 = 0.89$)	1	$Y = 1.12X$, ($R^2 = 0.99$)	$Y = 17.15X$, ($R^2 = 0.22$)	$Y = 23.03X$, ($R^2 = 0.29$)	$Y = 0.19X$, ($R^2 = 0.97$)
CR-L	$Y = 37.24X$, ($R^2 = 0.89$)	$Y = 0.88X$, ($R^2 = 0.99$)	1	$Y = 14.03X$, ($R^2 = 0.37$)	$Y = 18.37X$, ($R^2 = 0.35$)	$Y = 0.16X$, ($R^2 = 0.98$)
GC-H	$Y = 1.75X$, ($R^2 = 0.54$)	$Y = 0.03X$, ($R^2 = 0.23$)	$Y = 0.05X$, ($R^2 = 0.33$)	1	$Y = 1.34X$, ($R^2 = 0.98$)	$Y = 0.01X$, ($R^2 = 0.79$)
GC-L	$Y = 1.38X$, ($R^2 = 0.60$)	$Y = 0.03X$, ($R^2 = 0.28$)	$Y = 0.03X$, ($R^2 = 0.27$)	$Y = 0.74X$, ($R^2 = 0.98$)	1	$Y = 0.01X$, ($R^2 = 0.70$)
HVS	$Y = 234.78X$, ($R^2 = 0.90$)	$Y = 5.08X$, ($R^2 = 0.97$)	$Y = 6.07X$, ($R^2 = 0.98$)	$Y = 82.87X$, ($R^2 = 0.75$)	$Y = 114.79X$, ($R^2 = 0.67$)	1

Note: * Samplers: AC - acetate card (ground deposit), CR-L & CR-H - cotton ribbon samplers at 0.6 and 1.2 m above ground, GC-L & GC-H – vertical green card samplers at 0.5 and 0.9 m above ground, HVS - high volume sampler at 1.2 m above ground.

4 Conclusions

For both the ULV applicator and thermal fogger, tracer deposition on active and passive samplers decreased with downwind sampling distances. Overall, the effect of travel speed was only significant at the near locations. Thermal fog release height did not affect active sampler deposition but had a significant effect on passive samplers at 6-m ocation only. Overall, the higher release height (1.1-m) resulted in more deposition in most downwind locations compared to 0.6-m release height.

Depositions on active samplers were considerably higher than those on passive targets. Highest deposits were captured by the high volume air samplers while the lowest amounts were collected by ground targets. Overall, there were good correlations between depositions on active and passive samplers. Thus, presented relationships between various sampler deposits can be helpful for future studies while selecting samplers for field studies and understanding the capture efficiencies of the samplers used.

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References

Alexander, B., and M. Maroli. 2003. Control of phlebotomine sandflies. *Med Vet Entomol*, 17(1): 1-18.

Bjugstad, N., and P. Hermansen. 2009. Field measurements of spray drift in strawberry. *Agricultural Engineering International: the CIGR Ejournal*, Manuscript PM 1048. Vol. XI: 1-13.

Bonds (Barber), J. A. S., M. J. Greer, B. K. Fritz, and W. C. Hoffmann. 2009. Aerosol sampling: Comparison of two rotating impactors for field droplet sizing and volumetric measurements. *J Am Mosq Control Assoc,* 25(4): 474-479.

Britch, S. C., K. J. Linthicum, W. W. Wynn, T. W. Walker, M. Farooq, V. L. Smith, C. A. Robinson, B. B. Lothrop, M. Snelling, A. Gutierrez, H. D. Lothrop, J. D. Kerce, J. J. Becnel, U. R. Bernier, and J. W. Pridgeon. 2010. Evaluation of ULV and thermal fog mosquito control applications in temperate and desert environments. *J Am Mosq Control Assoc,* 26(2): 183-197.

Bui, Q. D., A. R. Womac, K. D. Howard, J. E. Mulrooney, and M. K. Amin. 1998. Evaluation of samplers for spray drift. *Trans ASAE*, 41(1): 37-41.

Chaniotis, B. N., R. E. Parsons, H. J. Harlan, and M. A. Correa. 1982. A pilot study to control phlebotomine sand flies (diptera: psychodidae) in a neotropical rain forest. *J Med Entomol*, 19(1): 1-5.

Cooper, J. F., D. N. Smith, and H. M. Dobson. 1996. An evaluation of two field samplers for monitoring spray drift. *Crop Prot*, 15(3): 249-257.

Desjeux, P. 2001. The increase in risk factors for leishmaniasis worldwide. *Tran Roy Soc Tropical Med Hyg*, 95(3): 239-243.

Farooq, M., W. C. Hoffmann, T. W. Walker, V. L. Smith, C. A. Robinson, J. C. Dunford, and I. W. Sutherland. 2009. Samplers for evaluation and quantification of ultra-low-volume space sprays. *J Am Mosq Control Assoc*, 25(4): 521-524.

Hayward, S. J., T. Gouin, and F. Wania. 2010. Comparison of four active and passive sampling techniques for pesticides in Air. *Environ Sci Technol*, 44(9): 3410-3416.

Jaward, F. M., N. J. Farrar, T. Harner, A. J. Sweetman, and K. C. Jones. 2004. Passive air sampling of PCBs, PBDEs, and organochlorine pesticides across Europe. *Environ Sci Technol*, 38(1): 34-41.

Khot, L. R., M. Salyani, and R. D. Sweeb. 2011a. Solar and storage degradations of oil and water soluble fluorescent dyes. *App Eng Agric*, 27 (2): 211-216.

Khot, L. R., D. R. Miller, A. L. Hiscox, M. Salyani, T. W. Walker, and M. Farooq. 2011b. Extrapolation of droplet catch measurements in aerosol application treatments. *Atomization and Sprays*, 21 (2): 149-158.

Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfiger. 1996. SAS systems for mixed models. Cary, NC: SAS Institute, Inc.

Miller, P. C. H., and M. C. Butler Ellis. 2000. Effects of formulation on spray nozzle performance for applications from ground-based boom sprayers. *Crop Prot*, 19: 609-615.

Mount, G. A. 1998. A critical review of ultralow-volume aerosols of insecticide applied with vehicle-mounted generators for adult mosquito control. *J Am Mosq Control Assoc,* 14(3):305-34.

Pant, C. P., H. L. Mathis, M. J. Nelson, and B. Phanthumachinda. 1974. A large-scale field trial of ultra-low-volume fenitrothion applied by a portable mist blower for the control of Aedes aegypti. *Bull World Health Organ*, 51(4): 409-415.

Salyani, M. 2000. Methodologies for assessment of spray deposition in orchard applications, Paper No. 001031, St. Joseph, Mich.: ASAE.

Salyani, M., and J. D. Whitney. 1991. Effect of oscillators on deposition characteristics of an airblast sprayer. *Trans ASAE*, 34: 1618-1622.

Salyani, M., and R. P. Cromwell. 1992. Spray drift from ground and aerial applications. *Trans ASAE*, 35: 1113-1120.

Salyani, M., and W. C. Hoffmann. 1996. Air and spray distribution from an air-carrier sprayer. *App Eng Agric*, 12: 539-545.

SDTF. 2001. A summary of tank mix and nozzle effects on droplet size [Internet]. Available from Spray Drift Task Force. http://www.agdrift.com/PDF_FILES/Tankmix.pdf

Sirak-wizeman, M., R. Faiman, A. Al-jawabreh, and A. Warburg. 2008. Control of phlebotomine sandflies in confined spaces using diffusible repellents and insecticides. *Med Vet Entomol,* 22: 405-412.

Tietze, N. S., P. G. Hester, and K. R. Shaffer. 1994. Mass recovery of malathion in simulated open field mosquito adulticide tests. *Arch Environ Contam Toxicol*, 26: 473-477.

USACHPPM Technical. 2005. Diagnosis and treatment of diseases of tactical importance to U.S. central command [Internet]. Available from U.S. Army Center for Health Promotion and Preventive Medicine. http://handle.dtic.mil/100.2/ADA457189.