Okinawa strain, these pupae were mistaken for the *b* pupae although subsequent reciprocal allelism tests between the 2 eye color mutants revealed that they are not allelic. The *mar* gene exhibits full penetrance, but with a little variation in the expression ranging from maroon to reddish brown.

A preliminary cross, (+*m*/*mar m*) × (+*m*/*mar M*), produced the progeny of 25 families at the following phenotypic ratio—♀+: ♀ *mar*: ♂ +: ♂ *mar* = 892: 17 : 586 : 462. The hypothesis of an independent assortment between the sex allele (*m*) and *mar* was rejected, based on a chi-square value of 467.5 (d.f.=3), and this value indicated close linkage between the 2 alleles.

Seven backcrosses, 4 of which involved *Wb*, were made as given in Table 1. First of all, the 1 : 1 segregation of each allele was examined by a chi-square in each of these backcrosses; all alleles, except *mar* involved in cross A, segregated at a 1 : 1 ratio ($P > 0.05$). In cross A fewer *mar* individuals were yielded than its wild-type ones ($0.05>p>0.02$). The chi-square tests for linkage between alleles indicated that the *sex* and *mar* loci are closely linked since the chi-square values for between *sex* and *mar* ranged from 70.56 (cross A) to 707.39 (cross D); whereas, all chi-square values for *sex-Wb* and for *mar-Wb* were 0.00 up to 2.44, which confirmed the previous finding (Tadano et al. 1980, Tadano 1981) that *Wb* is an autosomal gene.

The recombination distance between the *sex* and *mar* loci ranged from 2.8 ± 0.8 (cross E) to 8.0 ± 2.7 (cross A) map units; its weighted mean calculated from the results of crosses A, D, and E was 5.0 ± 0.6 map units.

Finally, the mutants of *Ae. albopictus* studied to date were assigned to 3 linkage groups: *proboscipedia (prb)* (Bat-Miriam and Craig 1966, Quinn and Craig 1971), *mar*, and *sex* to linkage group 1; *Wb* (and its allele *F*) and *p* to linkage group 2; and *b* to linkage group 3.

ACKNOWLEDGMENTS. The author appreciates the technical assistance of Mrs. S. Sugiyama of this laboratory in rearing mosquitoes. This study was supported in part by a grant from the Ministry of Education, Science and Culture, Japan.

References Cited

Bat-Miriam, M. and G. B. Craig, Jr. 1966. Mutants in *Aedes albopictus* (Diptera: Culicidae). Mosq. News 26:13–22.

Quinn, T. C. and G. B. Craig, Jr. 1971. Phenogenetics of the homoeotic mutant *proboscipedia* in *Aedes albopictus*. J. Hered. 62:3–12.

Tadano, T. 1981. Linkage studies on two new mutants, *Frosty-body* and *pigmented pupa*, in the mosquito *Aedes albopictus*. Mosq. News 41:348–355.

Tadano, T., A. Mori and Y. Wada 1980. Inheritance of *White-body* and *brown-eye* in *Aedes albopictus*. Mosq. News 40:79–83.

Yong, H. S., K. L. Chan, S. S. Dhaliwal, W. H. Cheong, G. L. Chiang and J. W. Mak. 1981. Genetics of glucose phosphate isomerase and phosphoglucomutase in *Aedes albopictus* (Diptera: Culicidae). Theor. Appl. Genet. 59:345–348.

FIELD EVALUATION OF *BACILLUS THURINGIENSIS ISRAELENSIS* AGAINST *AEDES VIGILAX* AND *CULEX SITIENS* IN FIJI[1]

M. S. GOETTEL[2], M. K. TOOHEY[2], R. C. RAM
Vector Research Unit, Ministry of Health, P.O. Box 30, Suva, Fiji.

J. S. PILLAI

Department of Microbiology, University of Otago, P O Box 56, Dunedin, New Zealand.

A new strain of *Bacillus thuringiensis* demonstrating rapid larvicidal activity against mosquitoes was isolated in 1977 by Goldberg and Margalit (1977) and was later named *Bacillus thuringiensis* var. *israelensis (Bti)* (de Barjac 1978). Preliminary field trials with *Bti* in the United States have demonstrated its efficacy for use against many species of mosquitoes breeding in irrigated pastures, storm drains, ponds, dairy lagoons, salt marshes (Garcia et al. 1980) and rice plots (Hembree et al. 1980).

This paper reports on the field application of *Bti* against *Aedes vigilax* (Skuse) and *Culex*

[1] M S G and MKT were supported by the United Nations Volunteers/World University Service of Canada joint sponsorship program. Research funds were provided by grants to JSP from the UNDP/World Bank/WHO Special Program for Research and Training in Tropical Diseases.

[2] Present Address: Department of Entomology, University of Alberta Edmonton, Alta., Canada T6G 2E3.

sitiens Wiedemann breeding in a brackish water habitat in Fiji.

MATERIALS AND METHODS

The trials were performed at the Ravi Ravi reclamation area in the province of Ba on the island of Viti Levu in a series of partially drained rectangular experimental fish ponds (approx. 70 × 90 m). The ponds were constructed with an elevated central portion so that a moat of water approximately 3 m wide remained on the outer fringe of the ponds when they were partially drained. Only one pond contained vegetation and that consisted of an emergent grassy area in one of the corners. All ponds had a naturally occurring mosquito population estimated at approximately 120 larvae per liter at a ratio of 12 *Cx. sitiens* to one *Ae. vigilax*.

The Sandoz formulation of *Bti*, SAN 402 I WDC was applied to 3 ponds at the rate of 0.5, 1.25 and 2.0 liters per hectare. One pond was kept as a control. The corresponding rates of application in parts per million (PPM–v/v) are given in Table 1. The 4 ponds each had a surface area of 0.1 ha with a mean depth/volume varying from a minimum of 17 cm/1.7×10^5 liters for the 1.25 liter/ha treated pond to a maximum of 30 cm/3×10^5 liters for the control pond. At the time of the *Bti* application the water temperature of the control pond was 35°C and 37°C for the treated ponds. The salinity varied from a minimum of 2.1% in the 2.0 liters/ha treated pond to a maximum of 2.4% in the control and 0.5 liters/ha treated ponds.

Table 1. Effects of field application of *Bacillus thuringiensis israelensis* on *Aedes vigilax* and *Culex sitiens* in Fiji.

	% Mortality			
	Aedes vigilax		*Culex sitiens*	
Dose	Mean[1]	SD	Mean[1]	SD
Control				
24 hrs	5	9	0	0
48 hrs	5	9	1	3
0.501/ha 24 hrs	25	12	77	17
(185 PPM) 48 hrs	43	21	87	11
1.251/ha 24 hrs	66	28	86	21
(725 PPM) 48 hrs	82	14	93	13
2.001/ha 24 hrs	69	13	78	22
(880 PPM) 48 hrs	92	3	91	7
2.001/ha 24 hrs	64	—	4	—
(880 PPM) 48 hrs grassy area[2]	90	—	28	—

[1] Mean of 4 replicates of 25 larvae each.
[2] Only one chamber/species.

Measured amounts of *Bti* were poured into a 4.5 liter pressure garden sprayer and the sprayer was then filled with strained water from the ponds. Little agitation was required to put the *Bti* into suspension and it was applied to the ponds as a coarse spray. The 4.5 liters were sufficient to give one uniform coverage per pond.

A slightly modified bioassay method of Hembree et al. (1980) was used to evaluate the application of the *Bti* on the mosquitoes. Bioassay chambers were constructed from 30 cm sections of 10 cm diam polyvinyl chloride sewer pipe. Three 1 cm diam holes were drilled on the sides of the containers approximately 5 cm from the bottom. The bottoms and side holes were then screened with a fine mesh cheese cloth.

Immediately after a pond was sprayed, 8 bioassay chambers were attached to wooden stakes set out in the 4 corners of the pond so that there was one chamber per mosquito species per corner. Each chamber was approximately ¾ below water level.

Early third or late fourth instar larvae of *Ae. vigilax* and *Cx. sitiens* that had been taken out of the ponds before spraying, separated according to species and counted into lots of 25, were then placed into the chambers. An additional 2 chambers were placed in the grassy area of one pond. Mortality counts were made at 24 and 48 hours.

Approximately one month after the trial, the ponds were visually inspected and comparisons were made with the control pond.

RESULTS AND DISCUSSION

Visual inspections of the treated ponds shortly after spraying revealed that larvae became affected by the *Bti* in approximately 15 to 30 min. The larvae became sluggish and remained near the surface of the water and were slowly pushed along by the action of the surface water ripples. After 3 hr, large "clouds" of dead larvae were seen floating at the leeward ends of the ponds.

The results obtained in the bioassay chambers revealed that mortality generally increased with dose and duration of exposure (Table 1). *Aedes vigilax* was less susceptible than *Cx. sitiens* at lower concentrations, although both were equally susceptible at the highest

concentration. Mortalities in the 2 chambers placed in the grassy area of the 2 liters/ha treated pond showed little change in the *Ae. vigilax* mortality but a significant lowering in the *Cx. sitiens* mortality as compared to the results in the non-grassy area. This indicates that the presence of grass may greatly affect the dispersal and efficacy of *Bti.*

Visual inspection of the ponds 32 days after *Bti* application revealed that the treated ponds contained approximately 50% fewer larvae than the control pond. Hembree et al. (1980) found that *Bti* had a residual activity of up to 5 days. In the present study no attempts were made to determine the reasons for the lowered mosquito populations in the treated ponds as compared to the control pond.

The rapid larvicidal activity and the ease of application of the *Bti* make it a promising candidate for the biological control of *Ae. vigilax* and *Cx. sitiens* in the South Pacific.

References Cited

de Barjac, H. 1978. Une nouvelle variete de *Bacillus thuringiensis* tres toxique pour les moustiques: *B. thuringiensis* var. *israelensis* serotype 14. C.R. Acad. Sci. 286D:797–800.

Garcia, R., B. A. Federici, I. M. Hall, M. S. Mulla and C. H. Schaefer. 1980. *B.t.i.*—a potent new biological weapon. Calif. Agric. 34:18–19.

Goldberg, L. J. and J. Margalit. 1977. Bacterial spore demonstrating rapid larvicidal activity against *Anopheles sergentii, Uranotaenia unguiculata, Culex univittatus, Aedes aegypti* and *Culex pipiens.* Mosq. News 37:355–358.

Hembree, S. C., M. V. Meisch and D. Williams. 1980. Field test of *Bacillus thuringiensis* var. *israelensis* against *Psorophora columbiae* larvae in small rice plots. Mosq. News 40:67–70.

CORDILURA VARIPES (SCATOPHAGIDAE), A PREDATOR OF *CULICOIDES VARIIPENNIS* (CERATOPOGONIDAE)

R. H. ZIMMERMAN AND E. C. TURNER, JR.

Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.

Predators of Ceratopogonidae were summarized by Bacon (1970), but no records exist for *Culicoides variipennis* (Coq.). Species of Scatophagidae are known to be entomophagous (Seguy 1952). Wallace[1] noted that *Cordilura varipes* (Walker) attacked small midges by crawling over the vegetation, but he did not identify these midges to species.

Culicoides variipennis breeds along the margins of several brine ponds in Saltville, Virginia. Adults emerge at dawn, expand their wings and groom themselves before taking flight. Between 0600–0900 hours, *Cordilura varipes*, which breeds in the surrounding marsh vegetation, has been observed to prey on *Culicoides variipennis*. Observations were made from June 1–Sept. 10, 1979. Though *Cordilura varipes* is a swift flyer, when attacking teneral midges it crawls from midge to midge. It jabs a midge several times with its proboscis and ingests the midge's body fluids. Several *Cordilura varipes* were taken to the laboratory and on 11 occasions when offered adult *Culicoides variipennis*, they fed in the same manner as observed in the field. Nothing further is known about this predator-prey relationship, nor is it known whether *Culicoides variipennis* constitutes a large percentage of the diet of *Cordilura varipes*.

ACKNOWLEDGMENT. We appreciate the identification of *Cordilura varipes* by F. C. Thompson, Systematic Entomology Laboratory, USDA.

[1] Wallace, J. B. 1967. The biology and descriptions of immature stages of the genus *Cordilura,* sensu lato, in the eastern United States (Diptera: Anthomyiidae). Ph.D. dissertation, Virginia Polytech. Inst., Blacksburg, VA. 161 p.

References Cited

Bacon, P. R. 1970. The natural enemies of the Ceratopogonidae—a review. Commonwealth Inst. Biol. Control Tech Bull. 13:71–82.

Seguy, E. 1952. Diptera, Family Scatophagidae. *Genera Insectorum.* 209:107 p.