EFFICACY OF VARIOUS *BACILLUS THURINGIENSIS* VAR. *ISRAELENSIS* FORMULATIONS AGAINST *PSOROPHORA COLUMBIAE* LARVAE AS ASSESSED IN SMALL RICE PLOTS, 1984–88[1]

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ABSTRACT. Granular, liquid and briquette formulations of *Bacillus thuringiensis* var. *israelensis* were tested in small rice plots during 1984–88 against *Psorophora columbiae* larvae. Vectobac AS®, Skeetal G®, Teknar HPD®, ABG 6172®, ABG 6188®, ABG 6193®, ABG 6197®, ABG 6199®, ABG 6138F® and ABG 6221® provided excellent control at high dosages and good control (generally > 85%) at relatively low concentrations. ABG 6221 and ABG 6172 provided excellent control at low concentrations. Additional testing of these formulations will be required to ascertain specific lower limits such that more economical larval mosquito control can be obtained.

INTRODUCTION

Expanded development and use of microbial formulations for controlling mosquito larvae has led to an abundance of compounds applicable to environmentally sensitive areas where use of other insecticidal materials may be restricted. The effectiveness of *Bacillus thuringiensis* var. *israelensis* (*B.t.i.*) has been demonstrated against numerous mosquito species (e.g., Garcia and Des Rochers 1979, Ignoffo et al. 1981). Researchers in the rice producing regions of Arkansas (Dame et al. 1981, Hembree et al. 1980, Stark and Meisch 1983) and California (Mulla et al. 1985) have shown the efficacy of several *B.t.i.* formulations against *Psorophora columbiae* (Dyar and Knab) and *Anopheles quadrimaculatus* Say larvae. Although the effectiveness of *B.t.i.* is well known, the activity of selected formulations in Arkansas rice fields has not been confirmed previously. The results of a 4-year study conducted to determine the efficacy of selected *B.t.i.* formulations against *Ps. columbiae* larvae in small rice plots in Arkansas are herein reported.

MATERIALS AND METHODS

Tests were conducted at the Rice Research and Extension Center, Stuttgart, AR. Plots were constructed to simulate rice field conditions and measured 6 × 6 m between levee centers with 16-m^2 rice growing pans. Commercially accepted rice varieties and management practices for Arkansas were used throughout the study. Ditch and pan water depths were approximately 23 cm and 10 cm, respectively.

All of the *B.t.i.* formulations used were manufactured by Abbott Laboratories except Skeetal® and Teknar HPD®. Granular *B.t.i.* formulations (ABG 6138F®, ABG 6197®, ABG 6199® and Skeetal G®) were metered evenly by hand across the plot; briquettes (ABG 6224A®) were distributed uniformly within the plot. Liquids (ABG 6172®, ABG 6173®, ABG 6182®, ABG 6188®, ABG 6193®, ABG 6221®, Skeetal®, Teknar HPD® and Vectobac AS®) were mixed with 1 liter of water and applied with a hand-held CO_2 pressurized sprayer (R & D Sprayers, Inc., Opelousas, LA 70570).

Treatment plots were randomized and replicated 3 times for each test. Control plots were replicated 3 times for liquid and granular formulations in 1984–87, and 4 times for briquette formulations evaluated in 1988. Second and third instar *Ps. columbiae* were collected from naturally occurring populations near the test site. Floating cages, each containing 10 larvae, were placed in rice plots at a rate of 1 cage/plot immediately following each *B.t.i.* application as described by Sandoski et al. (1986). Mortality was assessed 24 h posttreatment for the first 3 years of study, and at 1, 5 and 10 days for the briquette formulations. Percent mortality values were corrected for control mortality by Abbott's formula (Abbott 1925). Data were subjected to ANOVA for testing the hypothesis that mean mortality values among treatments were equal. Mean separations were facilitated using Duncan's multiple range test (DMRT) or least-square means (LSMEANS) (SAS 1985). For all tests, $P = 0.05$.

RESULTS AND DISCUSSION

Vectobac G at rates of 11.19 and 5.68 kg/ha was the only microbial tested in 1984. Both rates yielded 100% mortality.

[1] This study was accomplished as a cooperative effort between the University of Arkansas Entomology Department, the Rice Research and Extension Center in Arkansas and Abbott Laboratories as part of USDA, CSRS Southern Regional Project S-122 on Riceland Mosquitoes and is approved for publication by the Director, Arkansas Agricultural Experiment Station, Fayetteville, AR 72701.

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The formulations evaluated in 1985–87 yielded variable results, but control was generally good (Table 1). Skeetal provided excellent control when applied at 0.611 or 1.2 liters/ha (>91%), but mortality diminished significantly ($P < 0.05$) at 0.114 liter/ha (17%). Similarly, Vectobac AS resulted in >96% mortality when applied at rates of 0.153 liter/ha, but at concentrations of 0.114 liter/ha and below, less than 65% were killed. Teknar HPD was highly effective at virtually all rates tested. The observed mortality of 42% for the 0.114 liter/ha rate, although significantly different ($P < 0.05$), is likely an anomaly since greater mortality was recorded at lower application rates. ABG 6172 resulted in 100% mortality at all application rates. Conversely, <2% control was recorded for ABG 6173 when applied at 0.114 liter/ha, and only 79% mortality was observed at 0.153 liter/ha. ABG 6182 killed all of the *Ps. columbiae* larvae at 0.153 liter/ha, but only 4% at 0.114 liter/ha.

Table 1. Percent mortality of *Psorophora columbiae* larvae 24 h after introduction into small rice plots treated with various *B.t.i.* liquid formulations during 1985–87.

Year	Treatment	Rate (unit/ha)	Percent mortality[1]
1985	Skeetal	1.200 liter	91.4 a
		0.611 liter	100.0 a
		0.114 liter	17.1 cde
	Vectobac AS	0.305 liter	96.3 a
		0.153 liter	96.1 a
		0.114 liter	43.7 bcd
		0.076 liter	64.5 abc
	Teknar HPD	0.305 liter	100.0 a
		0.153 liter	100.0 a
		0.114 liter	42.3 bcd
		0.076 liter	85.8 ab
	ABG 6172	0.305 liter	100.0 a
		0.153 liter	100.0 a
		0.076 liter	100.0 a
	ABG 6173	0.153 liter	79.2 ab
		0.114 liter	1.2 e
	ABG 6182	0.153 liter	100.0 a
		0.114 liter	4.4 cde
1986	Skeetal G	2.020 kg	100.0 a
		0.995 kg	100.0 a
		0.484 kg	96.3 a
		0.323 kg	100.0 a
		0.229 kg	2.0 d
	ABG 6197	5.680 kg	100.0 a
		2.800 kg	98.0 a
	ABG 6199	5.680 kg	100.0 a
		2.800 kg	91.9 ab
	ABG 6188	0.652 liter	100.0 a
		0.326 liter	79.2 bc
	ABG 6193	0.652 liter	100.0 a
		0.326 liter	68.1 c
1987	ABG 6193	0.048 liter	100.0 a
		0.024 liter	100.0 a
		0.012 liter	87.0 ab
		0.006 liter	43.5 c
	ABG 6221	0.024 liter	91.6 a
		0.012 liter	52.0 bc
	ABG 6138F	0.920 kg	100.0 a
		0.460 kg	100.0 a
		0.230 kg	83.6 ab
		0.115 kg	16.7 c
	ABG 6197	0.460 kg	100.0 a
		0.230 kg	96.2 a
		0.115 kg	6.8 c

[1] Percent mortality values ($n = 30$) followed by the same letter are not significantly different ($P > 0.05$) by Duncan's Multiple Range Test (1985–86) or least-square means (1987).

Skeetal G was 100% effective at 0.323 kg/ha, but provided little control (<2%) at 0.229 kg/ha. ABG 6197 and ABG 6199 caused 91% mortality at concentrations of 2.8 kg/ha and greater. Likewise, ABG 6188 and ABG 6193 resulted in complete mortality at the higher concentrations, but also provided reasonable control (>68%) at the lowest rates tested. However, the lower mortalities differed significantly from their respective higher values ($P < 0.05$).

Mortality attributed to ABG 6193 application in 1987 (Table 1) was considerably higher at lower concentrations than observed in 1986. Dr. M. Adair of Abbott Laboratories attributed this phenomenon to probable changes in the manufacturers' fermentation process (personal communication); the result being increased potency in contrast to the 1986 formulations. ABG 6197 was not effective when applied at 0.115 kg/ha (6.8% mortality), but otherwise was effective at 0.23 kg/ha. Good control was also provided by ABG 6138F when applied at rates of 0.23 kg/ha and greater. ABG 6221 did not provide adequate control when tested below 0.024 kg/ha.

Briquettes were the only Vectobac formulation evaluated during 1988 (Table 2). All rates

Table 2. Percent mortality of *Psorophora columbiae* larvae after introduction into small rice plots treated with Vectobac briquettes (ABG 6224A) during 1988.[1,2]

Rate (briquettes/ 4.5 m^2)	Larval installation posttreatment (days)			
	0	1	5	10
1	100.0 Aa	11.9 Bbc	4.2 Bbc	—
2	97.7 Aa	0.0 Bc	0.7 Bc	—
3	88.9 Aa	8.6 Bbc	0.0 Bc	—
4	100.0 Aa	37.9 Bab	1.2 Bbc	—
6	100.0 Aa	83.4 ABa	39.1 BCb	3.1 Cb

[1] Means in the same row followed by the same upper case letter are not significantly different ($P > 0.05$) by least-square means.

[2] Means in the same column followed by the same upper case letter are not significantly different ($P > 0.05$) by least-square means.

of Vectobac briquettes provided excellent mortality when larvae were installed at 0 h post-treatment. There were some mortality differences between the 3 briquette/plot rate and the other rates although these differences were not significant ($P > 0.05$). Control decreased significantly ($P < 0.05$) from the 0 to 24 h installation for the plots treated with 1, 2, 3 and 4 briquettes. However, mortality at the 24 h installation in plots with 6 briquettes was not significantly different ($P > 0.05$) from that obtained from the 0 h introduction. Control was negligible at the 5-day installations for 1, 2, 3 and 4 briquette/plot treatments of Vectobac with mortality decreasing below 5% for all 4 rates. Mortality for the 6 briquette/plot rate, though greater than that achieved at lower rates, declined from 83.4 to 39.1% by the fifth day following treatment. Little control was obtained by the 6 briquette/plot treatment by day 10.

Several formulations, including Skeetal G, Teknar HPD, ABG 6172, ABG 6188, ABG 6193, ABG 6197, ABG 6199, ABG 6138F and ABG 6221, provided excellent control at relatively low application rates, in contrast to other formulations tested in this study. However, these formulations will require additional testing to determine specific lower limits from which more economical larval mosquito control could be obtained in Arkansas rice fields. Treatment decisions based on more specific information will allow for consistent levels of control which will result in reduced costs in materials and application.

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