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Department of Entomology, University of Life Sciences in Lublin
S. Leszczyńskiego 7, 20-069 Lublin
e-mail: edyta.drabik@up.lublin.pl

EDYTA GÓRSKA-DRABIK

The effects of temperature on the development of the moth *Acrobasis advenella* (Zinck.) in the laboratory

Wpływ temperatury na długość rozwoju *Acrobasis advenella* (Zinck.) w warunkach laboratoryjnych

Summary. To clarify the biological characteristics of *A. advenella* and to establish a forecasting for the pest, the growth duration of individual stages and the developmental threshold temperature for *A. advenella* have been investigated. For the same developmental stages, the development duration significantly decreased as the temperature was increased from 22 to 26°C. At the temperature of 10°C females do not lay eggs, and the reared caterpillars and pupae died. The duration of the embryonic developmental stage in the tested ranges of temperatures was between 9.3 (26°C) to 25 days (14°C). The rate of 1st stage larvae development at the temperature of 26°C was the shortest – 10 days. The longest development of larvae was observed at the temperature of 14°C – 17 days. At the temperature of 26°C the development of the larvae of the 2nd instar lasted the shortest – 6 days. The longest developmental stage of larvae was observed at the temperature of 14°C – 8.9 days. Laboratory rearing showed that older larvae – of the 3rd and 4th stages developed the shortest at the temperature of 26°C (3.3 and 12 days, respectively). The longest developmental stage of larvae was observed at the 14°C and it was 11.5 days for the 3rd and 32 days for the 4th instar. The duration of the pupae development in the tested ranges of temperatures ranged between 15 (26°C) to 36.5 days (14°C). This information may be used to establish the dates of this pest control.

Key words: *Acrobasis advenella*, *Aronia melanocarpa*, temperature, development time

INTRODUCTION

Of all the known environmental factors, temperature is the primary one affecting insects growth and reproduction [Szujecki 1998]. Insects, as poikilothermic organisms, significantly change activity depending on the temperature of a surrounding environment [Bale *et al.* 2002, Menéndez 2007]. An increase of the temperature to the thermal optimum level hastens the metabolism of insects, what directly translates into intensification of their activity. Moreover, shorter time of development of preimaginal stages means shortening the time of exposition to unfavourable environmental conditions (low temperature, excessive or insufficient humidity, attack of predators and parasitoids), therefore may contribute to increasing the reproductive success of insects. Many studies have been conducted to determine the relationship between the temperature and development or reproduction of pests. The results have provided useful information for predicting the occurrence of various pests and the number of generations per year as well as for their control [Harman *et al.* 1990, Infante 2000, Walczak 2003, Fantinou *et al.* 2004, Kang *et al.* 2009, Limonta *et al.* 2010, Ju *et al.* 2011, Miller 2011].

Acrobasis advenella is a moth from the Pyralidae family and Phycitinae subfamily. It commonly occurs in Europe. The larvae feed on plants of the genus *Crataegus* and *Sorbus*, and some sources add *Prunus* as well [Goater 1986, Palm 1986, Slamka 1997]. *Acrobasis advenella* is spread all over Poland. It is commonly present on native species of host plants. The occurrence of *A. advenella* on *Aronia melanocarpa* [Michx.] Elliot which is an alien species to the fauna of Poland, was described for the first time in 2004 in Southeast Poland. Currently it is present on all black chokeberry plantations in whole Poland [Górska-Drabik 2009, Górska-Drabik 2013a, b]. The crops monoculture has created the ecological conditions and abundant food source for *A. advenella*. Therefore, this species had become a major pest of the black chokeberry. In a plantation with a high occurrence of *A. advenella,* the average number of infested chokeberry inflorescences is 11.5%, with maximum of about 92% [Górska-Drabik 2013a]. Larvae damage flower buds and fruits of host plant. Their feeding negatively influences both quantity and quality of yield [Górska-Drabik 2014]. Spring, larvae leave the overwintering place and inhabit developing flower buds, where they feed till black chokeberry flowering. A small number is still present during flowering and fruits setting. A small amount is still present during flowering and fruits setting. The last instar of larvae falling into the soil and form cocoons, in which they pupate. Moths appear (emerged) in the end of June and females lay eggs into calyces of immature fruits. Larvae of the 1st instar leave the egg chorion, enter the seeds and drill shallow tunnels inside [Górska-Drabik 2013a]. In the available literature there is no information about the effect of temperature on the *A. advenella* developmental stages.

To clarify the biological characteristics of *A. advenella* and to establish a forecasting for the pest, the growth duration of individual stages and the developmental threshold temperature for *A. advenella* have been investigated.

MATERIAL AND METHODS

A developmental duration stage was conducted in a laboratory conditions. Overwintering larvae (2nd stage) of *A. advenella* were collected from black chokeberry plants in Boduszyn (near Lublin), in 2011 and 2012. During winter, black chokeberry stems which are the place for overwintering of larvae, were cut out. In the laboratory they were observed under a binocular, and the pieces with cocoons hidden inside were kept in an insectarium till early spring. The rearing was carried out in cylindrical plexiglas insulators secured with gauze. In the bottom of each insulator inflorescences of black chokeberry in a moist floral foam were placed. The duration of larvae development was defined from the moment of leaving the winter cocoon and active feeding on a plant. The moment was related with larvae body colour changing. At the beginning, the rearing was checked every day, and later every 2–3 days. The floral foam was systematically moistened to keep the inflorescences fresh. If needed, the plant material was replaced with a fresh one. In the final stage of rearing the larvae in inflorescences, a little amount of soil was placed in a rearing box in order to allow the larvae to pupate. When the larvae was not observed on a host plant, the soil was examined under a binocular. To determine the moment of starting the pupae stage, the surface of a cocoon was gently cut open. When the adult stage emerged the sex was determined on the basis of morphological features. Moths were paired and placed in plastic insect cages containing unripe fruits, in which females laid eggs. Fruits were checked every day under a binocular and replaced with new ones. The embryonic development was observed. Moths were fed with 20% honey solution.

Rearing of insects were conducted in 2011 and 2012, in a KBK-65W climatic chamber. The conditions of the experiment were set as follows: stable temperatures of 10, 14, 18, 22 and 26^{o}C, humidity 75 ± 5% and L : D = 10 : 14 photoperiod.

Statistical analysis

The differences between the means for the variables were determined basing on an analysis of variance (ANOVA), assuming normality of distribution and homogeneity of variance. Significance of the difference between the means was tested using the method of Tukey's Honestly Significant Difference test (HSD), at a significance level of P = = 0.05. The values of the means ($\bar{x}$) on figures and in tables were provided with standard errors values (±SE). Statistical analysis was performed using Statistica 9.1 packet (StatSoft, Tulsa).

RESULTS

The results of this study showed that temperature had significant effects on the duration of developmental of *A. advenella*. For the same developmental stages, the development duration significantly decreased as the temperature was increased from 22 to 26°C. At a temperature of 10°C females do not laid of eggs, and the reared caterpillars and pupae died.

Embryonic development rate

The duration of the embryonic developmental stage in the tested ranges of temperatures hesitated between 9.3 to 25 days (Table 1). The stage of black head capsule of the embryo at the temperature of 14°C was noted after 19.3 days, while at the temperature of 22°C it was noted on average after 6.4 days. At the temperature of 14°C eggs developed the longest, (25 days) and it was significantly longer in comparison to the other temperature values. The shortest embryonic development was noted at the temperature of 26°C and it was similar to the one at the temperature of 22°C.

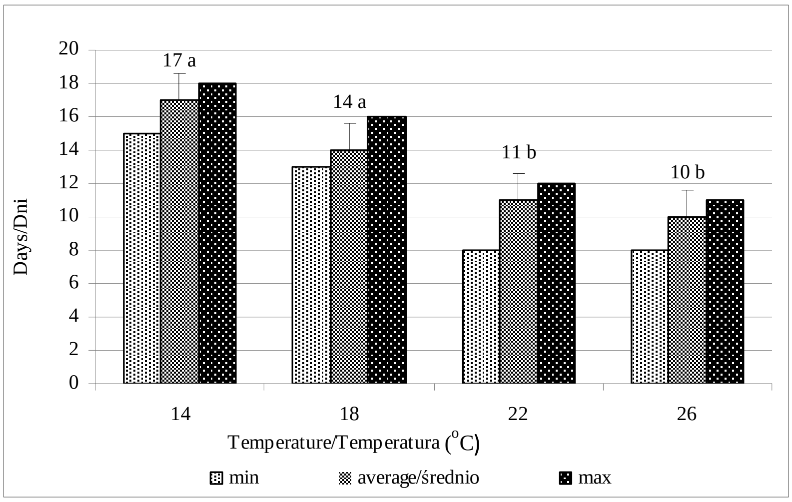
Rates of the 1st instar larvae development in fruits

The duration of larvae development in established temperature values ranged from 10 to 17 days (Fig.1). At the temperature of 26°C the development of larvae lasted the shortest – 10 days on average, while at the temperature of 22°C – 11. The significant statistical differences were not proved in relation to the rate of larvae development between these two temperatures. The longest development of larvae was observed at the temperature of 14°C – 17 days. The rate of 1st stage larvae development at the temperature of 18°C was 14 days and it was not significantly different than the rate of development at the temperature of 14°C.

Table 1. Influence of different temperatures on the development length of *Acrobasis advenella* eggs
Tabela. 1. Wpływ temperatury na długość rozwoju embrionalnego *Acrobasis advenella*

Temperature Temperatura (°C)	The length of embryonic development (days) Długość rozwoju embrionalnego (dni) ($\bar{x}$ ± SE)	
	To the stage of the embryonic black head capsule Do stadium czarnej główki	To hatching Do wylęgu
14	19.3 ± 0.18	25.0 ± 0.79 a
18	13.7 ± 0.36	17.3 ± 0.57 b
22	6.4 ± 0.43	9.7 ± 0.92 c
26	6.71 ± 0.42	9.3 ± 0.57 c

Values marked by various letters are significantly different at P ≤ 0.05 (Tukey's HSD test)
Wartości oznaczone innymi literami różnią się statystycznie, P ≤ 0,05 (test HSD Tukeya)

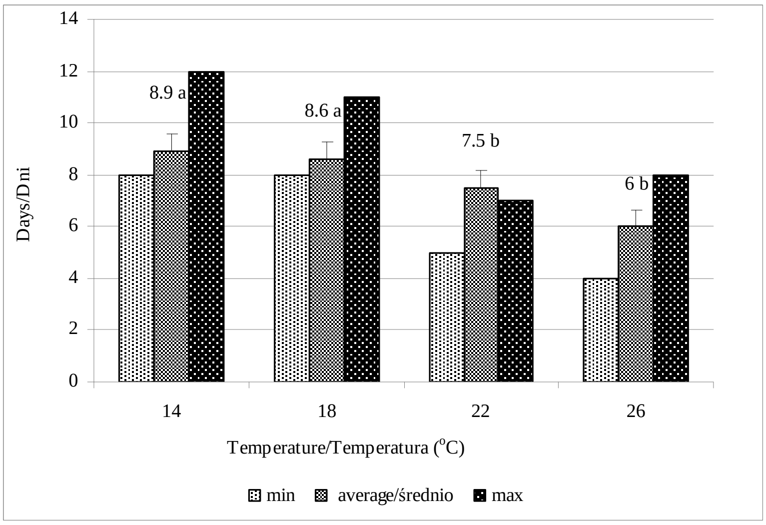


Values marked by various letters are significantly different at P ≤ 0.05 (Tukey's HSD test)
Wartości oznaczone innymi literami różnią się statystycznie, P ≤ 0,05 (test HSD Tukeya)

Fig. 1. The influence of different temperatures on the development length of *Acrobasis advenella* 1st instar larvae
Rys. 1. Wpływ temperatury na długość rozwoju gąsienic pierwszego stadium (L_1) *Acrobasis advenella*

The rate of 2nd–4th stages larvae development in inflorescences

At the temperature of 26°C the development of the larvae of the 2nd instar (from the moment of changing colour to inhabiting the plant) lasted the shortest – 6 days, while at the tempearature of 22°C it was 7.5 days (Fig. 2). The significant differences in rate of development of this stage between those two ranges of temperature were not proven. The longest developmental stage of larvae was observed at the temperature of 14°C – 8.9 days. The statistical analysis did not prove significant differences between the duration of development of larvae of the second stage at the temperatures of 14°C and 18°C.



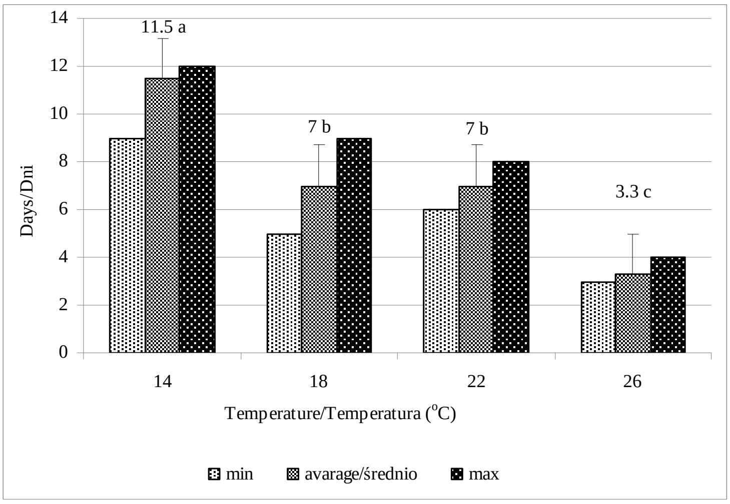
Values marked by various letters are significantly different at P ≤ 0.05 (Tukey's HSD test)
Wartości oznaczone innymi literami różnią się statystycznie, P ≤ 0,05 (test HSD Tukeya)

Fig. 2. The influence of different temperatures on the development length of *Acrobasis advenella* 2nd instar larvae
Rys. 2. Wpływ temperatury na długość rozwoju gąsienic drugiego stadium (L_2) *Acrobasis advenella*

Laboratory rearing showed that older larvae – of the 3rd and 4th stages developed the shortest at the temperature of 26°C. The development of larvae of the 3rd instar lasted 3.3 days, while 4th – 12 days. The longest developmental stage of larvae was observed at the lowest temperature established – 14°C and it was 11.5 days for the 3rd and 32 days for the 4th instar (Fig. 3, 4). In case of both developmental stages the statistical analysis did not prove the significant differences in the duration of development of larvae at the temperatures of 18 and 22°C.

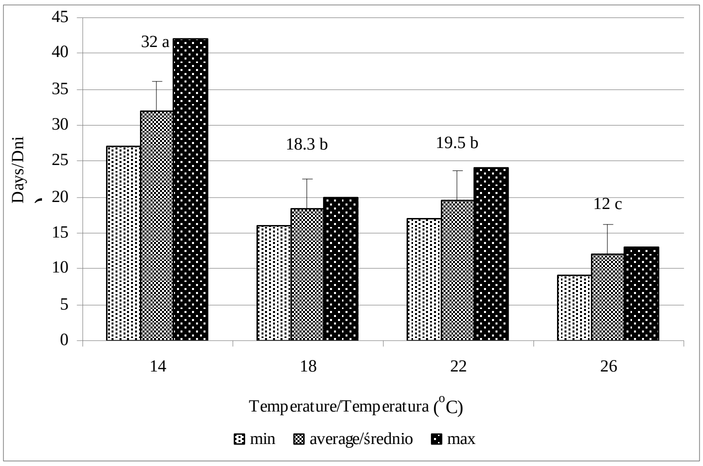
Rates of pupae development

The rate of pupae development at the studied values of temperature ranged from 15 to 36.5 days (Fig. 5). The shortest development was observed at the temperature of 26°C – 15 days, while at the temperature of 22°C it was 18.3 days, however the statistical analysis did not prove the significant differences between those values. The larvae developed the longest at the temperature of 14°C. In such conditions the mean period of emergence of the adult stage took place after 36.5 days.



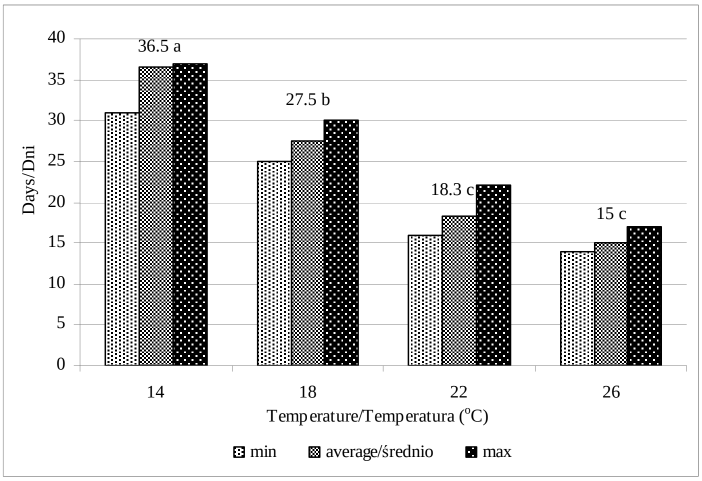
Values marked by various letters are significantly different at $P \leq 0.05$ (Tukey's HSD test)
Wartości oznaczone innymi literami różnią się statystycznie, $P \leq 0,05$ (test HSD Tukeya)

Fig. 3. The influence of different temperatures on the development length of *Acrobasis advenella* 3rd instar larvae
Rys. 3. Wpływ temperatury na długość rozwoju gąsienic trzeciego stadium (L_3) *Acrobasis advenella*



Values marked by various letters are significantly different at $P \leq 0.05$ (Tukey's HSD test)
Wartości oznaczone innymi literami różnią się statystycznie, $P \leq 0,05$ (test HSD Tukeya)

Fig. 4. The influence of different temperatures on the development length of *Acrobasis advenella* 4th instar larvae
Rys. 4. Wpływ temperatury na długość rozwoju gasienic czwartego stadium (L_4) *Acrobasis advenella*



Values marked by various letters are significantly different at $P \leq 0.05$ (Tukey's HSD test)
Wartości oznaczone innymi literami różnią się statystycznie, $P \leq 0,05$ (test HSD Tukeya)

Fig. 5. The influence of different temperatures on the development length of *Acrobasis advenella* pupae
Rys. 5. Wpływ temperatury na długość rozwoju poczwarek *Acrobasis advenella*

DISCUSSION

The development rate of many insects depends on a number of environmental conditions [Danks 2002]. Several studies have examined the developmental responses to environmental factors, especially temperature [Li *et al.* 2008, Wang *et al.* 2009, Ruszkowska *et al.* 2011]. An extensive published data is available on egg-to-adult development time for several species of stored-product moths or agricultural and horticultural pests reared at various temperature [Johnson *et al.* 1992, Subramanyam and Hagstrum 1993, Jakubowska and Walczak 2008, Li *et al.* 2013]. The results of these experiments allow to establish the emergence of individual developmental stages, thus as accurately as possible determine the terms of control. Learning the optimal conditions for development of pests contributes in the end to limit the control treatments.

Our study has demonstrated that temperature has had a significant influence on the development of *A. advenella*. Developmental threshold temperature for different developmental stages of *A. advenella* was above 10°C. The results have proven that the duration of development of *A. advenella* decreased as the temperature increased from 14 to 26°C.

The obtained results confirm the relations that the higher temperature, the quicker rate of insects development and the duration of all stages, both eggs, larvae and pupae, shortens [Szujecki 1998]. It was described in many studies. Subramanyan and Hagstrum [1993] studied the influence of temperature on development of six species of moths from the Pyralidae, of the genus *Ephestia*, *Plodia* and *Corcyra*. The authors showed that development time of each moth species decreased with an increase of temperature, and the rate of decrease was quicker between 15 and 24^oC and slower at the temperature of above 24^oC.

Similar results were observed by Taveras *et al.* [2004]. The authors proved, that the average duration of development of *Hypsipyla grandella* (Zell.), larvae (Pyralidae) for each stage decreased together with increase of the temperature. The development was the fastest at the temperature of 30°C, while the longest one was noted at the temperature below 15°C. The presented research has indicated, that the most advantageous temperature for the development of all stages of *A. advenella* was 26°C. However, the length of embryonic development stage and L_1, L_2 larvae and pupae stages was not different in the ranges of the temperature of 22 and 26°C. It shows that the optimal temperature of development for these stages ranges from 22 to 26°C.

The literature data shows that larvae of the moths belonging to other families responding to thermal conditions in similar way. Qureshi *et al.* [1999] demonstrated, that the development of eggs of *Helicoverpa armigera* (Hbn.) (Lepidoptera, Noctuidae) was the fastest at the temperature of 25°C, while at the temperature 5 degrees lower, it was significantly longer. The studies of Jakubowska and Walczak [2008] concerning the effect of temperature on the length of development of a common pest *Agrotis segetum* (Den. et Schiff.) (Noctuidae) indicated that the temperature had a huge influence on the rate of development of all stages of this insect. The life cycle of this species of noctuid was the longest at the temperature of 17°C and the shortest at the temperature of 24°C. The same results were obtained by Mervat [2013], who studied the influence of this abiotic factor on the rate of development of *Earis insulana* (Boisd.) (Noctuidae) and Karolewski *et al.* [2007] who examined the effect of temperature on the duration of larvae stages of two important foliophagous, which are *Lymantria monacha* (L.) and *Lymantria dispar* (L.) (Lepidoptera, Erebidae). In both cases, the increase of temperature shortened developmental stages from the egg to pupa. As given by Ipekdal and Çağlar [2012] in studies on the development and feeding activity of larvae of *Thaumetopoea wilkinsoni* Bull. (Lepidoptera, Thaumetopoeidae) temperature and a day length had the significant influence on these parameters. Together with the increase of the temperature the higher was the consumption of larvae. Of all the temperature values tested in the experiment (15, 20, 25 and 30°C), a faster development of larvae stages was observed at higher temperatures.

The same character of the effect of different temperature values on specimen of other groups of insects has been proven in different reports [Li *et al.* 2008, Jalali *et al.* 2010, Ju *et al.* 2011, Ruszkowska *et al.* 2011].

The results of the presented research have a big practical value. They can be useful to estimate the time of appearance of individual developmental stages of *A. advenella* on black chokeberry plantations depending on the thermal conditions. This information may be used to establish the terms of this pest control.

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Streszczenie: Celem pracy było określenie wpływu różnych wartości temperatury na tempo rozwoju jaj, gąsienic i poczwarek *A. advenella*. W wyniku badań stwierdzono, że próg termiczny rozwoju *A. advenella* wynosi powyżej 10^{o}C. Długość rozwoju embrionalnego wyniosła od 9,3 dnia do 25 dni. Najdłużej jaja rozwijały się w temperaturze 14^{o}C, natomiast najkrócej rozwój embrionalny przebiegał w temperaturach 26 i 22^{o}C; wyniósł odpowiednio 9,3 oraz 9,7 dnia. Tempo rozwoju gąsienic stadium L_1 w temperaturze 26^{o}C było najkrótsze i wyniosło średnio 10 dni, natomiast najdłużej gąsienice rozwijały się w temperaturze 14^{o}C – 17 dni. W temperaturze 26^{o}C rozwój gąsienic drugiego stadium (L_2) trwał 6 dni, natomiast przy 14^{o}C – 8,9 dnia. Hodowle laboratoryjne wykazały, że starsze gąsienice – stadium L_3 i L_4 – również najkrócej rozwijały się w temperaturze 26^{o}C. Długość rozwoju poczwarek w badanych wartościach temperatur wynosiła od 15 dni (26^{o}C) do 36,5 dnia (14^{o}C). Rezultaty badań mogą być pomocne w określaniu czasu występowania poszczególnych stadiów rozwojowych *A. advenella* na plantacjach aronii czarnoowocowej w zależności od panujących warunków termicznych. Informacje te można wykorzystać do ustalenia terminu zwalczania tego szkodnika.

Słowa kluczowe: *Acrobasis advenella*, *Aronia melanocarpa*, temperatura, tempo rozwoju