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Head: Docent Dr. Przemysław Trojan

Jadwiga GROMADZKA

RESPIRATORY METABOLISM OF THE COLORADO BEETLE (*LEPTINOTARSA DECEMLINEATA* SAY)

The respiratory metabolism of the developmental stages of the Colorado beetle was investigated at varying temperatures and at 20°C. The highest oxygen consumption rate, in mm^3 per one individual per an hour was recorded for L4 on its last feeding-day and the lowest for the pupa in the middle of its development. Larval oxygen consumption rate per unit body weight decreases with the increase in body weight of the individuals. Respiratory energy losses by one developing individual at a constant temperature were calculated. The variations in respiration rate at varying temperatures are similar to those at constant temperature.

The aim of the study is to trace the variations in the respiratory metabolism of the Colorado beetle during its growth at constant temperatures and to describe the nature of its metabolic reaction to the rapid changes of temperature which this insect encounters in its natural habitat.

In the physiological, and recently also in ecological, literature many data have been reported concerning the respiratory metabolism of various insects including beetles (Fink 1925; Birch 1947; Burges 1960; Petrova 1966; Klekowski, Prus, Żyromska-Rudzka 1967). Data of this kind become now particularly important in connection with the ever increasing scope of research works on the energy flow through selected populations or other ecolo-

gical units. One of the parameters included in studies on productivity is respiration (R), that is to say energy losses related to metabolism. If the caloric value of R is known, and additionally also the value of the production – P or of assimilation – A, the assimilated quantity of energy or the production rate of an ecological unit can be calculated.

The Colorado beetle was the object of many laboratory investigations, but no trial has so far been made to determine the respiratory losses in this insect during its development. In the literature concerned data can only be found regarding the respiration rate in adult individuals. Fink (1925), for instance, studied the oxygen consumption by the beetles fed various food (potato leaves and tubers, tomato leaves and fruit and others), Petrova (1966) reported results from measurements of respiration rate of the first and second generation beetles at diapause, remaining in various types of soil.

It is a commonly known fact that the respiratory metabolism depends on temperature and it is fairly easy to carry out laboratory investigations under precisely specified temperature conditions. In the field, however, the temperature varies considerably, which makes the transfer of laboratory data particularly difficult. In an attempt to describe the variations in respiration rate in the Colorado beetle under the conditions of rapidly changing temperature a series of respiratory metabolism measurements was carried out at temperatures different from the temperature at which the beetles were normally reared.

MATERIAL AND METHODS

The respiratory metabolism was measured at 15, 20, 25 and 30°C (± 0.1°C) and 70% RH, using the manometric microrespirometers according to Klekowski (Żadin 1966). A total of 1,050 including individuals of all stages was investigated. Larvae were reared at room temperature (± 20°C, the temperature varying from 18.5 to 21°C); from the first day after hatching onwards the respiration rate was measured every day at 20°C until the first days of the life of the imagines. The time between the hatching out of the larvae and the emergence of the beetles was 34 days.

At temperatures 15, 25 and 30°C the oxygen consumption rate was measured in individual developmental stages; for the measurements those individuals were selected whose age corresponded to the average age in the particular stage, e.g. L1 – ± 2-day old larvae, L2 – ± 6-day old larvae etc. Older stage groups were subdivided into the following age sub-groups: L1, L2, early L3, late L3, early L4, middle L4, late L4, resting L4 (prepupa), early pupa, late pupa and imago.

Oxygen consumption was read several times during an hour; the period of 15–20 minutes immediately preceding the reading was taken as an stabilize

period. The results obtained were adjusted to the standard conditions of temperature, pressure and humidity. Immediately after being taken out of the respirometers the insects were weighed to the nearest 0.1 mg.

RESPIRATORY METABOLISM DURING DEVELOPMENT AT CONSTANT TEMPERATURE OF 20°C

The amount of oxygen utilized by one-day old larvae is 1.51 mm^3. The oxygen consumption increases gradually during the first and the second stages, where after a rapid rise follows accompanying the intense growth in bodyweight. Maximum oxygen consumption – 132.80 mm^3 is attained on the last feeding day (on the 19th day from hatching) (Fig. 1). The fairly even rise in oxygen

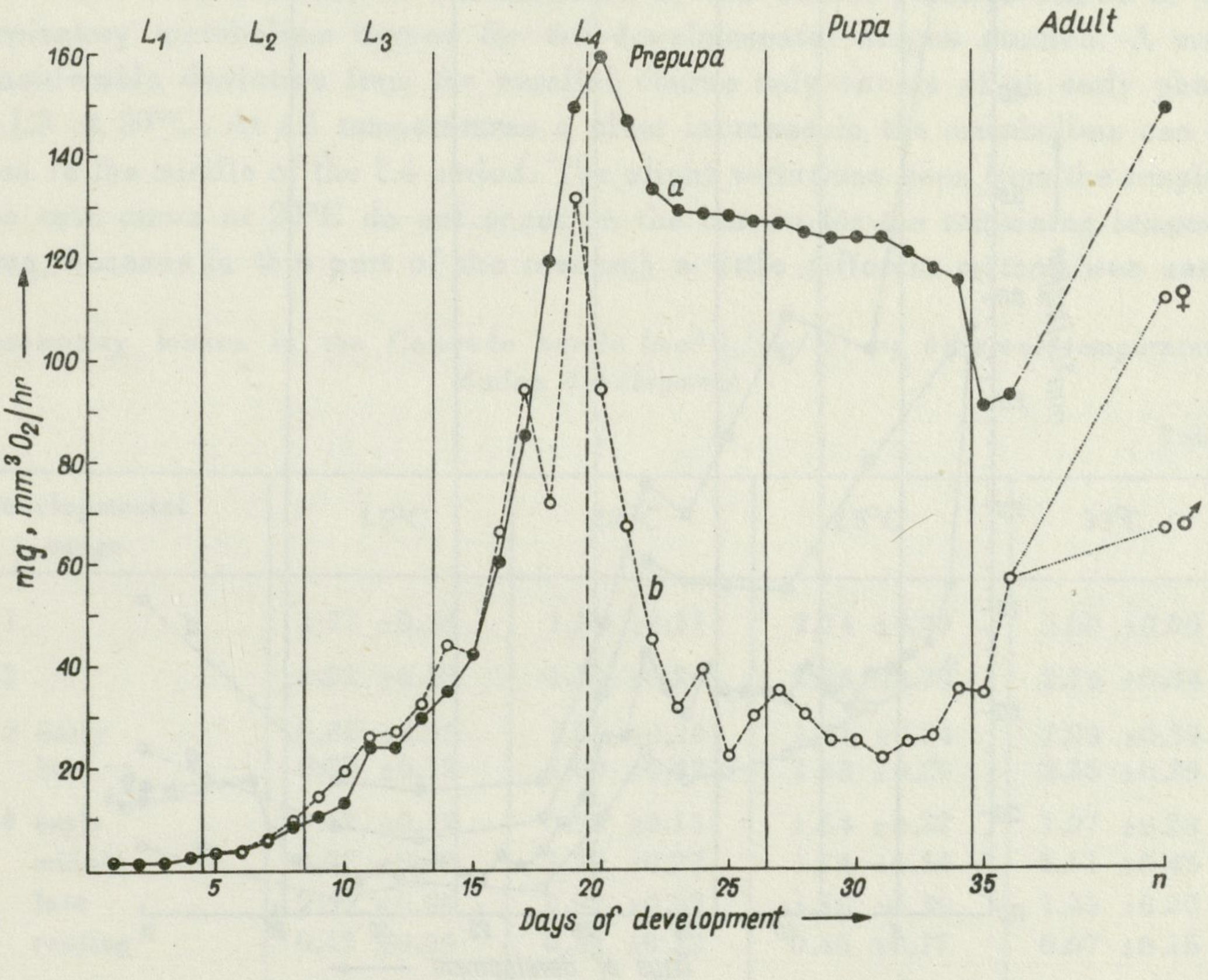

Fig. 1. Respiratory metabolism in the Colorado beetle during development
a – weight, *b* – oxygen requirements of an individual

consumption is disturbed at the beginning, in the middle and at the end of stage L4 when clear one-day growths occur. During resting L4 a rapid fall in oxygen consumption is seen down to a value of 22.93 mm^3 immediately before pupation. The pupa appears to take up most oxygen immediately after

pupation and again immediately before the emergence of the imago – 35.70 and 35.12 mm^3, whereas in the middle of the development period of this stage the lowest oxygen consumption rate is seen – 21.51 mm^3. Immediately after emerging the beetles take up 34.36 mm^3 oxygen, while in the 2-day old individuals oxygen consumption attains 57.07 mm^3. One full grown female takes up on the average 113.75 mm^3, and a male much less – 65.63 mm^3 oxygen per hour.

The oxygen consumption per unit live weight (Fig. 2) is the highest in one-day old larvae – 2.86 $mm^3/mg/hr$, where after with the increasing body

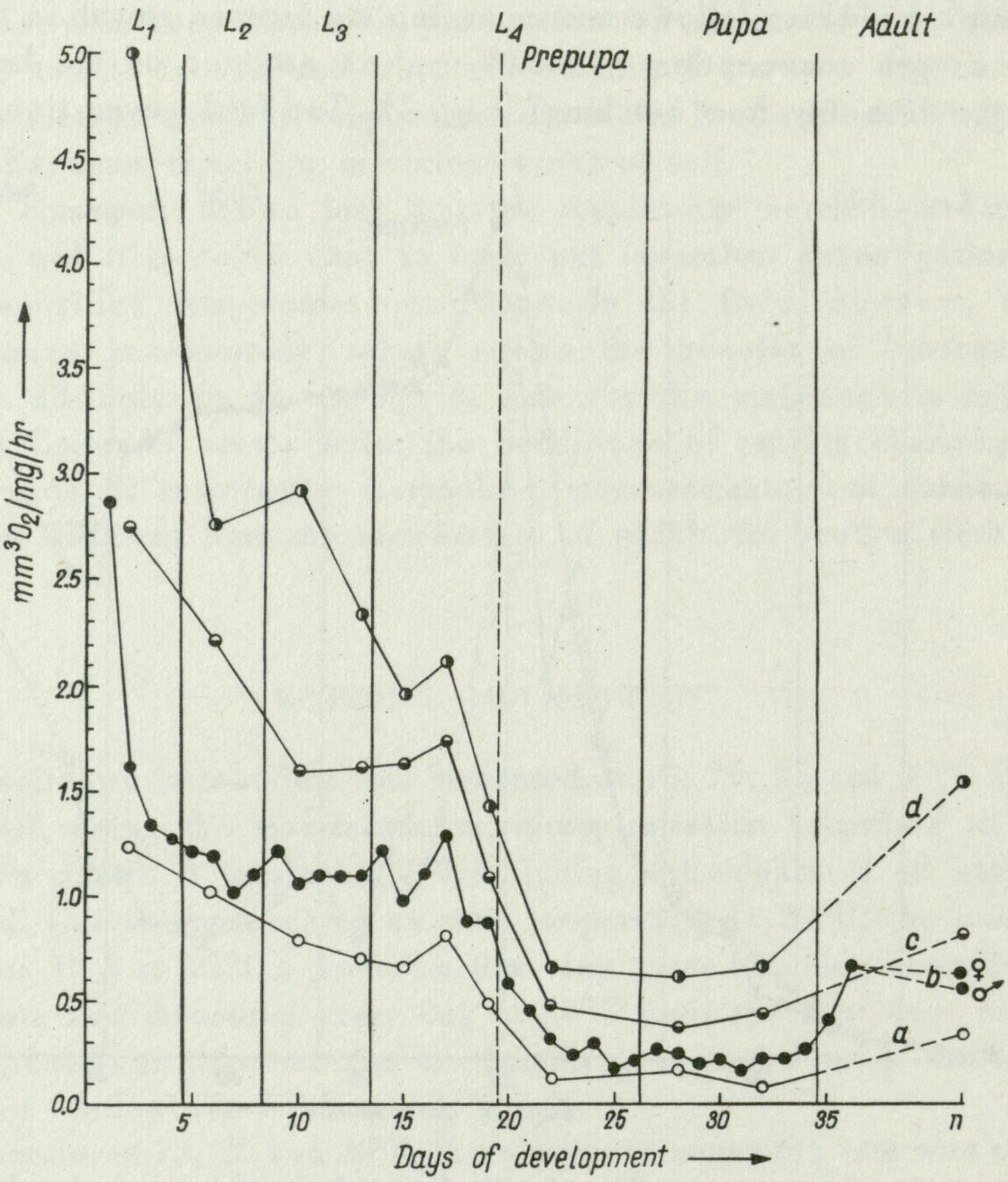

Fig. 2. Respiratory metabolism in the Colorado beetle at different temperatures
a – 15°C, *b* – 20°C, *c* – 25°C, *d* – 30°C

weight of the insect it decreases gradually to attain its minimum – 0.16 $mm^3/mg/hr$ in the middle of the pupal stage. It should be noted that in the middle of the L4 period a distinct rise in respiration rate is seen. Respiration

is intenser in adult females than in adult males, the former taking up 0.60 mm^3 and the latter 0.54 mm^3 oxygen/mg/hr.

RESPIRATORY METABOLISM AT VARYING TEMPERATURES

The respiration rate of the developmental stages of the Colorado beetle, after their being transferred from ± 20°C to 15, 25 and 30°C, was compared with the results obtained at 20°C (Fig. 2). Oxygen consumption in mm^3/mg/hr was the lowest at 15°C, whereas at 20, 25 and 30°C it was accordingly higher (Tab. I). A rapid change in temperature causes a greater change in respiratory metabolism rate in the youngest larval stages than in older larvae or resting stages. Attention is called by the very regular variations in respiratory rate at various temperatures, as demonstrated by the almost parallel course of the respiratory metabolism curves for the developmental stages studied. A more considerable deviation from the parallel course only occurs at an early phase of L3 at 30°C. At all temperatures a clear increase in the metabolism can be seen in the middle of the L4 period. The slight variations seen from the respiration rate curve at 20°C do not occur on the curves for the remaining temperatures, because in this part of the research a little different method was used.

Respiratory losses in the Colorado beetle ($mm^3 O_2$/mg/hr) at different temperatures during development

Tab. I

Developmental stage	15°C	20°C	25°C	30°C
L1	1.23 ±0.35	1.59 ±0.31	2.74 ±0.79	5.00 ±0.00
L2	1.02 ±0.58	1.19 ±0.26	2.23 ±0.38	2.76 ±0.34
L3 early	0.82 ±0.05	1.06 ±0.20	1.61 ±0.24	2.93 ±0.59
late	0.70 ±0.12	1.09 ±0.42	1.63 ±0.29	2.35 ±0.29
L4 early	0.67 ±0.12	0.98 ±0.13	1.64 ±0.22	1.97 ±0.28
middle	0.72 ±0.08	1.28 ±0.27	1.74 ±0.26	2.11 ±0.45
late	0.49 ±0.08	0.87 ±0.22	1.10 ±0.36	1.43 ±0.20
resting	0.12 ±0.03	0.32 ±0.12	0.48 ±0.17	0.67 ±0.16
Pupa				
early	0.16 ±0.00	0.25 ±0.04	0.38 ±0.07	0.61 ±0.09
late	0.09 ±0.04	0.23 ±0.06	0.44 ±0.14	0.66 ±0.13
Imago ♀	0.35 ±0.07	0.60 ±0.15	0.86 ±0.09	1.57 ±0.18
♂	0.31 ±0.10	0.54 ±0.15	0.78 ±0.11	1.56 ±0.48

DISCUSSION OF RESULTS

The respiration rate curve for the postembryonic growth of the Colorado beetle (Fig. 1) has a course characteristic of Holometabola (Roeder 1953). Maximum oxygen consumption per one individual takes place at the end of the larval feeding period after which comes a rapid fall noticeable during the resting stages. The pupal period is represented by a U-shaped respiratory metabolism curve, characteristic of many insect species (Szwanwicz 1956).

The course of the curve of oxygen consumption per unit weight in the larval stages confirms the known rule that the rate of respiration decreases with the growth in size of an organism (Petrusewicz 1967).

At the fourth larval stage a clear rise in respiration rate is seen; it seems that this may be explained by the intense physiological processes which are going on at that time connected with the storing-up of fats and preparation for the resting period (Busnel 1939). In this period also the larva of the Colorado beetle takes up the largest quantities of food per a unit of body-mass increment (the lowest productivity, Chłodny 1967).

For an accurate estimation of the quantity of energy needed for the maintenance of an individual or population the respiration quotient (RQ) is required the value of which varies with the growth of the animal, depending on the quality of the food burned (carbohydrates, fats, proteins). As the present research did not include the measurement of the respiratory quotient in the Colorado beetle, the respiratory energy loss sustained by one individual during its growth at ± 20°C was evaluated by using the simplified calculation – 4.7 Kcal/lO_2. During its growth from the hatching-out until the emergence of the beetle from the pupa an individual utilizes 27,807.84 mm^3 oxygen, this corresponding to 130.69 cal. The highest respiratory losses, amounting to 88.33 cal. (67.59%), have been recorded for the fourth larval stage – the time of the intensest feeding. In Table II are summarized respiratory losses of energy of individual developmental stages.

Respiratory energy losses in the Colorado beetle (cal/individual) during development at 20°C

Tab. II

Developmental stage	mm^3 0_2/individual stage	cal/individual stage	Per cent
L1	176.88	0.83	0.63
L2	560.40	2.63	2.01
L3	2,864.88	13.46	10.30
L4	18,795.12	88.33	67.59
Pupa	5,410,56	25.43	19.46
Total	27,807.84	130.69	100.00

The course of changes in the respiration rate during growth at varying temperature is very similar to the variations in the respiratory metabolism at constant temperature (almost parallel course of curves) (Fig. 2). It may be presumed, therefore, that both cases apply to the same rules and the duration of a possible disturbance in the metabolism, due to a rapid change of temperature, was shorter than the adjustment time allowed before measurements after each change of temperature. This would indicate that the Colorado beetle is a species which is able to adapt its respiratory metabolism, without any significant disturbances, to the changes of temperature which it encounters in nature. In such a case the results obtained from the research here described, combined with the data concerning the activity of Colorado beetle, the thermic conditions in the potato fields during the period under research, and the length of the development of Colorado beetle under these conditions, might be used for the calculation of the respiratory losses of energy in a Colorado population in its natural habitat.

SUMMING UP

1. The course of oxygen consumption in mm^3 per hour by one individual during its growth at constant temperature is characteristic of Holometabola.

2. In larval stages the oxygen consumption per unit body weight decreases with the increase in weight.

3. During the fourth larval stage a distinct rise in respiration rate is noted.

4. Energy losses due to respiration by one individual in the course of its development amount to 130.69 cal.

5. The course of variations in the respiration rate of the developmental stages at varying temperatures is very similar to the variations at constant temperature, which indicates that the Colorado beetle adapts quickly to the varying thermic conditions.

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METABOLIZM ODDECHOWY STONKI ZIEMNIACZANEJ (*LEPTINOTARSA DECEMLINEATA* SAY)

Streszczenie

W pracy podano wyniki pomiarów metabolizmu oddechowego stonki ziemniaczanej w trakcie jej rozwoju w temperaturze 20°C i w temperaturach zmiennych 15, 25 i 30°C. Metabolizm oddechowy mierzono przy pomocy mikrorespiratorów manometrycznych wg Klekowskiego. Przebadano 1.050 osobników wszystkich stadiów rozwojowych. Krzywa ilustrująca zużycie tlenu przez jednego osobnika podczas rozwoju postembrionalnego ma przebieg typowy dla holometabola (fig. 1). Maksimum zużycia tlenu występuje w końcowym okresie żerowania larw, po czym następuje gwałtowne obniżenie podczas trwania stadiów spoczynkowych. Zużycie tlenu przez stadia larwalne na jednostkę wagi maleje wraz ze wzrostem wagi (fig. 2). W czwartym stadium larwalnym występuje wyraźny wzrost intensywności oddychania związany prawdopodobnie z przemianami fizjologicznymi poprzedzającymi okres spoczynkowy. Samice oddychają intensywniej niż samce.

Stwierdzono, że przebieg zmian metabolizmu oddechowego w trakcie rozwoju w temperaturach zmiennych jest bardzo podobny do zmian intensywności oddychania w temperaturze, w której odbywała się hodowla (prawie równoległy przebieg krzywych z wyjątkiem odchylenia we wczesnej fazie L3 w temperaturze 30°C, fig. 2.). Wskazywałoby to na to, że stonka ziemniaczana jest gatunkiem przystosowującym swój metabolizm oddechowy szybko i bez specjalnych zakłóceń do zmian temperatury, z którymi spotyka się na co dzień w swoim naturalnym środowisku. W tabeli I zestawiono straty oddechowe ($mm^3/mg/hr$) poszczególnych stadiów rozwojowych w temperaturze stałej 20°C i w temperaturach zmiennych.

Obliczono przybliżone energetyczne straty oddechowe dla okresu rozwojowego. Jeden osobnik w ciągu rozwoju, od momentu opuszczenia jaja do wyjścia chrząszcza z poczwarki, zużywa 27 807,84 mm^3 tlenu co odpowiada 130,69 cal. (tab. II).

AUTHORS' ADDRESS:
Mgr. Jadwiga Gromadzka
Zakład Agroekologii
Polskiej Akademii Nauk,
Turew, powiat Kościan,
Poland.