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Temperature-dependent development and survivorship of *Idaea inquinata* (Scopoli) (Lepidoptera Geometridae) eggs at two humidity levels

Abstract - *Idaea inquinata* (Scopoli) mainly feeds on dried plants, nevertheless, it is also a potential pest of stored product as it is able to develop on cereal products. The few references on the biology of this species do not deal with the influence of temperature and relative humidity on egg hatching. To fill this gap, groups of 100 eggs, 24-48 hours old, were exposed to constant temperatures (13, 15, 36, and 38±1 °C), two relative humidities (35, 70±5%) and a photoperiod of 0:24 (Light:Dark); eight tests were carried out. Each test was replicated four times. The lowest proportion of hatched eggs was observed at 15 °C (9.5) and 36 °C (8.7) with 35±5% R.H. while at 13 and 38 °C eggs did not hatch. A non-linear function is used to represent the developmental rates and survivorship of eggs at 35 and 70% R.H. between lower and upper thresholds temperature.

Riassunto - *Sviluppo e sopravvivenza di uova di* Idaea inquinata *(Scopoli) (Lepidoptera Geometridae) a diverse temperature e umidità*.

Idaea inquinata (Scopoli) si sviluppa principalmente su piante essiccate, tuttavia è un potenziale infestante di cereali e derivati. La biologia di questa specie è poco conosciuta, in particolare non ci sono informazioni sull'influenza di temperatura e umidità relativa sulla schiusura delle uova.
Gruppi di 100 uova deposte da 24-48 ore sono state poste a temperature costanti (13, 15, 36, e 38±1 °C), due diversi valori di umidità relativa (35, 70±5%) e fotoperiodo 0:24 (Luce:Buio); sono state condotte otto prove, replicate quattro volte. Il numero più basso di uova schiuse è stato osservato a 15 °C (9,5) e 36 °C (8,7) con 35±5% U.R. mentre a 13 e 38 °C le uova non sono schiuse. Una funzione non lineare è stata impiegata per rappresentare il tasso di sviluppo e la sopravvivenza delle uova alle due umidità considerando il limite inferiore e superiore di temperatura.

Key words: Eggs hatching, Temperature, Relative humidity, Rusty wave moth

INTRODUCTION

Idaea inquinata (Scopoli) can be a serious pest in warehouses where dehydrated plants and cereals are stored; spices and medicinal plants can be heavily damaged and made unsuitable to essential oil extraction (Candura 1931a, b; Locatelli *et al*., 2005).

There are few references to the biology of this species (Candura 1931a; Locatelli *et al*., op.cit.). According to Candura, each female laid one hundred eggs within a week, oviposition started on the 4th and lasted until the 11th day. Eggs were laid singly or in pairs, and hatching occurred between the 4th and the 15th day, according to the season and to the weather, in a temperature range of 19-28 °C. Limonta *et al*. (2010) studied egg hatching at five temperature and two values of relative humidity, observing that *I. inquinata* tolerates a low relative humidity and high temperatures; in fact, high percentages of eggs hatched even at 34 °C at both relative humidities tested (35 and 70% R.H.). With 35% and 70% R.H., at 29 and 34 °C, the hatching period was the same but was shorter at 17, 21, 26 °C. At 17 °C, both at 35 and 70% R.H., a lower egg hatch and longer hatching period was observed. A significantly higher number of hatched eggs was observed at 26 and 29 °C at 70% R.H.

This paper deals with eggs development and survival at different temperatures and two humidity levels, tests were carried out in order to identify the thermal thresholds. The results are a contribution to the development of an integrated pest management system in warehouses.

MATERIALS AND METHODS

Idaea inquinata has been reared continuously for 6 years, on an artificial diet[1] in a thermostatic chamber at 26±1°C, 70±5% R.H. and photoperiod of 16:8 (Light:Dark). Ten newly formed couples were isolated and the number of eggs layed by each female was recorded.

Groups of 100 eggs, were put in Petri dishes (diameter 6 cm) at different temperatures and relative humidities. Specifically, 24-48 hours old eggs were used as more tolerant to cold than newly layed eggs (Bell, 1975). Tests were carried out at 13, 15, and 36, 38±1°C with two levels of relative humidity (35 and 70±5%) and a photoperiod of 0:24 (Light:Dark). Each combination of temperature and humidity was replicated four times. Egg hatching was observed daily. Eggs were considered hatched when the young larvae successfully chewed emergence holes in the chorion and left the egg shell. Observation were carried out daily until eggs appeared not viable.

For each level of relative humidity, the data of this and of a previous research summarized in the introduction section and published by Limonta *et al*. (2010) were submitted to ANOVA and Duncan's multiple range test (SPSS 17.0 for Windows and Microsoft Excel 2003).

The model of Brière *et al*. (1999) was used to predict the curvilinear relationship in the entire temperature range permitting development

$$r(T) = \alpha\, T\,(T - T_{min})\,(T_{max} - T)^{0.5}. \quad (1)$$

[1] Ingredients: 114 g bran, 61 g corn flour, 55 g wheat flour, 17 g wheat germ, 14 g dried yeast, 85 g glycerine, 67 g honey. The diet was stored in polyethylene bags at 6 °C.

The parameters T_{min}, T_{max}, α were estimated on the basis of our observations on individuals *via* non-linear least square regression techniques implemented in the SPSS Statistics 17.00 software.

The stage-specific survivorships (ε) between the upper T_{max} and the lower T_{min} thresholds for development is based on the Beta function

$$\varepsilon(T) = a\,(T - T_{min})^{b}\,(T_{max} - T)^{c}. \quad (2)$$

The values of T_{min}, T_{max} have been obtained from equation 1, while the parameters a, b, c were estimated on the basis of our observations on individuals *via* non-linear least square regression techniques implemented in the SPSS Statistics 17.00 software.

RESULTS

Idaea inquinata eggs are pearly colored, with a netlike pattern, maximum width is 5/7 of length. When eggs are just laid they adhere by the poles building a short lived coil, after a while they split.

The mean number of eggs laid by a female was 154.3±46.21 (SD), with range 76-211, and a mean hatching of 82. 8% (72.81-90.65).

Table 1 - Mean number (SD) of eggs of Idaea inquinata *(Scopoli) hatched at 13, 15, 17, 21, 26, 29, 34, 36, 38 and 40 °C, 35 and 70 % R.H.*

°C	% R.H.			
	35		70	
	Mean (SD)	Min-max	Mean (SD)	Min-max
13	0	-	0	-
15	9.5(1.29)a	8-11	25.2(2.75)a	22-28
17*	64.7(7.85)b	57-72	61.5(11.12)b	51-73
21*	83.5(3.87)c	79-88	73.7(7.27)c	63-79
26*	77.5(3.87)c	72-81	91.5(2.38)d	89-94
29*	78.5(3.51)c	75-82	91.0(6.48)d	84-97
34*	79.7(4.27)c	74-83	81.7(5.91)cd	73-86
36	8.7(5.85)a	2-15	15.5(10.78)a	4-30
38	0	-	0	-

35% R.H.: $F_{5,18}$=199.12 P<0.001; 70% R.H.: $F_{5,18}$=70.01 P<0.001
*data from Limonta *et al*., 2010.

Eggs hatched in the temperature range 15-36 °C with both the tested value of relative humidity (Tab. 1). At 36 °C a limited number of eggs hatched and newly born larvae died within few hours and a third of the larvae died when hatching from the egg. At 13 and 38 °C egg hatching was not observed.

At 15 °C the mean number of hatched eggs was 9.5±1.29 (SD) with 35% R.H., and 25.2±2.75 with 70%; at 36 °C the mean number of hatched eggs was 8.7±5.85 (SD) with 35% R.H., and 15.5±5.91 with 70%.

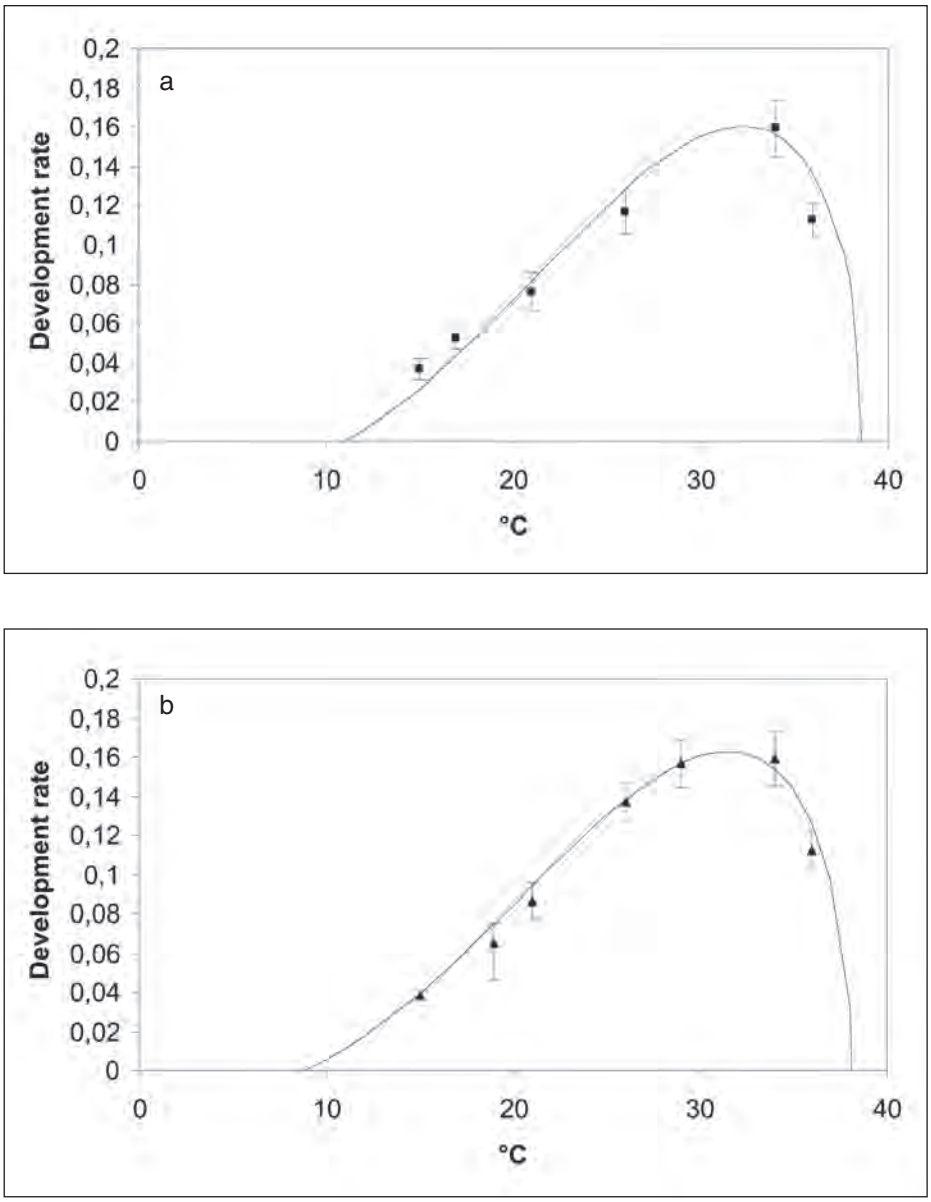

Figure 1 - The observed and predicted developmental rates of eggs of *Idaea inquinata* (Scopoli) at different temperatures with 35 (a) and 70% R.H. (b). (■▲: our data, used to parametrize the developmental rate functions. The rates are predicted by $r(T) = \alpha\, T\,(T - T_{min})\,(T_{max} - T)^{0.5}$ with the stage specific parameters (α, T_{min}, T_{max}) reported in Table 2).

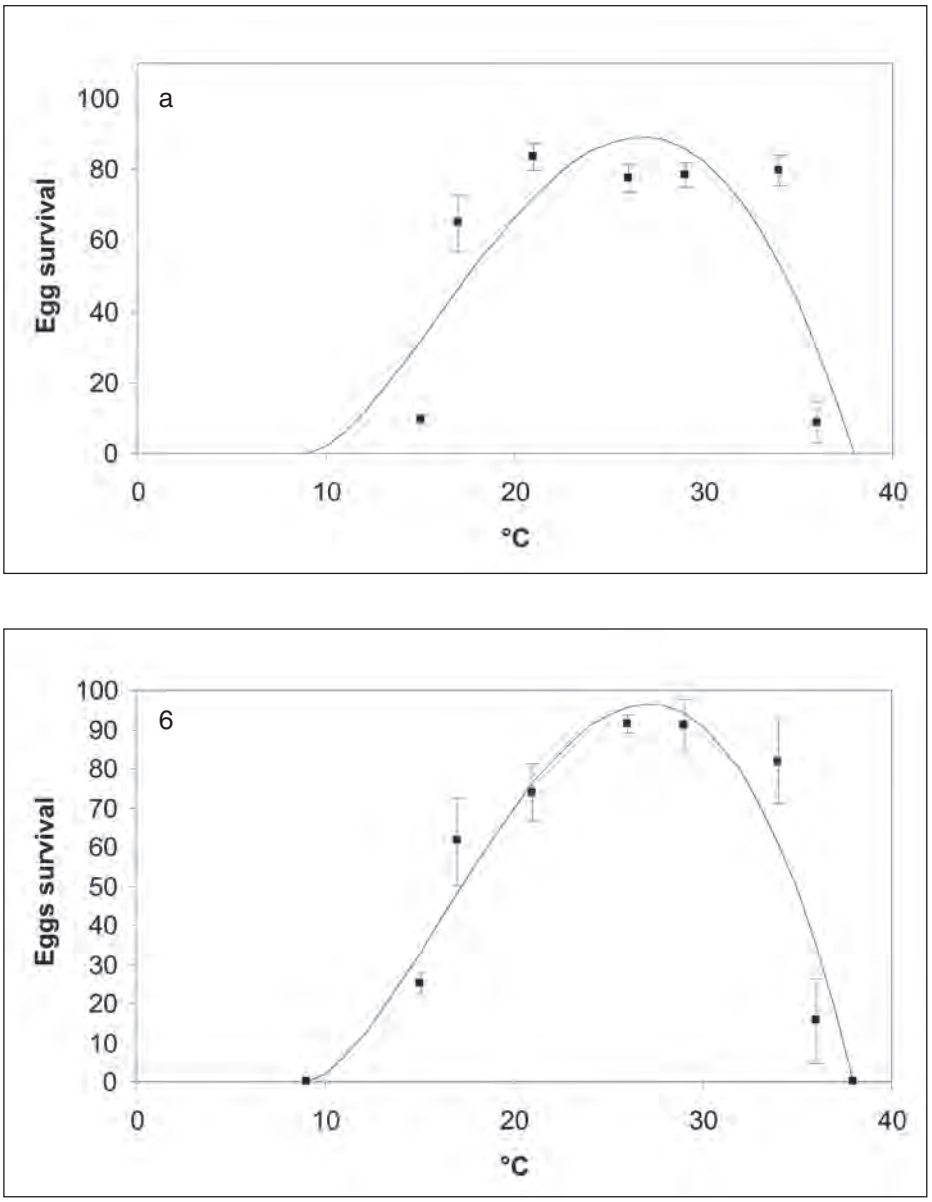

Figure 2 - The observed and predicted stage specific survival of eggs of *Idaea inquinata* (Scopoli) at different temperatures. with 35 (a) and 70% R.H. (b). (■▲: our data, used to parametrize the developmental rate functions. The survival is predicted by $\varepsilon(T) = a\,(T - T_{min})^{b}\,(T_{max} - T)^{c}$ with the stage specific parameters (a, T_{min}, T_{max}, b, c) reported in Table 2).

Table 2 - Parameter estimates and standard errors (SE) for the developmental rate (eq. 1) and surivival rate (eq. 2) for Idaea inquinata *(Scopoli) eggs (T_{min} = minimum temperature for development and survival, T_{max} = maximum temperature for development and survival).*

% R.H.	N	T_{min} [°C] (SE)	T_{max} [°C] (SE)	α (SE)	a (SE)	b (SE)	c (SE)
35	400	11.01 (0.165)	38.65 (0.104)	0.0096 (0.0000015)	0.65 (0.87)	1.634 (0.317)	1.043 (0.212)
70	400	8.86 (0.174)	38.10 (0.069)	0.00008888 (0.0000)	0.77 (0.71)	1.644 (1.043)	0.993 (0.142)

In fig. 1 the observed and predicted developmental rates of eggs of *I. inquinata* were reported and the curves for both the values of relative humidity are similar regarding the upper temperature of development (Table 2) and the higher developmental rate (32 °C), while the lower temperature of development is lower with 70% R.H. Brière *et al.* (1999) model satisfactorily represented the developmental rates.

In fig. 2 the observed and the predicted egg survival at the two values of relative humidity are depicted. By visual examination, the survival appears to be better represented by equation 2 in fig. 2b than in fig. 2a.

DISCUSSION

A higher mean number of hatched eggs of *Idaea inquinata* (Scopoli) was observed with 70% R.H. at the threshold temperatures of 15 and 36 °C. In the case of *Ephestia kuehniella* Zeller, Jacob & Cox (1977) found that "humidity has little influence on egg development and developmental periods increase only at very low relative humidities".

Eggs of *I. inquinata* did not hatch at 13 °C, and this lower threshold is similar to the one of *Plodia interpunctella* (Hübner), that is 13.5 °C (Savov, 1973). In the range 15-36 °C *I. inquinata* eggs hatched, as in *Ephestia cautella* (Walker) that complete embryonic development within 14-36 °C (Nawrot, 1979). The thermal thresholds for *Ephestia figulilella* Gregson and *E. calidella* (Guenee) are within 15 and 36 °C with 70% RH. *Corcyra cephalonica* (Stainton) eggs cannot survive out of the range 17.5-32.5 °C (Cox *et al*., 1981), while *Sitotroga cerealella* Oliver eggs hatch at 35 °C with different values of R.H. (Maity *et al*., 1999).

In *I. inquinata* at 36 °C, a limited number of eggs hatched, and larvae do not survived. At 38 °C eggs collapsed, as in *Galleria mellonella* L. where at 40 °C eggs dried, became brownish and did not hatch (Kumar *et al*., 2009).

Results of this study suggest that storing at 13 or at 38 °C can prevent the development of the Rusty wave moth. The use of high temperatures is not applicable as the properties of medicinal plants could be destroyed.

The equation 1 proposed by Briére *et al*. (1999) and equation 2 satisfactorily represent the developmental rates and the survival of eggs of *I. inquinata* at different temperatures. The same result has been obtained for other insects life stages reported in the literature

(e.g. Bell, 1975; Maity *et al*., 1999). In this paper different parameters have been found for the to humidity regimes under study. The predicted lower developmental threshold is lower at higher humidity, whereas the upper threshold appears to be similar at both relative humidities. This indicate that *I. inquinata* eggs find more suitable conditions at higher humidity than at lower values.

Here we assumed that thresholds for survival are equal to the thresholds obtained for the developmental rates. This assumption may be justified by the scope of this work, but should be revised if a more precise representation of the survival at temperature extremes is required.

This paper allows to make some tentative raccomandations on the management of this pest. First, in order to prevent development of *I. inquinata* on medicinal plants, they must be stored at temperature below 13 °C, a method economically sustainable. It is important to consider the distribution of interstitial space in the plant species and the part of the plant stocked as they influence the time necessary to obtain a uniform temperature in the commodity. Second the relationships between developmental rates and temperatures as well as humidities can be used as a component in a forecasting system.

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