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PRODUCTIVITY INVESTIGATION OF TWO TYPES OF MEADOWS IN THE VISTULA VALLEY

V. INTRODUCTORY STUDIES ON NUMBERS AND ENERGETICS OF *ORTHOPTERA*

(Ekol. Pol. 19:139–150). In this paper the dynamics of numbers of *Orthoptera* population was studied and energy budget of the dominant species, *Chorthippus montanus* (Charp.) (*Acrididae*) was determined. Measurements covered the consumption, biomass increase, quantity of dismissed faeces, and food assimilation of last larval instars and imaginal stage of the species. Attention was paid to effect which culture conditions, sex, and developmental stage may have on the mentioned parameters.

1. METHODS

1.1. Determination of density

Studies were carried out during the summer of 1968 on Strzeleckie Meadows in the north-western part of the Kampinos Forest in the association *Stellario-*

-*Deschampsietum*. A closer phytosociological and ecological characteristics of this association is given in the paper by Traczyk (1966).

In order to determine density of *Orthoptera* weekly samples have been taken with biocenometer[1] with 0.8 m side. Sampling was started on June 29, 1968 and continued to first slight frosts. On rainy days and with strong wind sampling was not performed, hence unequal intervals between sampling dates. In order to prevent flushing of insects the biocenometer has been thrown from the distance of ca 2 m while moving against sun to avoid casting shadow. Insects were removed by hands from the gauze covering walls of biocenometer. After the removal of all jumping insects, the studies area was watched during 15 minutes. This was necessary due to hidden in mosses larvae of all species as well as adult individuals of *Conocephalus dorsalis* (Latr.). These individuals, when not flushed, after some time entered walls of biocenometer and could be easily collected. As noted, the duration of 15 minutes was sufficient to capture all *Orthoptera* from beneath the trap. Captured insects were treated with ether and weighed on a torsion balance to the nearest 1 mg in order to obtain their fresh weight. Afterwards they were dried in 80°C and their dry weight was determined.

1.2. Culture experiments

Insects for cultures have been captured on Strzeleckie Meadows in the association *Stellario-Deschampsietum* and transferred to glass isolators (paraffin-lamps) having the capacity of ca 750 cm^3. Isolators were installed vertically above the Petri dish with some water, preventing insects from excessive desiccation (Fig. 1). This type of isolators is recommended by Chłodny (1969) as very useful in cultures of small grasshoppers. This opinion was confirmed also by my experiments. Cylinders of this kind are airy, light, and enable an easy access to insects. The leaves of young barley were used as food. They were placed directly on a net providing the bottom of cylinder. Similar food – young wheat – was used in laboratory cultures by Gangwere (1960) and Chłodny (1969). Checks of cultures were done daily. This short time prevented any obvious wilting and laying down of barley leaves and only slightly impaired the attractiveness of food for grasshoppers.

Due to fluctuations in moisture content of grass and in uneaten remnants left by insects, all calculations of daily consumption were done for the dry weight of grass. Since insects could not be fed with dry grass, the following procedure was accepted: similtaneously with preparation of food, 10 additional rations were dried for the determination of dry weight and it was assumed that

[1] Cage covered with nylon gauze on a framework of metal wire.

moisture content was the same in grass given to grasshoppers. After 24 hours grass browsed by grasshoppers was removed, dried and from weight differences

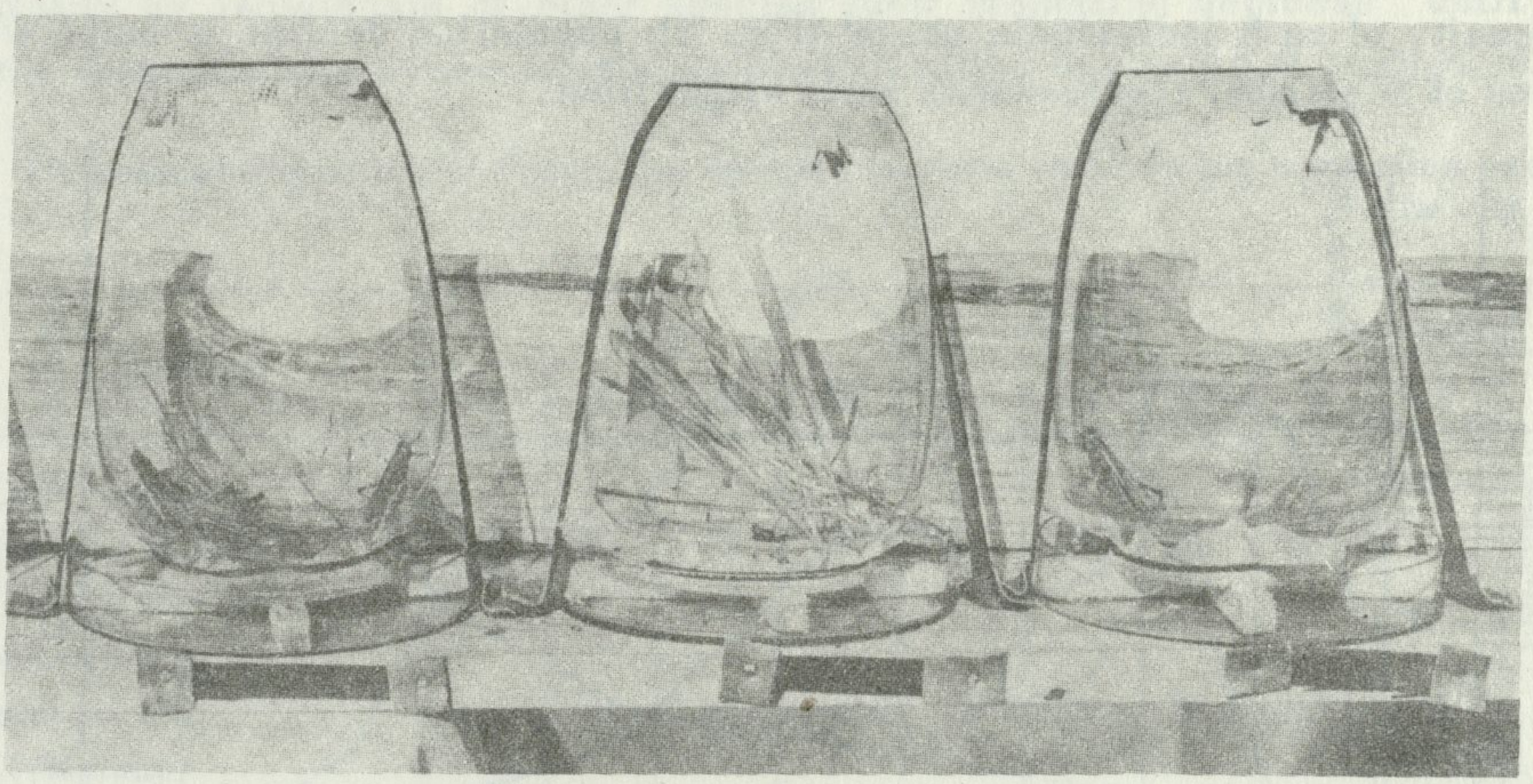

Fig. 1. Isolators with cultured grasshoppers

it was concluded on the quantity of dry matter ingested. During changes of food, apart from the measurements of the consumption, also the biomass increase of grasshoppers in cultures and the quantity of dismissed faeces were controlled. All measurements were done with the aid of a torsion balance weighing with the accuracy to 1 mg. Both dried leaves of barley, and faeces, and grasshoppers bodies were burned in calorimetric microbomb in order to obtain data expressed in calories. Cultures were run during three days and nights since the moment of insect collection in meadow and afterwards they were liquidated. The first experiment with larval instars of grasshoppers was carried out in mid-August in a glasshouse. Due to the difficulty in determining the age of studied larvae, after 3 diurnal cycles of experiments, they were kept further until the emergence of adult forms. Developmental stage of cultured insects has been determined on the basis of moults. Another experiment was carried out at the end of August and September for imaginal stages in two different environments: in a glasshouse and outdoors, on a moist meadow close to the Field Station of the Institute of Ecology, at Dziekanów Leśny.

2. RESULTS

2.1. Dynamics of numbers

Field samples for the determination of *Orthoptera* numbers have been taken during three months of 1968: since the beginning of July to the end of September.

This period does not include the beginning of larvae emergence which occured at end of May and first weeks of June. The emergence of larvae completes in mid-July and at this population reaches the maximum of its abundance giving the density of ca 8 individuals per m^2 (Fig. 2); population decline is noted with the end of September together with early slight frost.

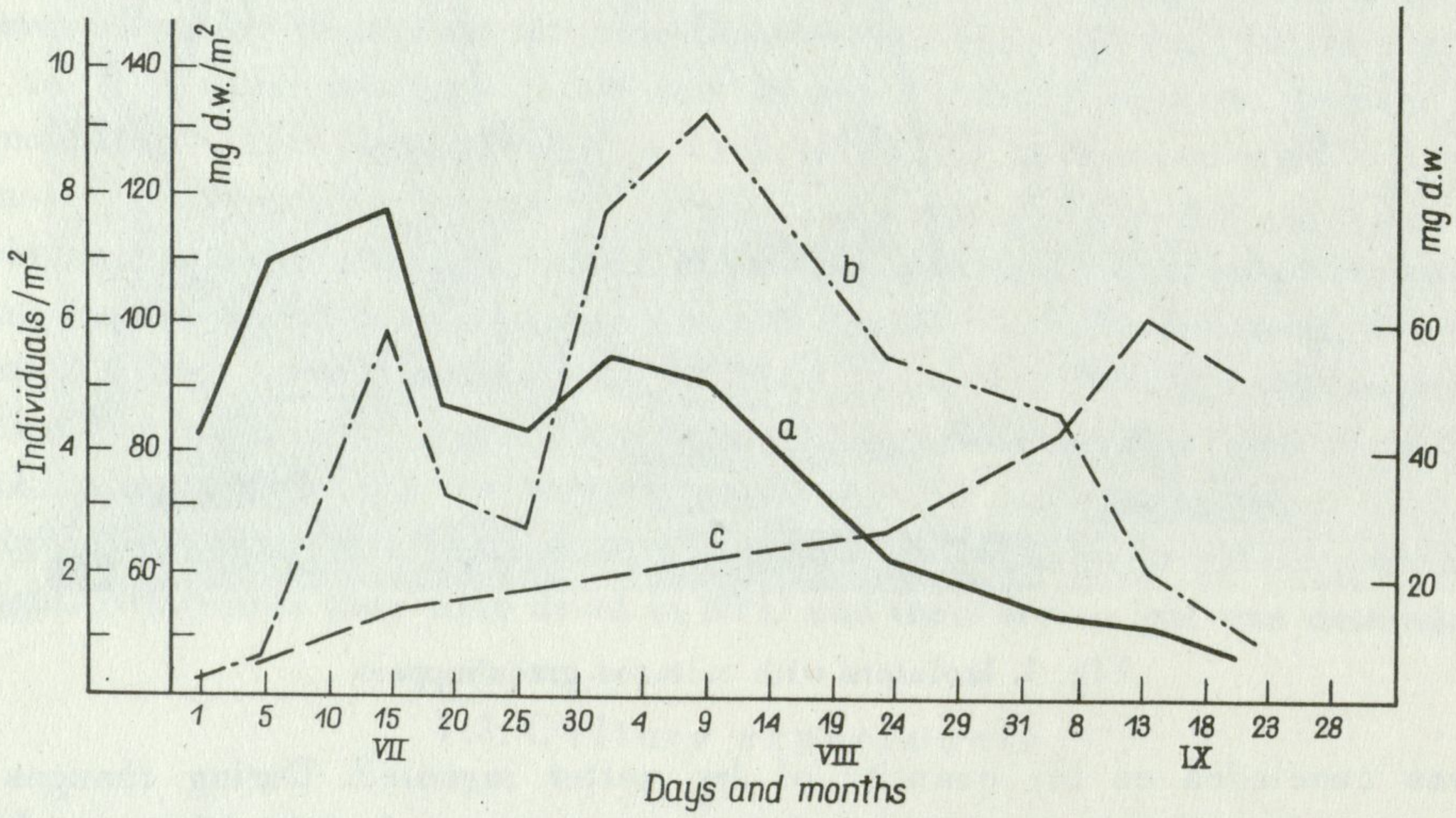

Fig. 2. Dynamics of numbers and biomass of *Orthoptera* population in Strzeleckie Meadows

a – numbers (ind./m^2), *b* – biomass (mg of dry weight/m^2), *c* – dry weight of individual

Changes in dry matter of individuals occurring per mean sample (Fig. 2) are similar to changes in numbers, but the maximum of it (132.3 mg per m^2) occurs later, at the beginning of August and is slightly (about 2 weeks) delayed in relation to the highest status of green vegetation biomass for the studied association of *Stellario-Deschampsietum* (compare Traczyk 1968).

For the sake of the illustration of changes in the weight of average individual in population the ratio between dry weight of individuals and density per given area unit was calculated. Weight increase continues until the first week of September (Fig. 2) and then attains its highest value: mean adult individual weighs 60.7 mg (dry weight). To the end of season the weight of adult individual slightly declines. This is probably connected with the deposition of cocoons by females, while the maximum of mass attained – with the preparation of organisms for this period.

Table I gives the list of *Orthoptera* species found in the studies association of Strzeleckie Meadows and the proportion of each of them in a mean sample of a group of adult individuals. Two *Orthoptera* families: *Conocephalidae* (*Tettigonioidea*) and *Acrididae* (*Acridoidea*) are represented on the area studied.

Conocephalus dorsalis was the only representative of *Conocephalidae*. Individuals of this species early attain sexual maturity and at beginning provide the species quantitatively dominant among all imagines. Along with attaining maturity by individuals of other species their proportion decrease until complete disappearance in the community studied at the beginning of September.

Percentual proportion of *Orthoptera* species (adualts only) during vegetation season

Tab. I

Species	July				August			Semtember		
	4	14	18	25	1	18	21	5	12	20
Conocephalus dorsalis (Latr.) (*Conocephalidae*)	100	50	75	31	33	18	34	8.5		
Mecostethus grossus (L.) (*Acrididae*)		50	25	38.5	9	15.6	20.5	29.6	10.4	11.1
Chorthippus montanus (Charp.) (*Acrididae*)				30.5	58	41.5	30.8	53.5	65	57.5
Ch. dorsatus (Zett.) (*Acrididae*)						20.5	14.7	6.4	23	31.4
Ch. albomarginatus (Deg.) (*Acrididae*)						4.4		2.4	1.6	

The family *Acrididae* is represented by the four species: *Mecostethus grossus*, *Chorthippus montanus*, *Ch. dorsatus*, and *Ch. albomarginatus*, *Chorthippus montanus* prevails quantitatively among the species mentioned. At the end of the season its proportion in adult population reaches 60%.

2.2. Energy budget of *Chorthippus montanus*

Consumption is the easiest to measure element in studies on the energy budget of phytophagous *Orthoptera*. Weighing technique is most convenient and most often used one in its measurements. Measured masses of consumed grass and weight increase of grasshoppers are expressed in calories, as units giving broader possibilities of comparison. Initial caloric values in the experiments carried out amount to: barley leaves – 4.158 cal/mg of dry weight, grasshoppers bodies – 5.616 cal/mg of dry weight, faeces – 4.058 cal/mg of dry weight. The following relationships (Petrusewicz 1967) while determining parameters of energy budget were used:

(1) $$C = P + R + FU = A + FU$$

(2) $$A = P + R = C - FU$$

C – consumption, P – production, A – assimilation, R – respiration, FU – faeces.

Measurements of consumption of *Ch. montanus* in IV and V developmental instars were taken for one culture in a glasshouse. The next culture was carried out on adult individuals. Larvae with mean weight of 77 mg ingest 11.68 cal daily in a form of food; this equals to 39.4 mg of tresh matter of barley leaves, i.e. about 0.51 mg of fresh barley falls to 1 mg of larva biomass (Tab. II).

Daily food ration of imagines and larvae of *Chorthippus montanus* in glasshouse conditions expressed in mg of fresh plant weight and in cal

Tab. II

Age of individuals in cultures	Number of individuals in culture	Mean weight of individual	Consumption per one individual / day		Consumption per 1 mg of individual biomass/ /day	
			Fresh weight mg	cal	Fresh weight mg	cal
Larvae ♀ ♂	18	77 ± 10.5	39.4	11.68	0.51	0.16
Imagines ♀ ♂	15	168 ± 50.4	97.89	29.05	0.58	0.18

Adult insects weighing 168 mg, i.e. about 2.2 times more, ingest during the same time 29.05 cal what is equivalent to 97.89 mg of a fresh matter of barley leaves, i.e. about 0.58 mg of barley per 1 mg of the biomass of individual. Average adult individual of *Ch. montanus* cunsumes thus 2.5 times more than larva at the end of its development. Food ration converted into body weight unit is therefore slightly grater in adult insects. My data are comparable with those quoted by Andrzejewska (Andrzejewska and Wójcik 1970); this author gives the consumption equal to 0.67 mg of fresh weight of grass per 1 mg of individual biomass for juvenile grasshopper larvae weighing 10–20 mg. For larger individuals weighing 20–60 mg what corresponds to the weight of larvae in my experiment, the food ration amounts on average to 0.40 mg of fresh weight of grass per 1 mg of grasshopper biomass. These data were obtained by Andrzejewska with the aid of field experiment. As the value of daily food ration for larvae in IV developmental instar Chłodny (1969) reports 31.3 cal, for the Vth instar – 49.6 cal. Mean for these data amounts thus to 40.4 cal. Author obtained these results in a long laboratory culture carried out since the emergence until attaining maturity by grasshoppers.

Great differences in the size of food ration were found between insects kept in glasshouse and on meadow (Tab. III). *Ch. montanus* female under meadow conditions ingest 22.06 cal per 24 hrs or 73.34 mg of fresh matter of barley leaves, i.e. 0.31 mg of fresh matter of this plant per 1 mg of the biomass of ndividual. A female kept in a glasshouse consumes 1.7 times more food, i.e 37.5 cal per 24 hrs what is equivalent to 126.3 mg of fresh matter of barley per insect and 0.53 mg per 1 mg of its biomass.

Similar relationship was obtained for males. During their staying on meadow they consumed 11.15 cal what equals to 37.57 mg of young barley per individual and 0.37 mg per an unit of their weight, respectively.

These same values for males kept in a glasshouse are following: 20.6 cal, 69.4 mg of fresh matter of leaves, and 0.70 mg per 1 mg of individual's weight. In this case the consumption in glasshouse increased 1.84 times.

Cultures revealed the dependence of daily food ration upon sex. Females are 2.4 times heavier than males and under meadow conditions consume 2 times and in glasshouse – 1.8 times more food than males. When converted, however, into body mass unit, the consumption of females is slightly lower (Tab. III). Kaufmann (1965) reports differences of similar order, although slightly lower values. According to this author males of *Ch. montanus* consume 28 mg of grass daily, while females – 56 mg. Knowing the duration of larval development and imaginal life, as well as the size of food ration, one can with some approximation determine the total of food ingested during the life of average individual. Larvae under laboratory conditions attain maturity after 37 days of culture; imagines live for about 30 days (Chłodny 1969). Accepting mean values consumption in a glasshouse for larvae on 11 cal as a daily food ration and for imago – on 30 cal (Tab. II), we arrived at the conclusion that *Ch. montanus* individual ingested during its life 1380 cal i.e. 4325 mg of fresh matter of barley leaves. For the same species Chłodny gives by about twice greater value: 2656.5 cal what is equivalent of 5275.2 mg of wheat leaf biomass.

It seems that one can indicate probable sources of so great discrepancy in these results. Chłodny's cultures were prolonged, while mine were short, 3 day cycles long each. The reason of undertaking short-duration cultures were reported in literature facts of excessive feeding of invertebrates under favourable, stabile conditions of a laboratory culture. It was anticipated that during a brief time animals brought from field will maintain their "field" food habits even in isolators.

Ch. montanus biomass increments have been measured with the aid of a weight technique. Following to liquidation of culture the ratio between fresh and dry matter and caloric values of insect bodies were determined. Thus the caloric equivalent of biomass was calculated.

Daily food ration (*C*) of imagines of *Chorthippus montanus* under meadow and glasshouse conditions expressed in mg of fresh weight of barley and in cal

Tab. III

Sex	Mean weight of individual (mg)	Meadow*					Glasshouse**				
		Number of ind. in culture	*C*/ind./day		*C*/mg ind./day		Number of ind. in culture	*C*/ind./day		*C*/mg ind./day	
			mg fresh weight	cal	mg fresh weight	cal		mg fresh weight	cal	mg fresh weight	cal
♂	99.5±7.4	7	37.57	11.15	0.37	0.099	8	69.4	20.6	0.70	0.207
♀	236±20.2	8	73.34	22.06	0.31	0.081	7	126.3	37.5	0.53	0.129

$t_{max.}$ – maximum temperature, $t_{min.}$ – minimum temperature, $h_{max.}$ – maximum relative humidity, $h_{min.}$ – minimum relative humidity,

* Meadow

$t_{max.} - t_{min.} = 18^{\circ}C$

$h_{min.} = 27\%$

$h_{max.} = 60\%$

**Glasshouse

$t_{max.} - t_{min.} = 13^{\circ}C$

$h_{min.} = 51\%$

$h_{max.} = 97\%$

Production efficiency, calculated as a ratio of P/C (production/consumption) is greater for larvae and amounts to 22.3%, while for imago – to 17.4% (Tab. IV). This means that larvae build into their bodies 22% of food, while imagines – only 17%. In the course of long laboratory culture Chłodny (1969) received similar values for this species. Production efficiency, calculated for the whole development of *Ch. montanus* amounts to 25.9%, while for the related species, *Ch. dorsatus* (Zett.) – to 23%.

Consumption (*C*), production (*P*), respiration (*R*), assimilation (*A*), faeces (*FU*), of imagines and larvae of *Chorthippus montanus*

Tab. IV

Age of individuals in culture	$P + R = A$ (percentage of consumption)			*A* emp. (cal)	$A + FU = C$ (percentage of consumption)			*C* emp. (cal)
Larvae ♀ ♂	22.3	37.5	60.3	7.04	60.3	39.8	100	11.68
Imagines ♀ ♂	17.4	42.9	60.4	17.50	60.4	39.5	100	29.05

Food assimilation was determined by the calculation of difference between consumption in terms of calories and caloric value of faeces dismissed ($C - F$) equalling to given food ration.

During 24-hours larvae assimilate 7.04 cal what comprises 60.3% of their consumption during that time (Tab. IV). During this time adult insects assimilate 17.5 cal or 60.4% of food ration. No dependence of assimilation upon sex was found.

Chłodny (1969) cites 63% as assimilation efficiency for larval instars, 53.5% for an adult insect. It should be mentioned that Chłodny examined all larval instars, thus including the youngest ones, where assimilation reached 80%. For related grasshoppers species values of assimilation efficiency amount to: *Schistocerca gregaria* 35–78% (Davey 1954), *Melanoplus bilituratus* 21–64% (Wiegert 1965), *Chorthippus parallelus* 34.3% (Gyllenberg 1969).

Values of daily food ration, production, assimilation, and respiration for the species studied presented in Tables II, III, IV are means from three days of culture. The range of variation in results both within one day and between them is considerable. The variation coefficient $\frac{\sigma}{\bar{x}}$ [2] attains the value of 60%. In all experiments an obvious underestimation of food ration from the first day

[2] σ – standard deviation, x – mean.

of culture was noted when compared with the remaining. This probably resulted from the response of animals transferred from a meadow to the change in environment.

3. DISCUSSION

Summing up results of the present paper it may be stated that:

1. Values of parameters of the energy budget were determined for larvae and adults of *Ch. montanus*.

2. The occurrence of differences in the size of diurnal food ration in relation to developmental stage, sex, and culture conditions was indicated.

The variation in diurnal food ration in relation to age, activity, and physiological status of animal as well as meteorological conditions was quoted in literature on many occasions. Culture experiments carried out by me in the two different enviroments in glasshouse and in meadow, indicated how pronounced could be the effect of physial environment (temperature and humidity) upon the size of consumption. It is understandable that the transferring to field of results obrained in laboratory should be very cautious until there are known better techniques which would allow to carry out experiments under conditions of a natural environment of an animal.

In the literature concerning the consumption by grasshoppers the attention is paid to still other important factors. And thus Chłodny (1969) during his long laboratory cultures of *Ch. montanus* and *Ch. dorsatus* evidenced the relationship between consumption size and the density of individuals in culture. Both the consumption and biomass increase in grasshoppers were lower in group cultures than in individual ones.

Andrzejewska (Andrzejewska, Wójcik 1970) found that mature grasshoppers females during the period of egg deposition gradually increase the quantity of food ingested. At the end of female life, after the deposition of eggs, the daily consumption per biomass unit is exceptionally large, similar to the daily consumption by the youngest larval instar.

The position of grass blades is of prime importance for the size of consumption in laboratory cultures. Kaufmann (1965) found that grasshoppers prefer the vertical position: blades situated horizontally were consumed to by far lesser extent. In short-term cultures carried out by me I had no trouble with this. Under high air humidity barley shoots dried a little during 24 hours period and, while supported by cylinder walls, for long maintained their vertical position.

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BADANIA PRODUKTYWNOŚCI DWÓCH TYPÓW ŁĄK W DOLINIE WISŁY

V. WSTĘPNE BADANIA NAD LICZEBNOŚCIĄ I ENERGETYKĄ *OTRHOPTERA*

Streszczenie

W pracy przedstawiono wyniki wstępnych badań nad liczebnością i energetyką *Orthoptera*. Eksperymenty prowadzono w okresie letnim 1968 r. w zespole *Stellario-Deschampsietum na* Łąkach Strzeleckich w Puszczy Kampinoskiej. Stwierdzono występowanie 5 gatunków *Orthoptera*, wśród których ilościowo dominował *Chorthippus montanus* (Charp.) (*Acrididae*) (tab. I).

Dla określenia zagęszczenia szarańczaków pobierano biocenometrem o boku 0.8 m cotygodniowe próby. Największe zagęszczenie – ok. 8 osobników/m² obserwuje się w połowie lipca (fig. 2). W następnych miesiącach liczebność *Orthoptera* zmniejsza się osiągając minimum w końcu września. Maksimum biomasy – 132,3 mg suchej masy na 1 m² populacja osiąga na początku sierpnia (fig. 2). Odmiennie przedstawiają się zmiany biomasy przeciętnego osobnika w próbie; maksimum ciężaru – 60,7 mg suchej masy przypada na początek września (fig. 2).

Określono parametry budżetu energetycznego larw i osobników dorosłych *Ch.*

montanus. W tym celu przeniesione z łąki owady hodowano w izolatorach szklanych (fig. 1) przez trzy doby. Jako pokarm brano źdźbła młodego jęczmienia. Kontrole hodowli przeprowadzano co dobę, mierząc konsumpcję (*C*), przyrost biomasy (*P*) i ilość wydalanych fekalii (*FU*). Pomiary prowadzono metodą wagową, a końcowe dane wyrażano w kaloriach. W obliczeniach respiracji (*R*) i asymilacji (*A*) wykorzystano następujące współzależności (Petrusewicz 1967):

$$1.\ C = P + R + FU = A + FU$$

$$2.\ A = P + R = C - FU$$

Stwierdzono, że larwy *Ch. montanus*, w IV i V stadium przyjmują w formie pokarmu 11.68 cal na dobę, co równa się 39,4 mg świeżej masy liści jęczmienia (tab. II). Owady dorosłe tego samego gatunku w tym czasie zjadają 2,5 razy więcej pokarmu niż larwy (29,05 cal czyli 97,89 mg świeżej masy liści jęczmienia).

Osobniki dorosłe *Ch. montanus* hodowano w dwóch różnych środowiskach – na łące i w szklarni. Stwierdzono istotne różnice w wielkości konsumpcji (tab. III). Samica *Ch. montanus* w warunkach naturalnych na łące przyjmuje 22,06 cal na dobę, czyli 73,34 mg świeżej masy liści jęczmienia. Samica hodowana w szklarni pobiera 1,7 razy wiecej pokarmu tj. 37,5 cal na dobę, co równa się 126,3 mg świeżej masy liści jęczmienia. Podobną zależność otrzymano dla samców. Podczas hodowli na łące przyjmowały one 11,15 cal, czyli 37,57 mg świeżej masy liści jęczmienia na osobnika. Te same wartości dla samców hodowanych w szklarni kształtują się następująco: 20,6 cal, 69,4 mg świeżej masy liści. W tym wypadku konsumpcja w szklarni wzrasta 1,84 razy. Przedstawione wyniki wskazują, jak duży wpływ na wielkość racji pokarmowej mają warunki środowiska, w których prowadzi się eksperyment.

Wydajność produkcji, obliczona jako stosunek *P/C* (produkcja/konsumpcja) jest większa dla larw i wynosi 22,3%, gdy dla imago 17,4%.

Asymilację (*A*) pokarmu obliczono jako różnice między konsumpcją, wyrażoną w kaloriach, a wartością kaloryczną wydalanych fekalii odpowiadających danej racji pokarmowej.

W okresie jednej doby larwy asymilują 7,04 cal, co stanowi 60,3% ich konsumpcji w tym czasie (tab. IV). W okresie tym owady dorosłe przyswajają 17,5 cal czyli 60,4% racji pokarmowej.

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