The second standard, temephos, was only effective for 2 days posttreatment.

The BAY 1272 formulation was not an effective larvicide in this study. A treatment rate of 3X that of the temephos rate was required for the same degree of efficacy as the standard.

In the chlorpyrifos treatment, the control periods obtained with the corncob pellets were about 3 times longer at each treatment level than those obtained with the polypropylene pellets. The control period with the corncob pellets ranged from at least 7 to 27 days at the 3 treatment rates.

In the temephos treatment, the polypropylene pellets were more effective that the corncob pellets. Complete control with the corncob pellet treatments was not obtained. The lowest treatment rate with the polypropylene pellet was as effective as the temephos standard, although the treatment rate was about 2× more than that of the standard.

The 2 types of pellets used in this study had different characteristics. The corncob pellets sank to the bottom and rapidly disintegrated into the grit particles, releasing the larvicide in the bottom substrate. The polypropylene pellets floated and did not disintegrate, thus releasing larvicide at the water surface. These characteristics possibly played a role in the effective action of the larvicides. Another factor that may have influenced the effectiveness of the 2 formulations was the treatment of the corncob grits with the technical grade of the larvicide and the treatment of the polypropylene powder with an EC formulation. In addition, rates of release from the 2 types of carrier and the sites of release may also have a role in effectiveness of the larvicides.

While control was obtained with the corncob pellets with chlorpyrifos and the polypropylene pellets with the temephos, the control periods were not extended proportionately to the increased amount of larvicide employed, compared to the standard treatment rates.

LABORATORY OBSERVATIONS ON THE BIOLOGY OF *TOXORHYNCHITES THEOBALDI*

YASMIN RUBIO[1, 2] AND CARLOS AYESTA[3]

The larvae of *Toxorhynchites* are predaceous upon aquatic invertebrates. Among their prey are mosquitoes of medical importance. It has been suggested that *Toxorhynchites* could be used as potential biocontrol agents.

Toxorhynchites theobaldi (Dyar and Knab) is a neotropical mosquito. Little is known about its natural breeding places. In Venezuela we have found this species in artificial containers in the cemeteries of Caracas and La Guaira, D.F. where it preys upon the mosquitoes *Aedes aegypti* (Linn.) and *Culex quinquefasciatus* Say, the chironomid *Atrichopogon* sp. and the psychodid *Telmatoscopus albipunctatus* (Rubio et al. 1980, Kazana et al. in press).

Because Venezuelan populations of *Tx. theobaldi* do not mate in captivity, eggs for experiments were collected from water-containing urns and flower pots in a cemetery at La Guaira, Venezuela. Eggs were found only in the shadiest places. Individuals for observations were reared on a diet of 20 *Aedes aegypti* larvae/day of the same developmental stage as the predator larva (Rubio et al. 1980).

The behavior of *Tx. theobaldi* was filmed using two 16 mm cameras. Eggs hatching were filmed by placing eggs in a small container made with two cover slips (0.17 × 20 × 20 mm) spaced 2 mm apart to allow the eggs to float freely in front of the camera. Fourth instar larvae and pupae were filmed using a similar but larger container prepared with two optical glasses 1 × 20 × 20 mm spaced 7 mm apart. The feeding behavior of larvae and the emergence of adults were filmed in petri dishes.

Oviposition was observed in the field around 1000 hr. The flight pattern observed was similar to other *Toxorhynchites* species (Furumizo and Rudnick 1978, Steffan et al. 1980, Trimble 1979). The females were never observed

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touching the water surface during or before oviposition. The eggs were white, oval, approximately 1 mm in length and float horizontally. Eggs hatched after 2 days at 28°C. The egg changed in color from white to pale brown before hatching, and elongated a few minutes before hatching. At that time the chorion became clearer so that it was possible to observe the pharate larva, especially its ocelli. The pharate larva split the chorion ventrally by jerking movements. The rear part of the body emerged first from the egg. A few seconds after emergence, the larva swam to the water surface and rested parallel to it. A few minutes later, the head capsule and siphon began to gradually darken. After approximately 30 min these parts were completely sclerotized, and the larva started to feed.

Larval length was measured daily. Figure 1 shows that a larva increased its length by approximately 1 mm daily. Data represent the mean lengths of 31 immature (12 males and 19 females) *Tx. theobaldi* that completed their development to adults. The relationship between mean size and development time was best expressed by a power function ($y = 1.89 \times ^{0.76}$, $r^2 = 0.98$).

To establish whether size and sex were related, a student *t*-test between final mean size for male and female 4th instar larvae was performed. The results were not significant ($p > 0.05$).

Toxorhynchites theobaldi captured its prey by ambush. As soon as it detected a disturbance in the water, it moved its mouth parts in the direction of the stimulus. If the prey swam within reach (approximately 5 mm), it was captured on any part of its body. Once the prey was captured, the larva generally descended to the bottom of the container for 15 to 30 sec., returning afterwards to the water surface, and kept its body rigid and straight while the prey was ingested. We observed that after the successive ingestion of two or three prey, the larva contracted its body into an "S" shape (probably to push the prey previously ingested into the hindgut). Then it relaxed, returning to the original position, to form an angle of about 45° with the water surface. Associated with the ingestion of prey, we frequently observed the evacuation from the anus of prey parts previously captured but not completely digested.

To establish the amount of prey eaten during the larval stages and its influence on development time, the following experiment was conducted: Twelve first instar *Tx. theobaldi* larvae were placed individually in plastic containers with 20.4 cm² of water surface and in 25 cc of tap water. Larvae were maintained at 28°C until they showed killing behavior (killing without consuming any part of the prey), and under dark conditions to prevent the aggregation of *Ae. aegypti* prey (Rubio et al. 1980). Four of them were offered daily 5 *Ae. aegypti* larvae. Four were offered 20 *Ae. aegypti* larvae and four were offered 40 *Ae. aegypti* larvae of the same developmental stage as the predator.

Those larvae offered 5 *Ae. aegypti* larvae did not reach adulthood. One pupated but died 4 days later and the others died in the 2nd or 4th instars. The mean larval developmental time for specimens fed on 20 prey larvae was 14.5 days while those fed on 40 prey larvae daily was 13.0 days. The results of a student *t*-test showed that the differences in total larval development time according to the amount of food provided were significant ($p < 0.05$). Among these individuals we found a similar trend in the consumption of prey, i.e., the amount of prey daily ingested increased from 1st to 3rd instar, then decreased reaching a minimum value at the

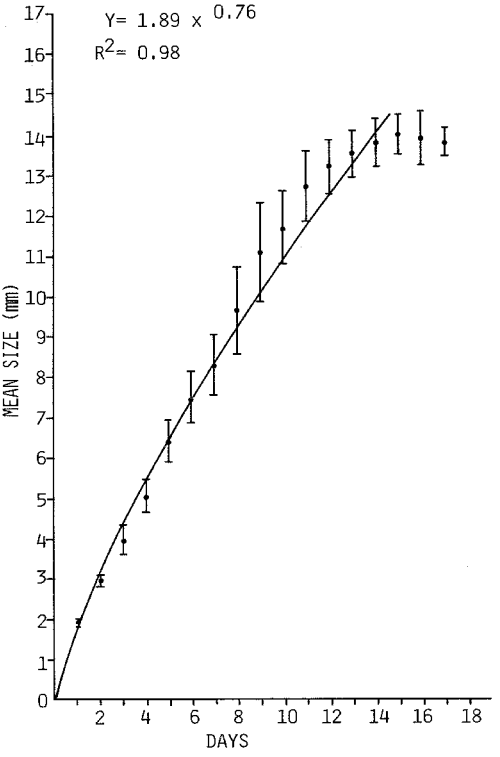

Fig. 1 Mean size (mm) daily increase for 31 *Tx. theobaldi* larvae offered daily 20 *Ae. aegypti* larvae of the same developmental stage as the predator.

middle of larval development time, then increased reaching a maximum the day before killing behavior started.

Killing behavior has been reported for several *Toxorhynchites* species (Lounibos 1979, Padgett and Focks 1980, Steffan and Evenhuis 1980). *Toxorhynchites theobaldi* provided with 40 prey daily started to kill 3 days before pupation; those with 20 prey available daily exhibited killing behavior 2 days before pupation. Of the 4 larvae provided daily with 5 prey, only one pupated and without killing any prey.

Cannibalism has been observed at all stages. It seems to be more frequent when the number of prey available is low. To establish a relationship between cannibalism and prey density, the following experiment was conducted: 40 *Ae. aegypti* 4th instar larvae were placed in each of 5 plastic containers with 65 cm^2 of water surface and in 500 cc of tap water. Increasing densities (2-4-6-8-10) of 4th instar *Tx. theobaldi* of the same age (5 days) were added to each container. The experiment was done under normal light conditions (12L: 12D) at 28°C for 24 hours and was replicated 2 or 3 times. Figure 2 shows the relationship between both variables. The amount of prey is expressed as the number of prey available per predator and varies between 20 and 4. Cannibalism is expressed as the mean number of *Tx. theobaldi* completely or partially ingested.

The relationship between variables is exponential; for more than 20 prey per predator, cannibalism approached zero, and with less than 10 prey per predator cannibalism increased dramatically. The fit, for equation $y = 10.96\ e^{-0.18x}$ was $r^2=0.96$. The preliminary experiment shows an exponential relationship between the number of prey available per predator, versus cannibalism. The cannibalistic behavior of *Tx. theobaldi* in nature could be different in a heterogenous medium and different predator's age composition, as observed in the cemetery containers (Rubio et al. 1980, Kazana et al. in press).

Prior to pupation, the larva floats parallel to the water surface and by means of contractions of abdominal muscles, the exoskeleton of the larva breaks at the dorsum of the thorax, whereupon the pupal trumpets touch the water surface. A few seconds later, the posture changes from horizontal to vertical, while the pupa detaches from the larval exoskeleton by muscular contractions of the abdomen. The mean time recorded for 3 complete filmings of the whole process was 1 min. 2 sec. (from the moment larva floated parallel to the water surface until the pupa freed itself from the larval skin). A few minutes later, the pupa starts darkening. The pupa will remain motionless at the water surface unless disturbed. Pupation in *Tx. theobaldi* can occur at any time of the day.

Prior to the emergence of the imago, the pupa rests parallel to the water surface. Muscle contractions of the thorax and abdomen cause a split in the thorax of the pupal skin. The imago's thorax appears first, then the head and finally the abdomen. When 2/3 of the body is out of the exuvia, the insect extends its legs pushing the exuvia backwards. It rests on the water surface for about 5 minutes before it is able to fly. The mean time recorded for emergence was 49 seconds. Sequences of the emergence of the imago are shown in Fig. 3.

The survival of *T. theobaldi* is presented in Table 1. These data represent laboratory observations on 58 eggs collected in August 1980. Each egg was placed individually in plastic containers with 20.4 cm^2 of water surface and in 25 cc of tap water and kept at 28°C. Each *Tx. theobaldi* was offered daily a diet of 20 *Ae. aegypti* larvae of the same developmental stage as the predator.

In a general sense, survival for the immature *Tx. theobaldi* was high and almost constant, similar to Slobodkin's (1962) Type I survivorship curve.

The mean duration from egg hatching to adults was 20.1 days. To establish whether development time and sex were related, student *t*-tests for 3rd and 4th instar larvae and pupae, as well as for the mean total development time between male and female were performed. The differences in duration of the development time between males and females of considered

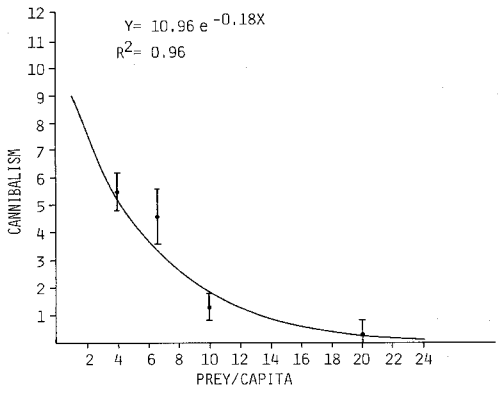

Fig. 2 Mean number of 4th-instar *Tx. theobaldi* larvae completely or partially ingested as a function of the number of *Ae. aegypti* prey per capita.

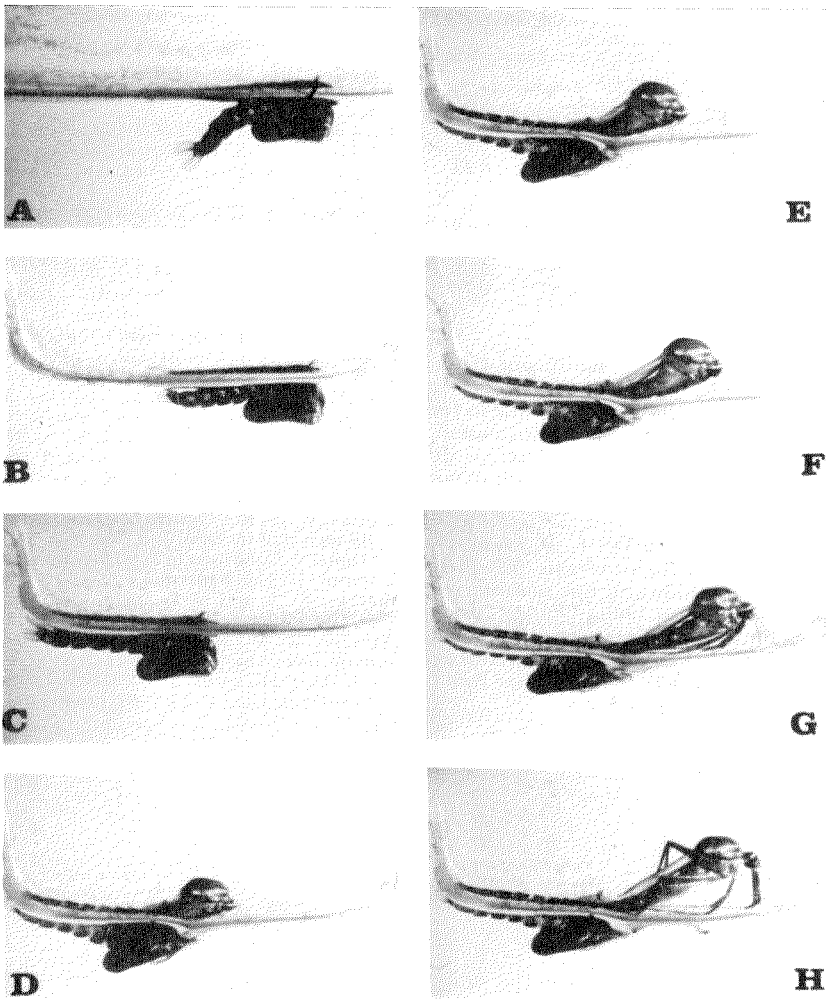

Fig. 3. Sequence of emergence of the imago of *Toxorhynchites theobaldi* from the pupa. Prepared from individual frames of the film. (Amplification IX).

Table 1. Laboratory observations on the survival of *Toxorhynchites theobaldi*.

Stage	Duration (days) Range Male	Range Female	Mean Male	Mean Female	Survival (l_x)
Egg			2.00	2.00	0.81
Larva					
1st instar	—	—	2.00	2.00	0.98
2nd instar	1–2	1–2	1.83	1.74	0.98
3rd instar	2–5	2–5	3.25	3.53	0.96
4th instar	6–9	5–9	7.33	7.53	0.95
Pupa	5–7	3–6	5.67	5.37	0.76

stages were not statistically significant ($p > 0.05$).

Video copies of the film will be available for teaching purposes. For further information, please contact Dra. Delia Agudo. Sistemas de Actualización, Vice-Rectorado Académico, Universidad Central de Venezuela. Caracas 1051 Venezuela.

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