Temperature-Dependent Development and Mortality of Australian Cockroach, *Periplaneta australasiae* (Fabricius) (*Blattodea*: *Blattidae*)

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Abstract

Stejskal V., Lukáš J., Aulický R. (2004): **Temperature-dependent development and mortality of Australian cockroach,** *Periplaneta australasiae* (Fabricius) (*Blattodea*: *Blattidae*). Plant Protect. Sci., **40**: 11–15.

The effect of temperature on the development of the 1st instar of *Periplaneta australasiae* (Fabr.) was studied at the four constant temperatures of 21°C, 24°C, 27°C and 30°C in temperature-controlled chambers. Mortality was 50% at 30°C, and 10% at 21°C, 24° and 27°C. Thermal constants were established by plotting linear regression to development rate. The thermal threshold for the development was 17.1°C and the thermal constant for 1st instar larvae was 147.1 day-degrees. As "safe temperature" (t_s) – the temperature to be maintained in stores or food premises to prevent the development of a pest species – we recommend 16°C.

Keywords: *Periplaneta australasiae*; development; thermal constants; thermal threshold; glasshouses; urban pest

Cockroaches are one of the most serious stored product, medical and agricultural pests worldwide (Cornwell 1968; Stejskal 1993; Stejskal & Verner 1996; Sanchez-Borges *et al*. 2003). Most of the synanthropic and stored product pests originate from tropical and subtropical regions (Stejskal & Honěk 1998; Stejskal & Kučerová 1993, 1996). The Australian cockroach, *Periplaneta australasiae* (Fabricius.), is no exception. This tropical synanthropic cockroach (Wang *et al*. 1995; Tawatsin *et al*. 2001; Sanchez-Borges *et al*. 2003) is currently spreading into the temperate zone (Lukas 1906; Stejskal *et al*. 1993; Bell *et al*. 1996; Mielke 1998, 2001). Glasshouses and food industry facilities offer optimal living conditions for this species. For example, Mielke (2001) reported a recent mass appearance of the Australian cockroach in a greenhouse in Magdeburg, Germany. It was shown that this species can feed not only on stored products but also on living plants (Bell *et al*. 1996). In addition, together with *Pycnoscelus surinamensis* (L.), *Periplaneta australasiae* is classified as the most serious invasive cockroach species since it invades undisturbed habitats (Peck & Roth 1992).

Integrated strategies to control geographical spread and, once established, population growth (Bell *et al*. 1996) of *P. australasiae* should include a predictive modeling. Such a predictive model requires data on the effect of temperature on development, which so far has not been established. The knowledge of thermal constants – lower development thresholds in particular – provides essential information to determine the development rate of a particular species of arthropod (Subramanyam *et al*. 1990; Honěk 1996a, b).

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Therefore, the goal of this work was to determine the lower development threshold (LDT) and sums of effective temperatures (SET) in *P. australasiae* and compare them with those of another synanthropic cockroach, *Blattella germanica* (L.) (Stejskal *et al*. 2003).

MATERIALS AND METHODS

A strain of *P. australasiae* from the reference laboratory of RICP and sensitive to pesticides was used for the experiments. The RICP strain is kept at a constant temperature of 25°C, at L12: D12 photoperiod and RH 75%. We studied the effect of temperature on the development of the 1st instar of *P. australasiae* assuming "rate isomorphy" (Jarošík *et al*. 2002). This principle implies that LDT is the same over the whole development. The experiments were conducted in parallel in five replication in four temperature-controlled chambers, with a constant temperature of either 21°C, 24°C, 27°C or 30 ± 0.5°C, at L16:D8 photoperiod and RH 75%. Larvae of the 1st instar 0–12 h after hatching (n_j – see Table 1) were placed into each temperature. The molting to 2nd instar (n – see Table 1) was checked at 12 h intervals. For each temperature, rate of development (DR: day^{-1}), a reciprocal of the development duration, was calculated for the 1st instar. The relationships between developmental rate (DR) and temperature (T) were described by a linear model:

$$DR = a + bT \quad (1)$$

where: a and b – parameters of the linear regression

From here, the lower developmental threshold (LDT), i.e. the temperatures when development ceases, can be estimated as

$$LDT = -a/b \quad (2)$$

as the sum of effective temperatures (SET) (number of day-degrees above LDT necessary for completion of development) as

$$SET = 1/b \quad (3)$$

Regression equations and parameters values were estimated from the mean developmental rates by the Least Squares algorithm using the linear procedure of QC.Expert™ 2.5 (TriloByte® Ltd.) statistical software program (Kupka 2002). The following criteria were used to assess the performance of each model and the precision of model fit: the coefficient of determination (R^2), the residual sum of squares (RSS), mean square prediction error (MEP) and Akaike information criterion (AIC). The better model is indicated by lower RSS, MEP and AIC, and a higher R^2.

RESULTS

The temperature-dependent effects on rate of development (RD) of *P. australasiae* are summarised in Table 1 and Figures 1 and 2. The average duration of development time of the 1st instar of *P. australasiae*

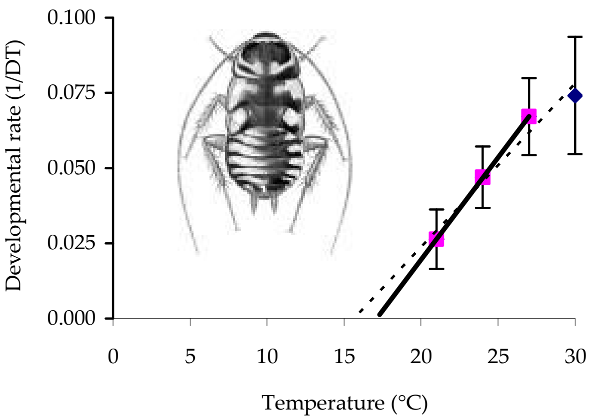

Figure 1. Temperature-dependent rates of development of the 1st instar of *Periplaneta australasiae*

Table 1. Temperature-dependent developmental parameters of the 1st instar of *Periplaneta australasiae*

Temperature (°C)	n_j	n	Mean ± SD (days)	Minimum (days)	Maximum (days)	Median (days)
21	114	99	37.9 ± 13.6	21.0	67.0	36.0
24	108	93	21.3 ± 4.6	14.9	32.3	20.3
27	107	89	14.9 ± 3.2	9.0	28.8	14.0
30	104	42	13.5 ± 4.4	9.0	28.0	11.5

n_i – initial number of the 1st instar larvae; n – number of larvae of molted in 2nd instar

Table 2. Parameters and criteria of linear models based on the data of means of developmental rates from two different temperature intervals

	Slope ± SD	Intercept ± SD	R^2	RSS	MEP	AIC
T (21; 27)	0.006798 ± 0.0000123	–0.116327 ± 0.000297	0.99*	2.738E-009*	1.232E-008*	–58.4*
T (21; 30)	0.005446 ± 0.000780	–0.085224 ± 0.020081	0.96	5.486E-005	8.216E-005	–40.7

*better value of given criteria of compared models

was 37.9 d at 21°C, 21.3 d at 24°C, 14.9 d at 27°C and 13.5 d at 30°C. The regressions of development rate on temperature were calculated using data of 21–30°C or 21–27°C (Table 2). The model using data of 21–27°C was better than the model using data of 21–30°C. The slope was 0.006798 and the intercept was –0.116327 (R^2 = 0.99) (Table 2). From here we computed LDT = 17.1°C and SET = 147.1 day-degrees. The temperature-dependent rate of mortality *P. australasiae* is summarised in Figure 2. Mortality rate decreased slightly in the interval of 21–27°C, reaching a maximum of 10%. A different trend was found at 30°C, where maximum mortality was 50%.

DISCUSSION

We found that the lower developmental threshold (LDT) of *P. australasiae* was 17.1°C, and the thermal constant for the development (SET) of 1st instar larvae was 147.1 day-degrees. The mortality rate increased with temperature, being signifi-

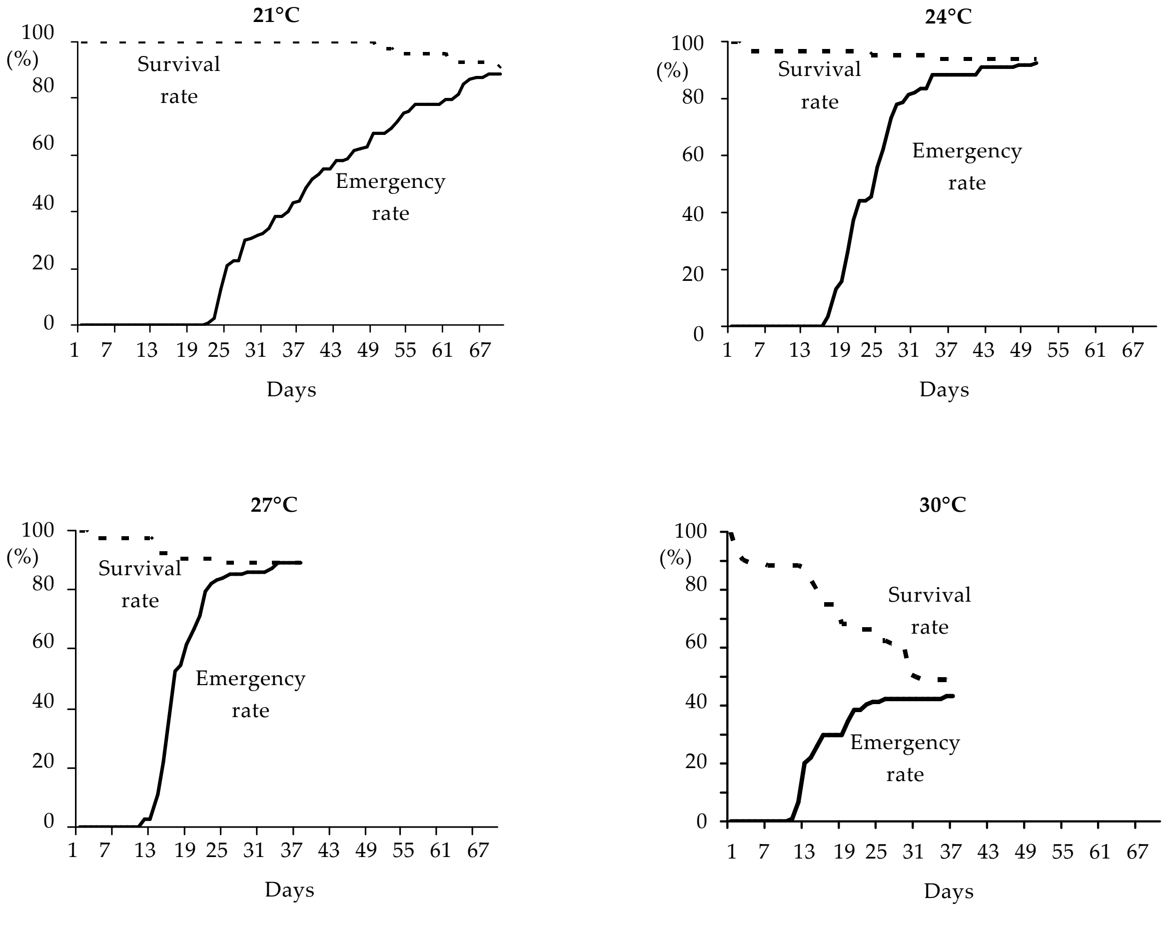

Figure 2. The temperature-dependent rate of emergence (solid line) and survival (dotted line) of *Periplaneta australasiae*

cantly higher at 30°C than at lower temperatures. While LDT was similar in *P. australasiae* and *B. germanica* (LDT = 16.2°C), SET in *P. australasiae* was much higher than in *B. germanica* (SET = 99.3 day-degrees) (Stejskal *et al.* 2003). High LDT is typical for insects of subtropical and tropical origin (Honěk 1996b). We determined 16°C as the approximate value of "safe temperature" (t_s) – which means a temperature to be maintained in stores or food premises to prevent the development of a pest species (i.e. $t_s \leq$ LDT). Cockroaches and their oothecae are frequently introduced into buildings with infested batches of stored products from external sources. Thus, it is necessary to detect the infested batches as early as possible to (i) prevent the spread of pests from them by pesticide treatment, and (ii) to trace back the external source of infestation and stop further introduction of infested material from the suspect source. Currently, the dominant monitoring and detection technique are pheromone/food-baited traps (Waldow & Sass 1984; Nishino & Manabe 1985; Takahashi *et al*. 1988; Stejskal 1998; Lukáš & Stejskal 2003). Yet by traps we can only detect the mobile stadium of cockroaches. Since oothecae are immobile and the 1st instars of cockroaches do not leave the shelter, the 2nd and higher instars of cockroaches caneasier be detected by catching them in traps (Stejskal 1998). Thus the sum of effective temperatures (SET) can be used to predict the time of appearance of the 2nd instars of *P. australasiae* in a newly infested facility. For example, from our data it can be predicted that the 2nd instar of *P. australasiae* appears in traps about 18 d at facilities with an average temperature of 25°C. At this temperature, the development time of *P. australasiae* is almost twice that of *B. germanica* (10.5 days) (Stejskal *et al*. 2003).

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Souhrn

Stejskal V., Lukáš J., Aulický R. (2003): **Vliv teploty na vývoj a mortalitu švába australského**, *Periplaneta australasiae* (Fabricius) (*Blattodea: Blattidae*). Plant Protect. Sci., **40**: 11–15**.**

Šváb australský *(Periplaneta australasiae)* je synantropní šváb, který se vyskytuje v oblasti tropického i mírného pásu. Je schopen způsobit vážné ekonomické škody okusem jak skladovaných produktů, tak pletiv živých rostlin. Cílem práce bylo zjistit spodní teplotní práh (SPV) vývoje švába australského (*P. australasiae)*, pod kterým je vývoj zastaven a na základě dalších získaných teplotních charakteristik zpřesnit předvídatelnost nebezpečí geografického šíření a aktuálního přemnožení tohoto škůdce. V laboratorních podmínkách byl při 4 konstantních teplotách (21 °C, 24 °C, 27 °C a 30 °C) sledován vývoj 1. instaru *P. australasiae*. Byl nalezen pozitivní vztah mezi teplotou a mortalitou; při teplotě 30 °C dosáhla mortalita 50 % proti 10 % mortality při teplotách 21 °C, 24 °C a 27 °C. Pomocí lineární regrese byl z naměřených rychlostí vývoje vypočten spodní práh vývoje (1617,61 °C) a termální konstanta (SET = 150 147,1 denních stupňů – DS). Bezpečná teplota (t_b), při které je ve skladech a potravinářských provozech zaručeno zastavení vývoje tohoto druhu, je 1516 °C. Geografické oblasti, ve kterých může suma efektivních teplot dosáhnout 150 DD nad spodním prahem vývoje 16,6 °C, jsou ohroženy invazí a kolonizací *P. australasiae*.

Klíčová slova: šváb australský; doba vývoje; spodní práh vývoje; termální konstanta; městští škůdci; skleníky

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