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USE OF BACTIMOS® BRIQUETS (*B.t.i.* FORMULATION) COMBINED WITH THE BACKSWIMMER *NOTONECTA IRRORATA* (HEMIPTERA: NOTONECTIDAE) FOR CONTROL OF MOSQUITO LARVAE

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ABSTRACT. The efficacies of *Bacillus thuringiensis* var. *israelensis* (Bactimos® briquets) and the backswimmer *Notonecta irrorata* were evaluated both individually and in combination to control mosquito larvae in plastic containers in Monterrey, Mexico. The combined strategy proved to be the most effective one.

The employment of effective mosquito control tactics is often the only means by which diseases transmitted by these insects can be prevented or controlled (World Health Organization 1982). Over the past half century, the primary tactics employed against target mosquito populations have involved the use of chemical larvicides and adulticides. Such tactics, although effective when they are initially employed, tend to eventually result in the development of resistance in the target mosquito populations, severe suppression of nontarget organisms, and/or general pollution of the environment when these tactics are the only ones employed or otherwise overused (Klowden et al. 1983).

Thus, more biorational approaches are needed to manage mosquito populations of public health importance. One such approach would be to combine a chemical insecticide that is highly specific for mosquitoes and otherwise relatively harmless to the environment with one or more biological control agents effective against these insects. A chemical of the kind just mentioned is the toxin produced by the bacterium *Bacillus thuringiensis* var. *israelensis* (*B.t.i.*).

When *B.t.i.* was combined with mosquitofish (*Gambusia affinis*), the combination of these 2 agents gave better control of *Culex tarsalis* Coq. populations than when each agent was used separately (World Health Organization 1984), giving evidence that *B.t.i.* can be used effectively in combination with at least noninsect predators of mosquito larvae.

However, *B.t.i.* is highly toxic to certain other members of the Culicidae whose larvae are predaceous on mosquito larvae, for example, *Toxorhynchites rutilus rutilus* (Coq.) (Lacey and Dame 1982). Fortunately, aquatic predators from other insect families are not affected by *B.t.i.* (Garcia et al. 1980, Garcia and Sweeney 1986). This agent might be used in combination with certain insect predator species to effectively control mosquitoes in a cost-effective, environmentally safe manner.

The objective of our study was to evaluate the efficacy of using *B.t.i.* in combination with the backswimmer *Notonecta irrorata* Uhler (Hemiptera: Notonectidae) to control mosquitoes. The 2 agents were assessed separately and in combination with each other on larval populations of mosquitoes maintained under experimental field conditions.

The study was carried out at the field station of Instituto Tecnologico y de Estudios Superiores de Monterrey (ITESM) located near the Monterrey International Airport, from September to December 1994. Eight 200-liter plastic containers were filled with 150 liters of water and were exposed 15 days before treatment to natural oviposition by local mosquito populations. The containers were situated in a shaded place, surrounded by grass; the temperature was 18–25°C and pH was 7.4–8.1.

The control agents used were Bactimos® slow-release briquets (*B.t.i.*, 10% AI) and adult *N. irrorata*, which were collected in artificial pools at the ITESM field station.

A random square design with 4 treatments was used. In 2 containers Bactimos was added at the equivalent rate of one briquet per 9.29 m^2 per container. We planned to reapply the *B.t.i.* when the larval density reached 5 larvae per dip. In the other 2 containers the same concentration of Bactimos was added plus 5 adult backswimmers per container. The third set of 2 containers had only 5 adult backswimmers added to each, and in the last set nothing was added and these containers served as the control.

Larval population densities were assessed weekly by taking 10 dipper samples from each treatment. The mosquito larvae were identified using the keys of Darsie and Ward (1981). The number of larvae collected for each mosquito species was recorded. An analysis of variance was used to detect treatment difference in larval densities (Zar 1974).

The mosquito species collected were *Aedes aegypti* (Linn.), *Culex pipiens* Linn., *Culex coronator* Dyar and Knab, and *Anopheles pseudopunctipennis* Theobald. The sampling data were analyzed ac-

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Table 1. Pooled data reflecting average number of mosquito larvae per dip per treatments for 4 mosquito species occurring in containers treated with Bactimos, backswimmers, and with both agents at the ITESM Field Station, from September through December 1994.

Days post-treatment	Average no. larvae per dip			
	Control	Bactimos	Back-swimmer	Inte-grated
7	4.2	0.8	3.4	3.9
14	2.7	0.6	0.5	0.0
21	7.3	0.3	4.9	0.3
28	2.5	0.0	1.6	0.1
35	2.2	0.4	1.8	0.0
42	11.4	3.7	5.8	0.0
49	5.4	0.2	0.9	0.0
56	9.4	1.4	0.1	0.0
63	12.5	0.2	0.1	0.0
70	15.6	17.2	2.1	0.0

Table 2. *Aedes aegypti* larval densities in plastic containers treated with bactimos, backswimmers, and both agents at the ITESM Field Station, from September through December 1994.

Days post-treatment	Average no. larvae per dip			
	Control	Bactimos	Back-swimmer	Inte-grated
7	0.7	0.1	0.0	0.2
14	0.3	0.0	0.0	0.0
21	0.0	0.0	4.7	0.3
28	0.8	0.0	0.3	0.1
35	0.4	0.0	1.5	0.0
42	4.0	0.2	0.9	0.0
49	1.0	0.0	0.3	0.0
56	3.1	0.3	0.0	0.0
63	5.9	0.2	0.0	0.0
70	13.1	0.0	2.1	0.0

cording to the following scheme: the data on 4 mosquito species were pooled, and then *Ae. aegypti* was considered as a mosquito species by itself, and data on *Cx. pipiens* and *Cx. coronator* were pooled and considered as *Culex* spp. Data on *An. pseudopunctipennis* were excluded because the larval densities for this species were very low in all the treatments.

Using the pooled data on the 4 mosquito species, the efficacy of Bactimos appeared to be very good (Table 1). By 42 days posttreatment, larval densities in the Bactimos treatment averaged only 3.7 larvae per dip as compared to 11.4 larvae per dip in the untreated control. The *B.t.i.* was applied again only in this treatment because larval density was close to 5 larvae per dip and according to laboratory data, any residual effect was gone. In the last sample (70 days posttreatment), the larval density was 17.2 larvae per dip.

The combination of both bacteria and predators gave good control (low larval densities) with no harmful effect on predators. The control afforded by *N. irrorata* alone was not as good as Bactimos alone although only in one occasion did the larval density exceed more than 5 larvae per dip. In the control containers, densities of more than 5 larvae per dip occurred during 6 sampling periods. The combination of both Bactimos and backswimmers consistently provided the best control of the pooled larval populations. There was a significant difference ($P < 0.05$) among the mosquito larvae densities when the different treatments were compared to the control.

Aedes aegypti larval densities were similar in the Bactimos only and combined control agents, always less than one larva per dip (Table 2). Densities of 0 larvae per dip again occurred more frequently in the containers treated with both agents. In the case of the predator strategy, *Ae. aegypti* larvae reach almost 5 larvae per dip in the 3rd sample (21 days posttreatment). In the control the larval densities increased at the end of the evaluation. A statistical difference between larval densities of *Ae. aegypti* was found among the treatments ($P < 0.05$).

In the case of *Culex* spp., the larval densities were greater than 5 larvae per dip by the end of the evaluation in containers where Bactimos was applied alone (Table 3). In the containers treated with both agents the lethal effect on mosquito larvae was very obvious. In the case of the predator release alone the larval density reached 4.9 per dip at day 42 after treatment; in the case of the control, larval densities were greater than 5 larvae per dip in 4 samples. Statistically, a difference was found among the treatments ($P < 0.05$).

Although we found efficient reduction of mosquito larvae in both Bactimos application alone and the combined Bactimos and predator application, we recommend the second approach from an economical point of view, that is, lower management costs, because the Bactimos had to be added less frequently to containers having notonectids in them to effect the level of control desired.

Table 3. Pooled larval densities of *Culex* spp. occurring in plastic containers treated with Bactimos, backswimmers, and both agents at the ITESM Field Station, from September through December 1994.

Days post-treatment	Average no. larvae per dip			
	Control	Bactimos	Back-swimmer	Inte-grated
7	3.5	0.7	3.4	3.4
14	2.4	0.6	0.2	0.0
21	7.3	0.3	0.2	0.0
28	1.7	0.0	1.3	0.0
35	1.8	0.4	0.3	0.0
42	7.4	3.5	4.9	0.0
49	4.4	0.2	0.6	0.0
56	6.3	1.1	0.1	0.0
63	6.6	0.0	0.1	0.0
70	2.5	17.2	0.0	0.0

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