

EFFECTS OF TEMPERATURE ON EMBRYONIC DEVELOPMENT OF BANANA WEEVIL *COSMOPOLITES SORDIDUS* GERMAR

L. TRAORE, C. S. GOLD¹, J. G. PILON et G. BOIVIN²

Department de Sciences Biologiques, Université de Montreal, C. P. 6128, Montreal (Quebec),
Canada, H3C 3J7

¹International Institute of Tropical Agriculture, P.O. Box 6247, Kampala, Uganda

²Agriculture Canada, Station de Recherches, 430 Boul. Gouin, Saint-Jean-sur-Richelieu (Quebec),
Canada J3B 3E6

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ABSTRACT

Developmental threshold and thermal requirements for eggs of banana weevil, *Cosmopolites sordidus* Germar, were determined under laboratory conditions at constant temperatures of 15, 18, 25, 27, 30, 32 and 34°C and a photoperiod of 12:12 L/D. The duration of the egg stage decreased from 34.9 days at 15°C to 4.9 days at 30°C, then increased again to 5.3 days at 32°C. Eggs did not hatch above the latter temperature although signs of embryonic development, such as formation of the head capsule, could be observed. Simple linear regression revealed a developmental threshold of 12°C and a thermal requirement of 89 days-degrees average. Highest rates of eclosion occurred between 25°C and 30°C.

Key Words: Banana weevil, *Cosmopolites sordidus*, development, thermal requirements

RÉSUMÉ

Le seuil et la constante thermique de développement des oeufs du charançon noir du bananier, *Cosmopolites sordidus* Germar ont été déterminés en laboratoire aux températures constantes de 15, 18, 25, 27, 30, 32 et 34°C et à une photoperiode de 12:12 (photophase/Scotophase). La durée du stade oeuf qui a été de 34.9 jours à 15°C s'est raccourcie à 30°C en passant à 4.9 jours; puis s'est accrue à 5.3 jours à 32°C. Au dessus de cette température aucun oeuf n'a éclos, bien que des signes de développement embryonnaire comme la formation de la capsule céphalique aient été observés. La régression linéaire entre le taux de développement et la température a révélé un seuil de 12°C et une constante thermique de 89 degrés-jours en moyenne pour l'accomplissement du développement embryonnaire. Les taux d'éclosion les plus élevés ont été observés entre 25°C et 30°C.

Mots clés: Charançon du bananier, constante thermique, *Cosmopolites sordidus*, développement

INTRODUCTION

Plantains (*Musa* spp. Type AAB) and highland bananas (Type AAA-EA) are among the most important staple crops in tropical Africa. Their production is threatened by a pest and disease complex including banana weevil (*Cosmopolites sordidus* Germar), nematodes, leaf spots and *Fusarium* wilt. Of these, *C. sordidus* has been reported as a "key" pest in both West and East Africa, contributing to yield declines and plantation deterioration (Swennen, 1984; INIBAP 1986; Gold *et al.*, 1993). Among *Musa* subgroups, plantains and highland bananas are especially susceptible to banana weevil (Haddad *et al.*, 1979; Mesquita *et al.*, 1984; Gold *et al.*, 1993).

The females oviposit into small cells created in the rhizome or base of the pseudostem. The larvae tunnel in the corm disrupting nutrient transport (Taylor, 1991), possibly interfering with root initiation and destroying existing roots and, in general, weakening the support structure of the plant. Damage includes snapping, toppling, stunted bunches, lengthened maturation times and reduced plantation life. Adult weevils are free living and feed on crop debris.

Classical biological control of banana weevil may be possible. The banana weevil, endemic to south-east Asia, is not considered a pest in its area of origin (P. Ooi, pers comm.). Generalist predators, attacking the weevil in crop residues, have been recovered in Indonesia and released in Africa and Latin America with limited success (Neuenschwander, 1988). The existence of egg parasitoids has not been explored although the weevil's biology suggests that the egg may be the stage most vulnerable to natural enemies (Neuenschwander, 1988; Koppenhoffer, *et al.*, 1993). Such parasitoids must be sought for in areas where climatic conditions, especially temperature, are most favorable for the development of banana weevils.

In this sense, the thermal constant for embryonic development can be used as an index in predicting the distribution of banana weevil and for selecting sites for foreign exploration. Moreover, information on embryonic development will be useful in developing mass rearing techniques for natural enemy production in biological control programmes.

The influence of temperature on the life cycle of *C. sordidus*, particularly embryonic development, has been studied by several authors (Cendena, 1922; Froggatt, 1923; Edwards, 1925; Fonceca, 1936; Cuille, 1950; Vilardebo, 1960; Beccari, 1967). However, the conditions under which these studies were carried out were not specified. Mesquita *et al.* (1983) and Schmitt (1993) examined egg eclosion at two different temperatures; however, data obtained from these studies are insufficient to describe the complete relationship between temperature and development of the banana weevil. This study, therefore, evaluated the embryonic development and mortality rates of banana weevil under seven constant temperatures. From the resulting data, a minimal temperature threshold and thermal requirements could be extrapolated.

MATERIALS AND METHODS

Embryonic development rates of banana weevil were determined at the International Institute of Tropical Agriculture Biological Control Centre for Africa (IITA/BCCA) in Cotonou, Benin. A colony of banana weevils was established with adults collected from various plantain stands in southern Benin (7–8°N. latitude, 0–300 masl and average temperatures around 27°C) between June 1991 and March 1992. The colony was maintained under laboratory conditions (23 ± 3°C; 12:12 dark/light).

Eggs were obtained by exposing fresh plantain (cultivar Agbagba) rhizome material (from 4–5-month-old plants) to banana weevil adults. The rhizomes were cut into thin slices (5–10 mm thick) and placed in 75 l plastic barrels. Six hundred adult weevils (male and female) were introduced into each barrel. High humidity was maintained by covering the colony with banana leaves and periodic misting with tap water.

Rhizome slices were changed every 12 hr and the eggs immediately extracted. Weevil eggs oviposited on the surface of rhizome tissues were collected with a camel-hair brush. Eggs inserted into the rhizome were extracted, under a microscope, with a sharp knife. Collected eggs were disinfected with a phtalimid fungicide and rinsed in distilled water. Eggs collected at the same time were treated as cohorts (normally 10–

50 eggs). Individual eggs were placed in No. 3 transparent polyethylene microcapsules (ca. 300 microliters) (cf. Boivin, 1986) to avoid contamination by fungal pathogens (eg. *Fusarium* spp.). The microcapsules were then distributed on wet filter paper and placed in a petri dish which was closed with parafilm.

Whereas only one temperature cabinet was available for this study, developmental rates for different temperatures (15, 18, 25, 27, 30, 32 and 34°C) were studied sequentially. For each temperature, four petri dishes were placed in a Percival incubator (over a period of 1 to 4 days) which was set at a constant temperature. The petri dishes were placed in plastic bowls (170 x 150 x 110 mm) to minimize temperature fluctuations within the temperature cabinet. In each incubator, temperature and relative humidity were recorded with a hygrothermograph while temperature in the bowls was measured every 12 hr with a thermal Technoterm 9500 model micro-processor. Relative humidity varied between 55 and 75% while temperature fluctuated within 0.5°C of the set temperature. Photoperiod was kept constant at 12 hr light with florescent lamps.

Eggs were observed daily under a binocular microscope. Signs of development (e.g. presence of mandibles) were noted and time of eclosion recorded. For each temperature, the experiment was terminated when a period of seven uninterrupted days without further eclosion elapsed. At 34°C, observations were stopped after three weeks without emergence following head capsules formation.

Measured parameters included incubation period (in days) and percentage of eggs

successfully eclosing. Data for the seven different temperatures were compared using analysis of variance (ANOVA) procedures with four replications (cohorts) for each temperature. Technically, the study design (sequential temperature regimes) do not fit the criteria for a random block analysis; therefore, interpretation of results should be seen as illustrative.

Developmental rates were related to temperature by non-linear regression (Harcourt and Yee, 1982) according to the following equation:

$$R(T) = a_0 + (a_1 * T) + (a_2 * T^2) + (a_3 * T^3)$$

where $R(T)$ is developmental rate with regard to experimental temperature, T is the incubation temperature and a_0 , a_1 , a_2 , a_3 are constants.

The lower thermal threshold was considered the juncture point of the regression line (temperature x developmental rate) on the X-axis. The thermal requirement in degree-days was calculated using Parent's (1969) formula:

$$C = (T - S) * D$$

where C = thermal requirement in degree-days, T = temperature during the experiment, S = developmental threshold and D = stage duration at temperature T .

RESULTS AND DISCUSSION

Temperature influenced both embryonic development and eclosion rates for banana weevils (Table 1). Duration of the egg stage lasted from

TABLE 1. Embryonic development times and eclosion rates for eggs of Banana Weevil *Cosmopolites sordidus* Germar, at seven constant temperatures.

Temperature (°C)	Eclosion (%)	Stage duration (days)	Range period	Days-degrees accumulated above 12°C
15	10.1 a ^a	34.9 a ^a (±3.1) ^b	32-40	104.7
18	30.1 b	13.4 b (±1.0)	12-30	80.4
25	42.4 c	5.8 c (±0.5)	6-8	75.9
27	42.6 c	5.3 c (±0.5)	5-6	79.5
30	37.1 c	4.9 c (±0.6)	4-6	88.2
32	22.7 bc	5.3 c (±0.6)	5-7	106.0
34	0.0	—	—	—

^aValues followed by the same letter are not significantly different by Fisher's PLSD test ($P \leq 0.001$)

^bStandard error values in parentheses

4.9 to 5.8 days between 25 and 32°C. However, egg development was considerably retarded at 15°C (34.9 days) and 18°C (13.4 days). Eclosion did not occur at 34°C, although presence of head capsules suggested that some embryonic development did occur. In general, eclosion rates were low (< 45%) with greatest success between 25 and 30°C. Both developmental rates and egg success were significantly different among temperature regimes (Table 1).

Linear regression of developmental rate against temperature suggests a lower thermal threshold of 12°C. (Fig. 1). This requirement is outside the normal range of the host plant which has a lower temperature limit estimated at 16°C (Montcel, 1985). On the basis of this temperature threshold, *C. sordidus* requires on average 89.0 degree days to complete development (Table 1).

The optimal temperatures for weevil eclosion and egg development, 25–30°C., are typical temperatures within Benin as well as throughout the primary African plantain growing zone (e.g. Gabon to Cote d'Ivoire) (S. S. Jagtap, pers. comm.). Therefore, temperature does not appear to be a limiting factor for banana weevil distribution in West Africa. Nevertheless, banana weevil is present in some localities in the east African highlands where mean temperatures may fall below 25°C. This suggests the existence of local weevil biotypes with slightly different temperature requirements. However, banana weevil does not occur at higher elevations in Cameroon (Lescot, 1988) and Uganda (Speijer P. R., Karamura E. B. and Kashaija I. N., unpublished)

Our results are consistent with previous studies on embryonic development of *C. sordidus* which also have shown an inverse relationship between stage duration and temperature (Moznette, 1920; Edwards, 1934; Cuille, 1950; Schmitt, 1993). These studies show increasingly longer developmental times at lower temperatures. Similar results have been demonstrated for other insects (Desforges and Pilon, 1986; Jensen, 1990; Tillman and Powell, 1991; Miller and Paustian 1992).

As temperature approaches the lower threshold, weevil development slows dramatically and eclosion rates decrease; for example, a drop of 3°C, from 18° to 15°, resulted in a 2.5 fold increase in the length of the egg period and a 67% drop in eclosion. Although it is likely that *C.*

sordidus has ecological races sensitive to local environments, the data suggest a cold sensitivity which may explain why banana weevils do not occur at higher elevations.

Handling during extraction of eggs may have increased mortality while placement of eggs in micro-capsules may also have reduced survivorship, as well. Moreover, extracted eggs are susceptible to desiccation. Bakyalire and Ogenga-Latigo (1992) reported eclosion rates of 62–73% while Schmitt (1993) found 56% of banana weevil eggs hatched. However, it is unclear if these studies reported egg viability only or included pathogen induced mortality. Data on "in situ" eclosion rates are unavailable; undoubtedly, banana weevil eggs have much higher success rates within the banana plant.

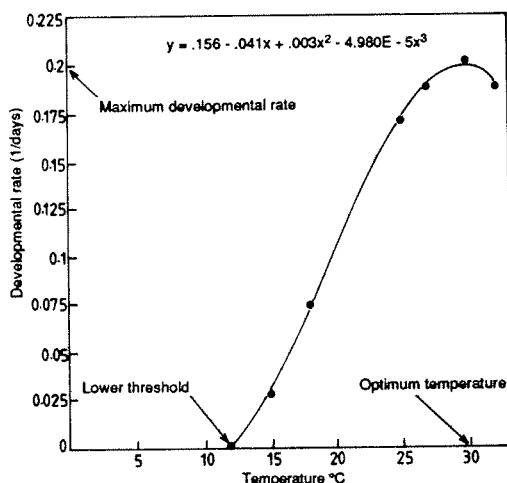


Figure 1. Development rates of banana weevil eggs incubated at 15–34°C. The curve was fitted to the mean rate by polynomial regression (Harcourt and Yee, 1982).

The relationship between temperature and embryonic developmental rate for banana weevil eggs (Fig. 1) shows that the thermal optimum, or temperature level most favourable for the egg stage is between 25 and 30° C. This temperature range is commonly found across the tropical regions where banana is grown. Nevertheless, these data suggest that weevil distribution within the tropics, may be limited by temperature.

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