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ESTIMATED FOOD CONSUMPTION BY THE COLORADO BEETLE (*LEPTINOTARSA DECEMLINEATA* SAY) UNDER CONDITIONS OF NATURAL REDUCTION*

Food consumption by a Colorado beetle population on a potato field depends on the intensity of natural reduction; under the conditions prevailing in the optimum zone of occurrence of this species in Poland it forms 16–17% of potential consumption. Consumption does not appear to depend on density but on the initial number of eggs and can be defined as the simple function $C_r = 0.18\ N_0$ kcal. There is no serious threat to potato crops until the number of eggs laid exceeds 800 eggs/m².

The object of the present study is to present ecological and energy methods of estimating leaf consumption by larvae and imagines of the Colorado beetle and to discuss the suitability of such methods for evaluating the role of this pest in potato fields.

Studies of the production of animal populations carried out under the International Biological Programme involve the introduction into ecological research of exact methods of measuring the energy requirements of animals. The new approach to this problem has opened up extensive prospects for plant

*Investigations were carried out under the International Biological Programme in Poland.

protection, since it permits of accurate evaluation of the role of pest populations on a cultivated field.

The Colorado beetle has been thoroughly investigated from the energy aspect. Chłodny (1967) ascertained the food requirements of the various stages of development and the production of biomass, while Gromadzka (1968) examined cost of maintenance depending on the temperature of the environment. The full energy budget of development was elaborated by Chłodny, Gromadzka and Trojan (1967). These data form a foundation for evaluation of the role of the Colorado beetle in an area on the basis of accurate energy parameters.

Under natural conditions a population is subject to the influence of two factors, i.e. production and elimination. The first of these – production (P) causes increase in biomass and number of individuals, and the second – elimination (E) causes a decrease in the number of individuals as the result of natural reduction. The proportions between these two factors simultaneously define the role of a given population in nature. Elimination defines the extent of ecological production and food consumption – dead individuals do not increase in weight, do not reproduce or consume food, which forms the most important factor from the standpoint of assessment of the harmfulness of a given species.

METHODS

Under natural conditions production and elimination processes take parallel courses, which creates the chief difficulty in respect of choice of method. The amount of food consumed by the Colorado beetle depends to a great extent on the temperature conditions prevailing in the habitat; temperature has a decisive effect on the development of this pest (Łarczenko 1958) and its costs of maintenance (Gromadzka 1968). In the case of imagines it is only possible to assess the amount of food consumed through knowing their numbers and possessing data on their daily food requirements. With an environment temperature of 20°C the female Colorado beetle consumes 15.5 cal/per day and a male 17.4 cal/per day (Chłodny, unpublished material). These data were calculated appropriately for the environment temperature.

Data for each month and area were elaborated according to the formula:

$$C_i = (\bar{N}♀C♀ + \bar{N}♂C♂) \cdot t \qquad (1)$$

where: C_i – consumption by imagines in a given month,
$\bar{N}$ – average density of males (♂) and females (♀) per 1 m²,
C – daily consumption by females (♀) and males (♂) in a given environment temperature,
t – number of days in a given month.

Assessment of consumption by larvae was based on the finding (Chłodny, Gromadzka and Trojan 1967, Chłodny 1967) that the ratio of consumption to production $\frac{C}{P}$ in the Colorado beetle exhibits a great degree of constancy; the amount of food consumed by larvae can be accurately estimated when their number and increase in biomass are known. Food consumption by larvae of the given stage of development was defined according to the formula:

$$C_l = \frac{N_o + N_t}{2} \quad \Delta G \frac{C}{P} \tag{2}$$

where: C_l – consumption by larvae in the given stage of development,
N_o – initial density of larvae of the given stage,
N_t – final density of larvae of the given stage,
ΔG – weight increase of individual during stage,
$\frac{C}{P}$ – consumption coefficient.

Consumption was estimated separately for each stage and then summed up. The rélation $\Delta G \frac{C}{P}$ is constant for the various stages (Tab. I).

Values of consumption conversion formula $\Delta G \frac{C}{P}$ for larvae of the Colorado beetle into calories

Tab. I

Instar	ΔG	$\frac{C}{P}$	$\Delta G \frac{C}{P}$
L_1	4.501	4.117	18.5
L_2	15.067	2.725	41.1
L_3	60.754	2.228	135.4
L_4	100.086	4.558	456.2
Total	180.408	3.608	650.9

The method elaborated by Karg and Trojan (1968) was used when assessing elimination. Data on the initial number of individuals (N_o) were obtained from the number of eggs laid throughout the whole growing season of the potato; the number of individuals beginning (N_o) and ending (N_t) the given stage of development was estimated on the basis of a known percentage of surviving individuals. Data were collected over a two-year period (1965–1966) during field work in potato fields in the Turew district (Wielkopolska region of Poland). The numbers of males, females, number and reduction of eggs and number of larvae belonging to the different stages were all determined. The field was inspected every 3 days over the whole growing season of the potato, 120 plants being examined each time.

CONSUMPTION BY LARVAE

Depending on the way in which we define them, we can distinguish four different concepts of consumption, three of which are applicable to an assessment of actual relations. The difference between them depends on the estimate of numbers and variations in such numbers.

Potential consumption (C_p) forms the simplest way of estimating the extent of consumption by the Colorado beetle, particularly of anticipated consumption. We estimate it starting with the formula:

$$C_p = N_0 \, \Delta G \frac{C}{P} \tag{3}$$

symbols as above (2). In practice we start with the number of eggs laid per 1 m^2 and multiply this number by the total consumption of the larvae, which is 1.27 g of green leaf mass (Chłodny 1967); consumption by the beetles which hatch out in the summer must be defined separately. Definition of potential consumption tells us how many potato leaves would be eaten if there were no biocenotic reduction in the potato field.

Apparent consumption (C_0). The final number of fourth stage larvae, which is easy to ascertain in a field, may serve as a basis for estimating consumption. In our formula:

$$C_0 = N_t \, \Delta G \frac{C}{P} \tag{4}$$

for explanations of symbols see formula (2). Consumption by the Colorado beetle as it develops is uneven, the majority of the food being consumed in the final larval stage, and thus assessment of consumption by larvae on the basis of accepting that it corresponds to the consumption proper to the established density of fourth stage larvae is based on natural history grounds.

Actual consumption (C_r). In order to assess actual consumption we must be in possession of data on the initial and final number of larvae in a given stage, and we can then define consumption by larvae most accurately by means of the following formula:

$$C_r = \frac{N_0 + N_t}{2} \Delta G \frac{C}{P} \tag{5}$$

The way of calculation given above takes into consideration the existence of elimination during the course of the given stage of development.

Indefinable consumption (C_n). Differences occur between values of actual consumption (C_r) and apparent consumption (C_o), $C_r - C_p$, and this value corresponds to the quantity:

$$C_n = \frac{N_0 - N_t}{2} \Delta G \frac{C}{P} \tag{6}$$

when

$$C_r - C_0 = \frac{N_0 - N_t}{2} \Delta G \frac{C}{P}$$

indefinable consumption corresponds to the amount of food consumed by individuals which were eliminated during the course of the given development stage. This value therefore constitutes a measure of the underestimation of consumption through the use of coefficient of apparent consumption (C_0). Considerable differences occur between the different assessment (Tab. II). The highest assessment of consumption is obtained by using the coefficient of potential consumption, and the lowest using the coefficient of apparent consumption. Actual consumption, contained between these two values, gives an estimate close to apparent consumption.

Food consumption (kcal/m²) by larvae of the Colorado beetle

Tab. II

Stage	Potential	Apparent	Indefinable	Actual
	$C_p = N_0 \Delta G \frac{C}{P}$	$C_0 = N_t \Delta G \frac{C}{P}$	$C_n = \frac{N_0 - N_t}{2} \Delta G \frac{C}{P}$	$C_r = \frac{N_0 + N_t}{2} \Delta G \frac{C}{P}$
L_1	4.220	1.108	1.134	2.242
L_2	2.462	2.363	0.049	2.413
L_3	7.785	7.785	0.000	7.785
L_4	37.427	34.628	1.367	35.995
Total	148.470	34.628	13.807	48.435

CONSUMPTION BY IMAGINES

Definition of consumption by imagines is based on their average numbers and the temperature conditions. Production processes are considerably inhibited here. Only two types of consumption can be defined here. Actual consumption (Tab. III) defines consumption in accordance with the numbers found in nature and the known temperature conditions.

Actual food consumption (*C*) by imagines of the Colorado beetle in cal/m²

Tab. III

Month		VI	VII	VIII	IX
Days (t)		12	31	31	23
Temperature		17.2	17.4	16.6	15.0
♀♀	$\bar{N}/m^2$	0.16	0.24	4.37	21.96
	NC	1.60	2.40	43.7	140.5
	NCt	19.2	74.4	1354.7	3231.5
♂♂	$\bar{N}/m^2$	0.11	0.10	1.59	2.12
	NC	1.23	1.12	17.81	23.74
	NCt	14.8	34.7	552.1	546.0
Total C		34.0	109.1	1906.8	3777.5

Potential consumption takes as a starting point the number of beetles which would have hatched out in the second half of summer from all the eggs laid if there were no biocenotic reduction. Numbers obtained in this way are many times greater than those which result from the actual extent of consumption by the Colorado beetle.

RELATION BETWEEN DIFFERENT DEFINITIONS OF CONSUMPTION

Comparison was made of estimated consumption by Colorado beetle larvae in relation to actual consumption for two potato fields on which no chemical control of the pest was carried out. The difference between them was expressed in the 5 times greater initial density of eggs (Tab. IV). Extent of consumption for different larval stages estimated by different methods did not differ considerably, particularly in the case of the older larvae. If, however, we take into consideration the whole period of larval development the differences become completely distinct. The greatest deviation from the actual state results from application of the coefficient of potential consumption, which

Comparison of different estimates of consumption by larvae of the Colorado beetle in relation to actual consumption

Tab. IV

N_0/m^2	228.0			1102.1		
Relation	$\frac{C_p}{C_r}$	$\frac{C_o}{C_r}$	$\frac{C_n}{C_r}$	$\frac{C_p}{C_r}$	$\frac{C_o}{C_r}$	$\frac{C_n}{C_r}$
L_1	190.0	42.2	57.7	151.6	70.3	29.7
L_2	108.0	92.0	8.0	125.9	74.1	25.1
L_3	104.4	95.4	4.6	118.7	81.3	18.7
L_4	102.6	97.6	2.4	112.9	87.1	12.9
L_1–L_4	427.2	70.3	29.7	391.4	56.4	43.5

over-estimates by about 4 times as much the extent of consumption in nature in relation to the actual extent. A far closer approximation is achieved by using the coefficient of estimated apparent consumption, except that under-estimation of consumption may be as much as 45% of its actual extent.

Comparison of potential and actual consumption with different initial densities of the Colorado beetle

Tab. V

Year	N_0/m^2	Consumption kcal/m²						$\frac{C_r}{C_p}$
		Potential C_p			Actual C_r			
		larvae	adults	total	larvae	adults	total	
1965	228.0	148.4	107.2	255.6	34.7	5.8	40.5	15.8%
1966	1102.1	717.4	475.4	1192.8	183.3	18.5	201.8	16.9%

Full comparison of potential consumption by the Colorado beetle per 1 m² of a potato field (Tab. V), including consumption by both larvae and imagines, indicates that the ratio of effective consumption (C_r) to potential consumption (C_p) does not depend on the density of the pest and is 16–17%. The above data make it possible to formulate the relation between the number of eggs laid (N_0) and potential consumption

$$\frac{C_p}{N_0} = 1.10 \text{ kcal} = \text{const.}$$

for actual consumption this relation for the three cases examined is

$$\frac{C_r}{N_0} = 0.18 \text{ kcal} = \text{const.}$$

After conversion we obtain a simple definition of extent of actual consumption (C_r) with a known number of eggs laid per 1 m².

$$C_r = 0.18\ N_0 \text{ kcal} \quad (7)$$

and of potential consumption (C_p)

$$C_p = 1.1\ N_0 \text{ kcal} \quad (8)$$

Both functions (7, 8) form a good basis for forecasting the degree of destruction to a potato field and crop losses. Under the conditions obtaining in the Wielkopolska region the optimum density is 4 potato plants per 1 m², the leaf mass produced by these plants approximately 310 kcal/m². The harmfulness threshold for the „Lenino" potato, which is distinguished by a high degree of resistance to the effects of the pest's destructive activities on it is about 50% of leaf mass (Trojan 1967). Entering the threshold value of destruction of potato plants on a consumption graph makes it possible to assess the critical density of the pest's eggs at about 800 eggs per 1 m². Up to this density the pest does not constitute a threat to the potato crop. In our experience at densities exceeding 1000 eggs/m² we did not find any reduction in potato crop in relation to fields on which chemical control had been carried out. The time at which the plant is destroyed is an additional factor here. Maximum intensity of consumption occurs in the second half of August and September. During this period the tubers of the Lenino potato are almost entirely formed and therefore even complete liquidation of the leaves which took place at the beginning of September did not cause reduction in potato crop.

CONCLUSIONS

1. The number of potato leaves consumed by the Colorado beetle under conditions of biocenotic reduction observed in Poland can be defined by the formula: $C_r = 0.18\ N_0$ kcal.

2. Actual consumption forms 16–17% of potential consumption. The difference between the two estimated values of consumption by the Colorado beetle point to the importance of the part played by the biocenosis of a potato field in liquidating the injurious effects of this pest's activities.

3. In the Wielkopolska region, which forms the optimum zone for development

of the Colorado beetle in Poland, the critical density of eggs laid per 1 m^2 is 800 eggs. It is not until this number is exceeded that the pest may constitute a danger to a potato plantation.

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OCENA KONSUMPCJI POKARMU PRZEZ STONKĘ ZIEMNIACZANĄ (*LEPTINOTARSA DECEMLINEATA* SAY) W WARUNKACH REDUKCJI NATURALNEJ

Streszczenie

Znajomość budżetu energetycznego stonki ziemniaczanej (*Leptinotarsa decemlineata* Say) pozwala na ścisłą ocenę rozmiarów konsumpcji pokarmu przez stonkę na polach ziemniaczanych w warunkach równoczesnego rozwoju populacji oraz eliminacji osobników na skutek redukcji naturalnej. Wyróżniono i omówiono pojęcie konsumpcji potencjonalnej, pozornej, rzeczywistej i nieuchwytnej u larw oraz potencjalnej i rzeczywistej owadów dorosłych. Konsumpcja potencjalna stanowi złe przybliżenie rzeczywistej i blisko 4-krotnie przecenia rzeczywistą u larw. Konsumpcja rzeczywista stanowi 16—17% potencjalnej w bilansie konsumpcji pola ziemniaczanego. Jej wielkość jest niezależna od zagęszczenia wyjściowego jaj stonki (N_0) i wyraża się wzorem:

$$C_r = 0.18\, N_0 \text{ kcal.}$$

Dopiero po przekroczeniu zagęszczenia 800 jaj/m^2, w Wielkopolsce stonka przedstawia groźbę dla plantacji ziemniaczanych.

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