AERIALLY APPLIED, LIQUID *BACILLUS THURINGIENSIS* VAR. *ISRAELENSIS* (H-14) FOR CONTROL OF SPRING *AEDES* MOSQUITOES IN MICHIGAN

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ABSTRACT. Liquid *B.t.i.* (Vectobac® 12AS), when mixed with water at a 1:3 ratio and applied by helicopter at a rate of 1.17 liters *B.t.i.* (4.68 liters mix) per ha, was 99% effective in a small (mass median diameter on dye cards: 178 μm) droplet size but ineffective (65%) in a large (553 μm) droplet against spring *Aedes* larvae in snowmelt pools. There were about 6 times as many smaller droplets as larger ones impacting the treated pools, which probably explained the difference in effectiveness of the 2 treatment regimes. Results indicate that liquid formulations of *B.t.i.* could be aerially applied for spring *Aedes* control at a considerable cost savings and efficiency over aerially applied, granular formulations.

Spring *Aedes* mosquitoes such as *Aedes stimulans* (Walker), *Ae. fitchii* (Felt and Young), Ae. *intrudens* Dyar, *Ae. sticticus* (Meigen), *Ae. provocans* (Walker), *Ae. implicatus* Vockeroth and *Ae. canadensis* (Theobald) comprise an important group of pest mosquitoes in Saginaw County, MI (R. G. Knepper, unpublished data). Typically, larvae of these single generation species hatch in late March in seasonally flooded woodland pools formed by melting snow and spring rainfall. Adults emerge in early May in large numbers and some persist throughout the summer.

The Saginaw County Mosquito Abatement Commission (SCMAC), located in the east-central lower peninsula of Michigan, annually treats 10,000 ha of spring pools through aerial application (helicopter) using a granular formulation (5–8 mesh corncob) of *Bacillus thuringiensis* var. *israelensis* (H-14) (*B.t.i.*) at a rate of 5.6 kg/ha. This application is conducted during a 1-wk period in April to control larvae and is highly effective (Knepper and Walker 1989, Fanara et al. 1984) but requires extensive logistical arrangements for refilling the helicopter payloads with the bulky granules. Aerially applied liquid formulations of *B.t.i.* may offer several advantages over granular formulations, such as: greater number of treated ha per sortie, requiring fewer landings and takeoffs; cost savings per ha; and increased safety and efficiency in refilling the helicopter payload.

Aerially applied, liquid *B.t.i.* is effective against *Anopheles quadrimaculatus* Say in rice field environments (e.g., Sandoski et al. 1985). However, the SCMAC lacked data on effectiveness of liquid formulations at appropriate dosage and droplet size specifications for spring *Aedes* larvae. This study examined the effectiveness of liquid *B.t.i.* applied by helicopter at 2 different droplet sizes but the same dosage rate, for control of spring *Aedes* larvae in central Michigan.

Fifteen pools were chosen for study in April 1989, with 5 pools in each of 3 separate wooded areas. Pools in 2 woods were designated for treatment, while the pools in the third woods were left untreated as controls. Each pool was divided into 4 parallel transects across the long axis of the pool. Three sampling stations were established along each transect, so that samples were collected near the edges and the middle of each pool. At each station, 4 dips (350 ml mosquito dipper) were taken for a total of 48 dips per pool per day. Mosquito larvae were sorted and counted in the field and then preserved for identification at a later time. At the time of application, larvae were third and fourth instars, and species present were *Ae. stimulans*, *Ae. intrudens*, *Ae. provocans* and *Ae. canadensis*. All sites were similar in species composition but highly variable in population densities. Pools were sampled for pre-treatment data on 2 days prior to application, and on 3 days after application. Data were expressed as the total number of larvae collected per pool (over all stations) per day. At the time of the study, water temperatures ranged from 3 to 16°C, while temperature variance was very slight (1–2 C°) during any given sampling day. Pool depth ranged from 4 to 27 cm, and pool surface area ranged from 500 to 800 m^2.

Application was performed with a Hughes 500 helicopter having a payload capacity of 272 kg. The formulation used was Vectobac® 12AS (Abbott Laboratories), applied at a dosage of 1.17 liters (40 fl. oz) per ha. The spray mixture was a ratio of 1:3 (*B.t.i.*:water) to yield 4.68 liters (158 fl. oz) of finished spray per ha. To generate a small droplet size (targeted range, 150–200 μm diam), a flat fan nozzle with a 23-D5 core pressurized at 26 psi was used. To generate a larger droplet size (targeted range, 400–600 μm diam), a raindrop nozzle with a 23-D5 core pressurized at 30 psi was used.

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Prior to application over experimental pools, calibration of equipment was performed to determine precise droplet sizes. This was done in an open grass area by placing 40 stakes (45 cm tall) in a row 90 m long and perpendicular to the prevailing wind direction. The outer 30 m of stakes on either end of the line were spaced at 3-m intervals while the stakes in the center 30-m section of the line were spaced at 1.5-m intervals. On top of the stakes 2.5 × 7.5 cm water-sensitive paper strips (CIBA-GEIGY) were held in place by double-sided tape. The helicopter flew at a 27 m altitude with an air speed of 112–128 kph and approached perpendicularly to the row of stakes, toward the middle of the line, and made an application over the line with an effective swath width of 15 m. Papers were allowed to dry for 5 min, collected, and diameters of droplets measured with a 7× comparator. The number of droplets was also counted on each paper. Two runs for each targeted droplet size were made. Mass median diameter (MMD) of droplets was calculated as described by Stowe and Grayson (1982). Immediately after the 2 calibration runs for each targeted droplet size, the helicopter made an application over pools in the appropriate woods.

The MMD of the small droplets was 178 μm (1,608 droplets measured) and the MMD of large droplets was 553 μm (257 droplets measured). Histograms of droplet size ranges are shown in Fig. 1. These results indicate that the targeted droplet size was achieved for each range desired, but that there was a 6-fold increase in number of droplets generated for the small droplet range compared with the large droplet range. A repeated-measures analysis of variance (Steel and Torrie 1980) on log-transformed data showed a highly significant difference among treated and control pools (F = 20.32, df = 2, $P < 0.001$) and a highly significant difference among sampling days (F = 17.83, df = 4, $P < 0.001$). Numbers of larvae in untreated pools did not change substantially during the sampling period (Fig. 2C). Numbers of larvae in pools treated with *B.t.i.* in the larger droplet size decreased somewhat but were still found in considerable numbers after treatment (Fig. 2A), but numbers of larvae in pools treated with *B.t.i.* in the smaller droplet size decreased to almost a mean of 0 after treatment (Fig. 2B). Percent reduction, taking into account changes in numbers of larvae in treated and control pools before and after (last sampling day) treatment (Mulla et al. 1971), showed 99% reduction in pools treated with *B.t.i.* in the smaller droplets, and 65% reduction in pools treated with *B.t.i.* in the larger droplets.

We concluded that aerial application of liquid *B.t.i.* against spring *Aedes* larvae provides acceptable control when proper droplet size is utilized. Droplets in the targeted range of 150–200 μm MMD gave excellent control whereas larger droplets (550–600 μm MMD targeted range) gave poor results. The number of droplets produced per unit area in the droplet ranges was probably responsible for the observed control in the treated pools. Although the dosage is a standard application rate as recommended by the manufacturer, there still is no criterion in regard to droplet size. The limitations of droplet size for effective aerial *B.t.i.* application within a woodland habitat still needs further evalua-

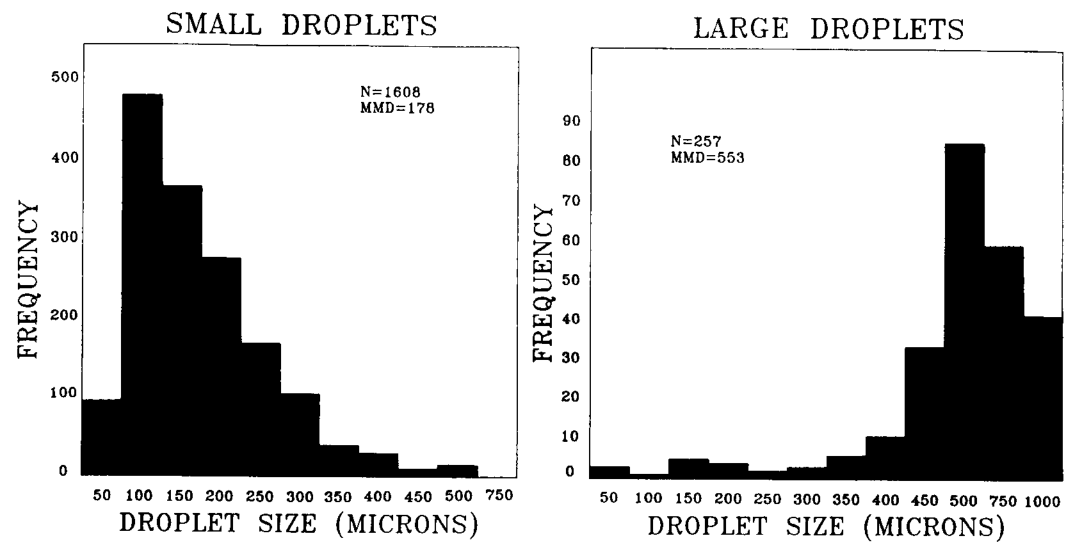

Fig. 1. Droplet size range and mass median diameter of 2 droplet size ranges of aerially applied, liquid *B.t.i.* prior to application against spring *Aedes* mosquitoes in Saginaw County, MI.

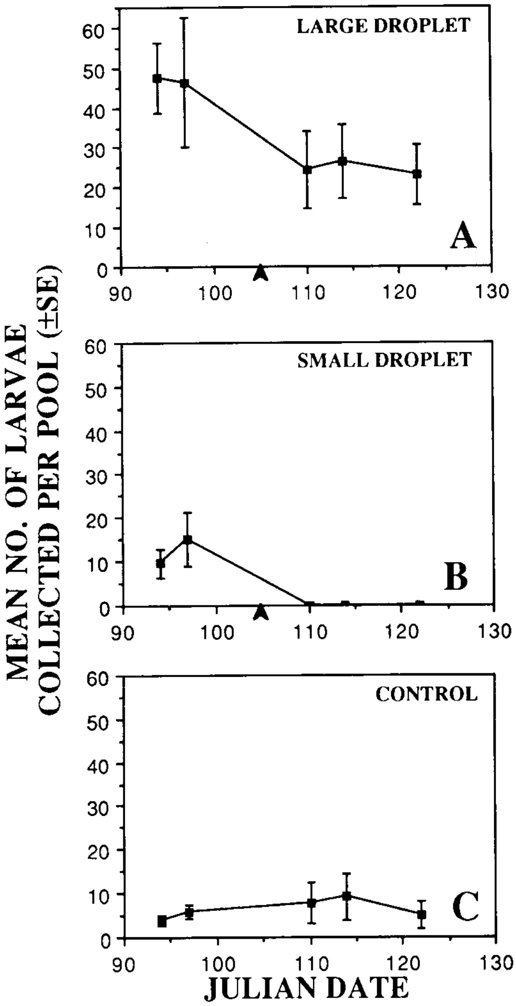

Fig. 2. Mean number of total spring *Aedes* larvae collected per pool in pools treated with *B.t.i.* in a large droplet (A), pools treated with a small droplet (B), or untreated pools (C) in Saginaw County, MI, April 1989. There were 5 pools in each treatment group. Arrows indicate date of treatment (X-axis, Julian date).

tion. A monetary comparison reveals that liquid *B.t.i.* cost \$5.38 per ha versus \$10.88 per ha for the granular product.

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