# Life Cycle, Behaviors and Control of Bamboo Shoot Borer, *Cyrtotrachelus dichrous*, by Entompathogenic Nematode, *Steinernema carpocapsae*

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## ABSTRACT

The experiments were carried out in three Amphoes of Tak province, North of Thailand during May 1993 and October 1994. For life cycle studies, a couple of male and female adults of *Cyrtotrachelus dichros* were released in a field net cage that securely sealed around a young bamboo shoot aged 1.5-2 weeks. There were 40 pairs of male and female adults released and the life cycle started from egg oviposition and the rearing for the study was *in vivo*. The total borer underwent the univoltine life cycle with the egg duration of 2 days. The total larval duration were 8-15 ( $\bar{x}$ = 12.3±2.05) days and possessed four instars of which consecutive stadia were 2-3 ($\bar{x}$ = 2.2±0.38) days , 2-3 ($\bar{x}$ = 2.7±0.54) days, 2-4 ($\bar{x}$ = 2.9±0.63) days and 3-5 ($\bar{x}$ = 4.5±0.52) days respectively. Pre-pupation duration was 2-5 ($\bar{x}$ = 3.81±1.11) days while pupation was in soil for 7-9 months. The adult emerged after the first heavy rain of the rainy season in May with the adult duration of 1-2 ( $\bar{x}$ = 1.5±0.59) months.

The behaviors on mating, sex attraction, oviposition, feeding, pre-pupation and pupation site searching were discussed in details in this paper

The control of the borer was successful by soil application of the entompathogenic nematode, *Steinernema carpocapsae*, at 10 replications of 4 treatment rates: 0, $2x10^6$, $4x10^6$ and $8x10^6$ individual nematodes per soil surface area of 10 $m^2$. The average mortality corresponding with the treatments were 10, 40, 80 and 100 percent respectively.

## INTRODUCTION

Sweet bamboo (*Dendrocalamus asper* Backer) has been long well known among Asian people for food, industries, furniture, housing, basketery and many other home and cultural uses. There are more than 20 provinces out of the total of 78 provinces in Thailand cultivated sweet bamboo commercially for export and domestic consumption. In 1984, the total export values of sweet bamboo was 3.68 miollionUS$ (8,558 million tons) and there were about 70 bamboo factories registered in Prachinburi province which encountered the minimum of about 16,000 tons of fresh bamboo shoots per year (Sukonthasit 1986).

The bamboo shoot borers or Rhynchophorinae weevils (*Cyrtotrachelus* spp.) attacking sprouts of bamboo culms had been mentioned in the literatures from India and China since 1893 (Cotes 1893). The borers were firstly reported with heavy attacks on muli bamboo (*Melocanna bambusoioides*) in India during 1899-1900, in its neighbouring countries in 1914 (Stebbing, 1914) and in Java on *M. bambusioides* and *Dendrocalamus strictus* in 1931 (Karshoven 1961). In Thailand, The first report on injuries of bamboo plantations caused by *Cyrtotrachelus longipes* and *C.dux* was in 1970 (Jaiklom 1970). There was a report on bamboo plantation injuries in Kanchanaburi province in 1991 (Choldamrongkul and Loepanitkul 1991) and in 1992 the damages extended to 20-60% in Tak province (Attajarusit *et al.* 1992) where *C. dichrous* and *C. longipes* were found 95% and 5% of the catch respectively (Choenram 1993)

The distribution of the borers were found in all bamboo planting areas of Bangkok, metropolitan

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Chon Buri, Kanchanaburi, Nakhon Ratchasima, Tak, Lampang, Phetchanbun and Chiang Mai (Choenram 1993). The distribution patterns of the borer were also investigated (Attajarusit *et al.* 1997 in printing). For a partial life cycle study in Phetchabun province, it was reported that the egg, larval and pupal durations were 4-5 days, 21-25 days and 10-11 months respectively (Choenram 1993). In Kanchanaburi province, the egg duration was observed to be 3-5 days while the larval duration was 20-28 days (Choldamrongkul 1990). However, both studies had not yet shown the complete life cycle studied but the confirmation of the univoltive cycle of the borer. Hence, the aims of these studies were to investigate the complete life cycle of *Cyrtotrachelus dichrous* which was the major bamboo shoot borer population of Tak province and also to observe the behaviors for mating sex and attraction, larval food consumption, pupal site searching and tunnel formation.

As sweet bambo is edible and harvested within 1-2 weeks after emergence from culm, the control measure by using biological agent against the borer is needed. The entomopathogenic nematode, *Steinernema carpocapsae*, has been long well known to give good control of insects especially soil inhabitants (Gaugler 1981 and Kaya 1985). In Thailand, there were success of the uses of the nematode on 19 economic insect pests (Somsook 1991). The attempts to control the borer in this study were determined to be at the pupal stage by using different concentration of the nematode suspensions for soil treatment.

## MATERIALS AND METHODS

### I. Life Cycle Study

The study was carried out in the field of bamboo plantations of Amphoe Mae Sot, Pob Phra and Mae Ramad of Tak province, North of Thailand during May-October of 1993 and 1994. A number of large nylon net field cages of diameter 1 m and 2 m high were hung to cover new bamboo shoots aged 1.5-2 weeks. The openings of the net cages were securely sealed into the dug soil around each caged bamboo shoot. There were a pair of male and female adults caught from field released in each cage. Observation and records started when the eggs were newly oviposited in the caged shoots. There were maximum of 2 eggs allowed on each shoot for the optimum food competition of the larvae and the convenience of the notation of the moults. When the shoot had been already infested by two eggs, the adult couple were removed to a new shoot for more egg oviposition, there were the total of 52 adults used and the total of 50 eggs collected.

Each hatched larva was naturally reared *in vivo* in the field on the caged bamboo shoot which was cut opened for the record of larval development and behaviors. When the consumed shoot started getting unfavorable to the larval feed, the larva was transferred to a fresh and newly cut-opened or to an artificially hollowed shoot for the larval continuous feed until the larva reached its pre-pupation stage. For pre-pupation, each pre-pupating larva searched for its pupation site in the soil nearby the shoot. The pupation tracks and tunnels were traced twice daily to ensure the correct date of pupation, then a square net cage of 45x75x40 cms was put out to cover the tunnel area in order to capture the newly emerged adult after the first rain of next rainy season in May 1994. All the cages were numbered with the records of pre-pupation and pupation dates. Meteorological data on temperatures and rainfalls of 1993 and 1994 were also noted at Mae Sot Site.

In May 1994, the newly emerged adults were recorded for emergence, dates then paired and put in the nylon-net field cage (as used at the beginning of the experiment in 1993). The adult life span and the female fecundity were recorded. There were the total of 50 individual adults observed.

### II. Behavior Studies

The observations on the borer behaviors for oviposition, larval food consumption, pre-pupation, pupal site searching and pupation were recorded from nature as well as from those reared individuals in the experimental cages for the life cycle study.

### III. Control by using *S. carpocapsae*

The experimental design was randomized complete block (RCB) with 10 replications and 4 concentration rates of applications (treatments) *i.e.*, 0, $2x10^6$, $4x10^6$ and $8x10^6$ nematode individuals per 10 $m^2$ of soil surface areas. The experimental soil area was chosen, hoe ploughed and numbered. Each treated soil area was soakedly watered followed by

watering of each treatment nematode suspension by mean of a water container, then numbered and tagged for each suspension concentration and replication number. There was one larva used for each treatment, therefore, there were the total of 40 larvae used. Mortality counts took place after two weeks of the applications and were done by hoe diging. Dead pupae were collected to laboratory for the test on causal organism. The experiment carried out in Mae Pa district of Tak province during August-September 1994.

## RESULTS

### I. Life Cycle Study

The eggs were creamy white, oval and laid singly in the skin of the young bamboo leaf sheathes (Fig. 1). All observed eggs indicated the solid two days of the egg duration. The larva was creamy in color with strong and tough skin with brownish black head capsule. The total laval stage duration was 8-15 ( $\bar{X}$ = 12.3±2.05 ) days and possessed 3 moults and 4 instars with the consecutive stadia of 2-3 ( $\bar{X}$ = 2.2±0.38) days, 2-3 ( $\bar{X}$ = 2.7±0.54) days, 2-4 ( $\bar{X}$ = 2.9±0.63) days and 3-5 ( $\bar{X}$ = 4.5±5.2) days respectively. Pre-pupation duration was 2-5 ( $\bar{X}$ = 3.81±1.11) days while pupation was the only over-seasonal stage from dry season through summer with the duration of 7-9 months. The pupa was exarate, creamy white and concealed within a loosely built leaf-cocoon in the soil. The adult life span was 1-2 ( $\bar{X}$ = 1.5±0.59) months. The borer showed a univoltine duration. The total life cycle was tabulated in Table 1. with meteorological data shown in Table 2.

### II Behavior Studies

#### Larval Behavior

The significant injury behavior caused by the bamboo shoot borer was the tunelling of the larvae within the emerged bamboo shoots (Fig. 2 and 3) followed by the infection of the soft rot bacteria, *Erwinia carotovora* (isolated by L. Wanapee, Plant Pathology Div., Dept. of Agriculture, Bangkok) which distributed by rain water to all nearby shoots. The borer infestation became very serious in cooperation of the soft rot bacteria in the water clogged areas after heavy rains. The larvae started boring into the shoot within 24 hours after hatch. The normal size of the bamboo shoot at the egg hatch was approximately 1-2 meters or at the shoot age of 1.5-2 weeks. The larvae fed and lived inside the shoot through out their life span of 8-15 days. Most tunnels were built upwards to the tip of the shoot and the larval growth was to compete with the growth of the shoot soft tissue before turning into a hard bamboo stem. The larvae turned downwards before prepupation and chewed a round exit hole of 1.5-2.0 cm in diameter as the exit of the pre-pupating larvae (Fig. 4). The larvae stopped eating and shortening their bodies which turned to golden yellow, rolled in spherical shape and dropped out of the exit holes on the soft soil near the bamboo culms. In the scarcity of the food at the end of rainy season (October). The females were forced to lay eggs on a grown up shoot as high as almost 3-5 meters, then

Table 1. Life cycle of the Bamboo shoot borer, *Cyrtotrachelus dichrous* in Tak province, Thailand during May 1993-October 1994.

| Development | min.-max. (d) | $\bar{X}$ ±Sd̄ (d) |
|---|---|---|
| Egg | 2.0 | 2.0 |
| Larva | | |
| 1st instar | 1-3 | 2.2±0.38 |
| 2nd instar | 2-3 | 2.7±0.54 |
| 3rd instar | 2-4 | 2.9±0.63 |
| 4th instar | 3-5 | 4.5±0.52 |
| Total | 8-15 | 12.3±2.05 |
| Pre-pupation | 2-5 | 3.81±1.11 |
| Pupation | 7-9 months | |
| Adult | 1-2 months | 1.5±0.59 months |

Table 2. Meteorological records of Amphoe Mae Sot, Tak province from 1993 to 1994*.

| Year/month | Temperature (°C) | | | Rainfall (mm) | | |
|---|---|---|---|---|---|---|
| | min. | max. | mean | min. | max. | mean |
| **1993** | | | | | | |
| June | 22.6 | 35.1 | 26.9 | 0 | 12.1 | 101.8 |
| July | 22.4 | 34.0 | 26.2 | 0 | 36.1 | 192.1 |
| August | 21.3 | 33.2 | 25.2 | 0 | 58.5 | 331.8 |
| September | 21.8 | 33.8 | 25.9 | 0 | 42.6 | 216.4 |
| October | 19.3 | 34.4 | 25.9 | 0 | 53.8 | 68.9 |
| **1994** | | | | | | |
| June | 22.5 | 33.0 | 25.9 | 0 | 32.6 | 244.4 |
| July | 22.3 | 33.0 | 25.1 | 0 | 207.4 | 908.2 |
| August | 22.3 | 31.5 | 24.8 | 0 | 77.4 | 493.8 |
| September | 22.0 | 33.5 | 26.1 | 0 | 16.8 | 97.1 |
| October | 15.3 | 34.2 | 25.2 | 4.01 | 22.4 | 53.2 |

* Climatology Division, Meteorological Department, Bangkok 1993 and 1994

the larvae had to drop off from almost 5-6 meters high to pupate in the soil.

**Prepupation Behavior**

After the pre-pupal larva dropped vertically on the soil surface, it started crawling actively for an appropriate site for making pupation burrow. The selected ground was always with loose top soil, hidden under dry leaves. The larva then drilled vigorously into the soil. The favor disfance for pupation was 1-2 meters from the bamboo culm and at 5-8 inches depth (Fig. 5). The tunnel had 2 or 3 branched tunnel routes. All tunnels (normally 2 to 3) looked the same in size and had their openings up on to the soil surface separately. The larva made many laborous trips up and down the tunnels to collect the leaf litters or even fresh weed leaves around the tunnel openings to make pupal coccoon at the end of one of the tunnels. The coccoon building finished within 2-3 days after the larval drop out off the shoot and was signed by the dug soil plugged at the tunnel openings. The end of the tunnel where the pupal coccon lived was shut off by the tunnel wall that securely sealed or panelled by fine soil grain. The pupation cocoon was enclosed within the distance of 1-1.5 inches from the tunnel wall.

**Pupation Behavior**

The larva changed itself to an exarate pupa within the first week of pupation and after 45-50 days it changed to an immature adult with a very soft body and creamy white in color (Fig. 6). The stage was in hibernation for 7-9 months.

**Adult Behavior**

In nature, when the first heavy rain of next rainy season came, in May 1994, the emerging adult crawled out from the tunnel and flew to young bamboo tips in the plantation. The adult was not a long distance flier and was easily caught except when stayed on a very high bamboo stem. From field cage experiment, the newly emerged adults stayed without feeding for 12 to 24 hours, then started its feeding activities. Mating took place within the first week of emergence.

The observed mating behaviors started with the male attracted the female by pearching on a 5-6 m. bamboo stem which mostly stood up-high outstandingly, and fed on the young tip while waiting. The male kept waiting patiently for 6-24 hours when a female appeared and attracted to the water-soaked feeding wounds then, the male crawled on her back for mating while the female started feeding (Fig. 7). Sometimes the female's feeding process was stopped by mating interference which lasted for 2-4 hrs. After separation from the male, the fertile females searched for oviposition. For oviposition, the female made water-soaked wound in spindle or oval shape in the bamboo leaf sheath and probe her snout into the tissue to make a burrow for an egg. When there were plenty of shoot available, the favorite oviposition site was the young shoot of 1-1.5 weeks at the hight of 1-1.5 meters However, when the food was scarce towards the end of October the eggs were found in the older shoots of 2-3 weeks. The

Fig. 1. Egg of C. dichrous laid singly in the water-soaked, spindle shape wound in the young bamboo leaf sheath (egg drawn out to show the egg burrow).

Fig. 2. Larvae tunelled in the shoot.

Fig. 3. In a severe outbreak plantation of Tak province, there were more than 6 full grown larvae found in one bamboo shoot.

Fig. 4. An exit hole cut by a pre-pupating larva.

Fig. 5. A tunnel opening (pointed by blue ball pen) on soil surface to underground pupation site.

Fig. 6. An immature (hibernation) stage in the pupal cocoon.

Fig. 7. Mating of male (top) and female (below) adults.

eggs. were laid singly and were 1 to 4 eggs per shoot. The number of eggs per female was 25-60 and the fertility finished at 1-2 days before the female death.

### III. Control by using *S. carpocapsae*

The result from laboratory showed that all treatment mortality was due to the infection of *S. carpocapsae* except the control treatment of which one individual out of the total 10 individual pupae disappeared. The disappeared pupa was thought to be eaten by a predatory rodent, a wild rat, as its foot prints left on the dug up tunnel soil. However, 10% mortality was counted for control treatment. At $2x10^6$, $4x10^6$ and $8x10^6$ individual nematodes treatment concentrations, the percentages of mortality were 40, 80 and 100 respectively with abundance of the infectious nematodes seen viable under microscope. The result suggested the excellent control of *S. carpocapsae* against *C. dichrous*.

## DISCUSSION AND CONLUSION

The life cycle study showed that the borer was univoltine with a long hibernation period of 7-8 months in the soil. The egg duration was 2 days while the larva possessed 4 instars with the total larval duration of 8-15 ( $\bar{X} = 12.3 \pm 2.05$) days. The lava tunnelled into the shoot and brought in the soft rot bacteria, *E. carotovora*, through the wound opening. Pre-pupation encountered 2-5 days starting from shortening of the larval body, rolled off the exit hole for pupal site searching and building the tunnels. Pupation started when the cocoon was securely enclosed at the end of one of the tunnels. The pupa stayed in an exarate form for 45-50 days then turned into an immature adult in creamy color with a very soft and immobile body. This hibernation period lasted for 7-9 months and ended when the first heavy monsoon rain came in May. The adult stayed 1-2 ( $\bar{X} = 1.5 \pm 0.59$) months in bamboo plantation and started feeding within 12-24 hours after emergence. The male adult made water soaked feeding wounds on a high bamboo stem for a female sex attraction and kept on feeding while waiting for 6-24 hours. After mating, a female laid single eggs of 1-4 eggs per shoot. The female fecundily was almost to the last day of her life and there were 25-60 eggs per female.

This life cycle study showed slight differences in egg duration from the previous studies of Choenram (1993) in Petchabun province and of Choldamrongkul (1996) in Kanchanaburi province. The previous literatures stated that the egg durations were 4-5 and 3-5 days respectively. This may be due to the differences of the temperatures and rainfalls which differed annually at different geographical locations.

The most amazing and wonderful behavior was in the pre-pupation stage which encountered the dropping off of the pre-pupating larva from the prepared exit hole by the shortening and rolling of the larval body into a ball shape with head hidden inside in the manner of self-protection followed by the immediate searching for a suitable pupal site after touching the ground and fast drilling into the soil. The tunnels to pupal site were constructed with many branched tunnels of the same size and with 1 to 3 openings on the soil surface to false the enemies. The other superior self-protection behavior was the blind end of one of the tunnels to abide the pupal coccoon. The tunnel wall where the pupal coccoon was concealed was finely constructed and panelled by the very fine soil grains to blind all invaders. Hence, the pupal site allocation for measurement of depthness by not disturbing the life cycle observation and development were difficult and required experiences. The loss of the numbered pupae and the immature adults during hibernation by predation of rodents also depressed the borer population of the next season.

The control of the borer by soil application of the entomopathogenic nematode, *S. carpocapsae* was successful to 80% mortality at the concentration of $4x10^6$ nematode individuals/$10m^2$ and with 100% killed when the concentration was doubled to $8x10^6$ nematode individuals. However, natural predations by wild rats and human were very effective since the larvae were delicious meal for both natives.

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