EFFECTS OF PRESSURE AND FLOW RATE ON CYTHION® DROPLET SIZE PRODUCED BY THREE DIFFERENT GROUND ULV AEROSOL GENERATORS

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ABSTRACT. A study to determine the effects of machine pressure and insecticide flow rate on the size of aerosol droplets as they relate to the Cythion® label was conducted with 3 different ground ULV aerosol generators. An increase in flow rate required a corresponding increase in blower pressure to maintain the labeled droplet mass median diameter of 17 μm or less. Droplets larger than 48 μm were frequently sampled at machine pressures less than 6 psi (41.4 kPa). At the highest labeled flow rate of 8.6 fl oz/min (254.3 ml/min), machine pressures of 7–8 psi (48.3–55.2 kPa) were required for each of the 3 aerosol generators tested to consistently conform to the droplet criteria of the Cythion label.

INTRODUCTION

During the late 1970s, mosquito control districts throughout the United States became concerned that the maximum vehicle speed of 10 mph (16 kmph) on the Cythion® label for applying ultra low volume (ULV) malathion by ground equipment severely limited the area that could be treated during critical time periods. Supplemental Cythion labels were issued to the states of Georgia in 1978, South Carolina in 1979 and Florida in 1981 permitting ULV application rates up to 8.6 fl oz/min (254 ml/min) at a maximum vehicle speed of 20 mph (32.2 kmph). By 1983, the national Cythion label for malathion ULV concentrate incorporated the higher vehicle speed and flow rate. In all cases, including the supplemental labels, special emphasis was placed on maintenance of specified droplet size at the increased dosage.

In 1987, changes in Florida Statutes, Chapter 388, and Chapter 10D-54 of the Florida Administrative Code regulating mosquito control required that operational records on kinds, amounts, uses, dates and places of application of restricted use pesticides be maintained for at least 2 years. Pesticides used for mosquito control in Florida are not labeled for restricted use by the Environmental Protection Agency (EPA). However, changes in these regulations have regenerated an emphasis throughout the state on monitoring and maintaining insecticide particle size within the requirements of respective labels approved by the EPA.

Most truck-mounted cold aerosol generators used for applying ULV insecticides for adult mosquito control are also equipped with variable flow control systems. These systems, when properly calibrated, automatically adjust to dispense the proper amount of insecticide depending upon vehicle speed. To check flow rate or collect droplets at particular speeds, the vehicle must be moving forward or be on a lift so that the transmission or speedometer is operative. Of particular concern are those units having a "calibrate mode" which delivers the flow rate for a particular speed, usually 10 mph (16 kmph), when the vehicle is in a static position. Due to the ease and simplicity of operation in the calibrate mode, most droplet samples have been taken at the labeled flow rate for a vehicle speed of 10 mph (16 kmph). While conforming to all labeled droplet specifications at the 4.3 fl oz/min (127 ml/min) flow rate, the aerosol generator could easily fail to meet labeled criteria at higher flow rates unless machine pressure was increased.

The influence of operating pressure on droplet volume median diameter (VMD) at flow rates of 4 fl oz/min (118.3 ml/min) or less is well documented by Mount and Pierce (1972), Mount et al. (1975), Peterson et al. (1976) and Haile et al. (1982). The following research was conducted to demonstrate the critical interaction between pressure and insecticide flow rate on particle size particularly as it relates to the EPA approved Cythion label at flow rates up to 8.6 fl oz/min (254 ml/min).

MATERIALS AND METHODS

Three different truck mounted cold aerosol generators were used to produce malathion droplets during the study. The first was a Leco HD ULV cold aerosol generator (Lowndes Engineering Co., Valdosta, GA) equipped with a 16 h.p. Wisconsin engine and a belt driven blower capable of producing a maximum pressure of 8 psi (55 kPa). The second was an experimental nozzle assembly designed by Lowndes Engineering Co., using 2 smaller Leco MD ULV nozzles mounted in a "T" assembly and constructed in such a manner that the unit replaced the single nozzle on the 16 h.p. Leco HD ULV generator. The same engine and blower fitted with the double head Leco nozzles produced a maximum pressure of 7 psi (48 kPa). The third aerosol generator was a 4-nozzle Curtis Dyna-Fog™ Cyclotronic ULV (Curtis Dyna-Products Corp., Westfield, IN) equipped with a direct drive blower powered by an 18 h.p. Honda engine. This assembly is currently marketed on their Maxi-Pro 4™ ULV which produces 8-psi (55-kPa) maximum pressure at the nozzle.

The insecticide delivery system was a FMI pump (Fluid Metering, Inc., Oyster Bay, NY) equipped with a digital rheostat to control pump motor speed. The insecticide volume delivered by the FMI valveless pump is not affected by fluid viscosity or temperature. The digital readout on the motor rheostat made it possible to quickly change flow rates with ease and accuracy and remain independent of pressure generated by the ULV aerosol generators. The same pump system and rheostat settings were used during the study on each of the 3 ULV generators described earlier.

Each aerosol generator was equipped with a pressure gauge which had been calibrated using a test gauge accurate to 0.1 psi (0.7 kPa). Engine speed was adjusted during operation to achieve the desired pressure, usually 3–4 psi (21–28 kPa), for atomizing insecticide droplets. During each replicate, the insecticide flow rate was set for the maximum labeled rate of 4.3, 6.5 or 8.6 fl. oz./min (127, 192 or 254 ml/min) for the 10, 15 or 20 mph (16, 24 or 32 kmph) vehicle speed, respectively. The pressure was then increased to the maximum for that engine in 1 psi (7 kPa) increments to determine the influence of pressure on atomization.

Aerosol droplets of technical malathion were collected and measured using the procedures described in "Modern Mosquito Control" (Anonymous 1986). Dupont Teflon® coated microscope slides (Anderson and Schulte 1971) were used to collect impinged droplets 25 ft (7.6 m) downwind of the stationary aerosol generator. Prior to use, the oleophobic characteristic of the Teflon coated slides was checked to verify a malathion spread factor of 0.69 using methods described by Rathburn (1970). Droplets were collected on 2 different slides at each flow rate and pressure using the diagonal hand wave method (Benzon 1988). A minimum of 3 replicates were taken at each flow rate and pressure with each replicate being taken on a different day. At least 200 droplets from each slide were counted using a compound microscope at a magnification of 200× and the data analyzed using the computer program "DROP"® developed by Athena Systems, Inc., Newtown Square, PA.

RESULTS AND DISCUSSION

The effects of pressure and flow rate on droplet size as they relate to the Cythion label requirements are shown in Tables 1–3. In general, for each aerosol generator tested an increase in pressure at each of the 3 flow rates (4.3, 6.5 and 8.6 fl oz/min) improved the malathion droplet spectra in relationship to the requirements of the current national label. Increasing the mala-

Table 1. Effects of air pressure and flow rate on Cythion droplet size using a Leco Model HD ULV aerosol generator.

			Cythion label droplet specifications*					
Flow Rate fl oz/m	No. of reps.	Air Pressure (psi)	Mean VMD μm	Mean % <24 μm	Mean % 6–18 μm	Mean % >32 μm	Mean % >48 μm	Percent of reps. passed
4.3	3	3	20.8	79.3	58.5	6.5	0.3	0
	3	4	17.5	87.8	69.7	2.8	0.0	33
	3	5	16.3	92.5	75.5	1.5	0.2	67
	3	6	14.2	97.2	85.3	0.0	0.0	100
	3	7	13.0	97.0	84.5	0.3	0.0	100
	3	8	11.5	99.7	86.7	0.0	0.0	100
6.5	3	4	19.6	82.2	65.3	6.3	0.2	0
	3	5	17.5	89.5	72.5	2.3	0.2	33
	3	6	14.7	95.9	82.9	0.5	0.0	100
	3	7	14.0	95.6	84.1	0.2	0.0	100
	3	8	12.5	98.7	89.9	0.0	0.0	100
8.6	3	3	23.5	72.5	60.0	16.2	2.7	0
	3	4	16.1	86.2	75.2	3.5	0.5	33
	3	5	18.0	86.7	69.2	4.3	0.7	0
	3	6	15.9	94.7	78.7	0.8	0.0	100
	3	7	15.7	93.8	78.1	1.2	0.0	100
	5	8	16.2	93.8	78.9	0.4	0.0	100
* Label requirements			17 or <	>67%	>50%	<3%	0.0	

Table 2. Effects of air pressure and flow rate on Cythion droplet size using a Leco Model HD ULV aerosol generator modified with a pair of Leco MD ULV nozzles.

			Cythion label droplet specifications*					
Flow Rate fl oz/m	No. of reps.	Air Pressure (psi)	Mean VMD μm	Mean % <24 μm	Mean % 6–18 μm	Mean % >32 μm	Mean % >48 μm	Percent of reps. passed
4.3	3	3	19.3	81.6	68.1	7.0	0.3	0
	3	4	16.4	91.4	76.9	2.3	0.2	33
	3	5	14.6	94.0	74.0	1.3	0.0	100
	3	6	14.9	95.5	80.0	1.0	0.0	100
	3	7	12.6	97.8	79.8	0.0	0.0	100
6.5	3	3	21.4	77.6	63.7	10.4	1.5	0
	3	4	17.7	86.6	68.6	3.8	0.2	33
	3	5	18.1	86.8	66.8	3.0	0.0	33
	3	6	15.2	91.2	76.8	1.7	0.2	67
	3	7	12.9	96.3	76.6	0.2	0.0	100
8.6	3	3	23.0	72.5	58.7	14.7	3.2	0
	3	4	19.6	79.9	65.7	8.5	1.2	0
	3	5	17.5	84.9	71.0	6.0	0.5	0
	3	6	16.7	88.0	74.3	3.3	0.2	66
	3	7	15.9	90.8	78.8	1.8	0.0	100
* Label requirements			17 or <	>67%	>50%	<3%	0.0	

Table 3. Effects of air pressure and flow rate on Cythion droplet size using a Dynafog Cyclotronic ULV aerosol generator.

			Cythion label droplet specifications*					
Flow Rate fl oz/m	No. of reps.	Air Pressure (psi)	Mean VMD μm	Mean % <24 μm	Mean % 6–18 μm	Mean % >32 μm	Mean % >48 μm	Percent of reps. passed
4.3	3	3	20.2	79.7	64.5	8.8	1.0	0
	3	4	17.8	85.8	74.3	6.7	1.7	0
	3	5	15.5	92.5	76.3	1.7	0.2	66
	3	6	12.8	96.2	83.0	1.2	0.0	66
	3	7	11.4	99.2	92.8	0.0	0.0	100
	3	8	10.3	99.8	88.5	0.0	0.0	100
6.5	3	4	19.6	82.8	62.7	6.5	0.8	0
	3	5	18.1	86.0	70.7	5.5	1.2	0
	3	6	17.2	90.2	72.4	2.2	0.7	33
	3	7	13.9	97.3	88.5	0.2	0.0	100
	3	8	14.0	97.8	87.8	0.2	0.0	100
8.6	3	3	21.1	78.8	62.4	10.5	2.5	0
	3	4	19.3	80.6	68.1	8.8	1.8	0
	3	5	19.6	81.3	63.2	8.0	0.8	0
	6	6	15.7	91.8	82.2	2.6	0.0	83
	3	7	14.2	94.8	85.7	1.0	0.0	100
	3	8	16.4	95.7	74.7	0.2	0.0	100
* Label requirements			17 or <	>67%	>50%	<3%	0.0	

thion flow rate with pressure remaining constant reduced droplet size. However, the negative effects brought about by increasing volume were more prominent at lower operating pressures and resulted in failure of the 3 aerosol generators to meet labeled requirements at pressures of 5 psi (35 kPa) or less. The Leco HD with the standard single nozzle operating at 6–8 psi (41–55 kPa) consistently met label droplet requirements for flow rates at vehicle speeds of 15–20 mph (24–32 kmph) Table 1. With the other generators, 7 psi (48 kPa) or greater was necessary to repeatedly conform to label requirements at the higher flow rate.

The stated concern of American Cyanamid Co. (Anonymous 1986) relative to droplet size is the ability of larger droplets of technical malathion to damage automotive paint surfaces. Table 4 shows the mean diameter, corrected using the spread factor for Teflon, and range in

Table 4. Mean diameter[a] of the largest droplet of Cythion® at 8.6 fl oz/min flow rate and the indicated pressure with 3 ground ULV aerosol generators.

Air Pressure (psi)	Leco[b]		Leco 2[c]		Dynafog[d]	
	Mean	Range	Mean	Range	Mean	Range
3	80	72–88	66	56–74	66	60–72
4	53	42–65	67	58–72	65	56–72
5	52	49–53	46	37–53	53	49–63
6	35	33–37	44	35–56	43	39–49
7	41	35–46	37	35–39	37	35–39
8	34	30–38	—	—	33	30–37

[a] Corrected diameter in microns.
[b] Leco Model HD ULV.
[c] Leco Model HD ULV modified with 2 Model MD ULV nozzles.
[d] Dynafog Cyclotronic ULV.

microns of the largest droplet recorded in each series of replications from 3 to 8 psi (21–55 kPa) at the maximum labeled flow rate of 8.6 fl oz/min (254 ml/min) for each of the 3 aerosol generators. The production of any droplet greater than 48 μm is a violation of labeled requirements. The data clearly indicated that at machine pressures of 5 psi (34 kPa) for the standard Leco and 6 psi (41 kPa) or less for the other 2 machines, droplets greater than 48 μm were frequently sampled and the 3 machines used in this study did not conform to the Cythion label.

In summary, these data show the direct interaction of insecticide flow rate and machine pressure in the production of malathion droplets from ground ULV aerosol generators used for mosquito adulticiding. To maintain droplet spectra, an increase in flow rate must be accompanied by a corresponding increase in pressure. Mosquito control districts using variable flow equipment should be especially aware that although a particular aerosol generator conformed to all labeled droplet requirements at a particular application rate (usually 4.3 fl oz/min (127 ml/min) or less in the stationary or calibrate mode), compliance to labeled droplet requirements may be inadequate at flow rates up to 8.6 fl oz/min at 20 mph (254 ml/min at 32 kmph). Data on droplet spectra should be collected and maintained at the maximum flow rate applied by each aerosol generator. Conformance to labeled requirements at the maximum flow rate minimizes the probability of producing larger droplets that damage automotive paint surfaces as the flow rate and vehicle speed decreases.

The optimum malathion droplet size diameter for adult mosquito control ranges from 5 to 15 μm (Mount 1970, Mount and Pierce 1972, Lofgren et al. 1973) with a range of sizes from 5 to 25 μm where insecticidal efficiency changes only slightly (Haile et al. 1982). The data shown in Tables 1 and 3 indicate that approximately 95% of the malathion droplets sampled with the 2 commercially available aerosol generators were within the optimum efficiency range for adult mosquito control at operating pressures of 7–8 psi (48–55 kPa) and flow rates of 8.6 fl oz/min (254 ml/min). These data also show that aerosol generators equipped with variable flow equipment and operating at higher blower pressures produce a greater percentage of malathion droplets within the the lower range of the reported optimum size for mosquito control when the flow rate is reduced.

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