INSTITUTE OF ECOLOGY-POLISH ACADEMY OF SCIENCES

EKOLOGIA POLSKA

Vol. XIX Warszawa 1971 No. 13

Institute of Ecology, Laboratory of Grassland Ecosystems and Plant Ecology, Warszawa

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PRODUCTIVITY INVESTIGATION OF TWO TYPES OF MEADOWS IN THE VISTULA VALLEY

VII. ESTIMATION OF THE EFFECT OF PHYTOPHAGOUS INSECTS ON THE VASCULAR PLANT BIOMASS OF THE MEADOW

(Ekol. Pol. 19: 173–182). The joint effect of the whole phytophagous invertebrate fauna on the amount of biomass produced by vascular plants was investigated in two meadow associations: *Stellario-Deschampsietum*, ord. *Molinietalia*, and *Arrhenatheretum elatioris*, ord. *Arrhenatheretalia*. In a field experiment the crop of plants in areas from which insects had been eliminated (by insecticides) was compared with the crop of plants infested by insects. The presence of this fauna resulted in a noticeably lower growth rate of plants; the maximum of biomass was retarded, and consequently the crop was lower.

I. INTRODUCTION

The aim of the investigation was to determine the effect of the phytophagous invertebrate fauna on the biomass of the meadow vegetation. The role of the phytophagous fauna in a meadow habitat is difficult to determine. The quantity of the plant biomass actually eaten by the herbivores generally is not equal to the losses caused by their feeding. The effect of feeding depends on a number

of different factors, such as, for instance, the way of feeding and the feeding site on the plant, associated with which is the type of damage caused (Varley, Gradwell 1958, Nourteva 1962, Ricou, Duval 1969, Andrzejewska, Wójcik 1970). It may also be expected that with a simultaneously presence of several groups of herbivores, differing in their effects on the plant, the value of the actual reduction of the plant production will differ from that estimated by summing up the effects of individual groups. In a meadow habitat, numerous herbivores occur simultaneously, each feeding on a different part of the plant, and it is impossibile, even for technical reasons to study the effects of individual groups. Therefore the assessment of the joint effect of all the herbivores, occuring in a meadow, on the primary production seems to be the most appropriate approach. It may be expected that the values obtained by this method will be similar to the actual results of the action of the herbivores under natural conditions.

II. METHOD

To estimate the joint effect of all herbivores on the meadow vegetation a field experiment was carried out. Two meadows were chosen for this purpose: 1) a mid-forest periodically wet meadow (association *Stellario-Deschampsietum*, ord. *Molinietalia*), within a nature reserve, unharvested (symbol SM), 2) a riverside fresh meadow (association *Arrhenatheretum elatioris*, ord. *Arrhenatheretalia*), subject to some agricultural treatment and harvested (symbol K II). The botanical aspect of the two habitats concerned has been described in detail by Traczyk (1966, 1971).

The effect of insects on the primary production of the meadow was estimated by comparing the plant mass produced in the insectless areas with the mass of the plants fed on by insects. For the elimination of insects from the experimental areas insecticides were used.

As indicated by the data found in the relevant literature, even those insecticides which are in fact known not to be phytotoxical may under certain conditions affect the growth and the condition of the plants, directly, or indirectly by causing injuries, e.g. necrotic lesions or burns (Miksiewicz 1963). The severity of the injuries, which may vary, depends on the species and growth stage of plants, as well as on the soil and weather conditions (Kochman, Węgorek 1963, Borys 1964, Dvorak, Stanek 1968). As the weather conditions and soil moisture vary during the season, it is difficult to forsee and determine the effect of the poison on the whole meadow vegetation. For this reason in the experiments here presented three insecticides were

used which differed in their chemical composition, effectiveness time and site of deposition in the plant. If therefore the insecticides used had been ones that affect the plant growth, a different quantity of plant mass would have been produced in each of the areas treated with the different insecticides.

The poisons used were the following insecticides: "Tritox", "Pędraczak" and "Intration", commonly applied in agriculture and fruit-farming. A contact insecticide Tritox (containing DDT – 10%, methoxychlorine – 15%, lindane – 5%) was used in the form of water-emulsion for spraying the plants. To kill the soil fauna Pędraczak (a granular substance – γ-isomer of HCH, with a 2% content of lindane), also a contact insecticide, was sprinkled over the litter between the plants. Intration (thiometon – 50%), a systemic insecticide, was used in water solutions for spraying the plants (Encyklopedia Ochrony Roślin 1963, Zalecenia ogólne na rok 1969).

The effect of Tritox and Intration was similar. Within a short time following treatment all the insects present in the grass-layer and in the litter were killed. As Pędraczak was sprinkled over the litter, the insects present in the higher layers of vegetation were only killed when they came down during their vertical migrations – diurnal or related to their growth cycle.

In meadow patches, as homogenous as possible in regard of vegetation composition and structure, five areas, 1.5 × 10 m, were fenced in. The distance between adjacent belts was 1 m (Fig. 1). Four of the plots were treated with insecticides in each of the first three plots a different insecticide was used, whereas the fourth plot was treated with all the insecticides together. In the fifth plot, the control plot, no insecticide was applied, nor any other disturbing factor introduced. The experimental plots were treated with insecticide doses as specified in the manufacturers' instructions.

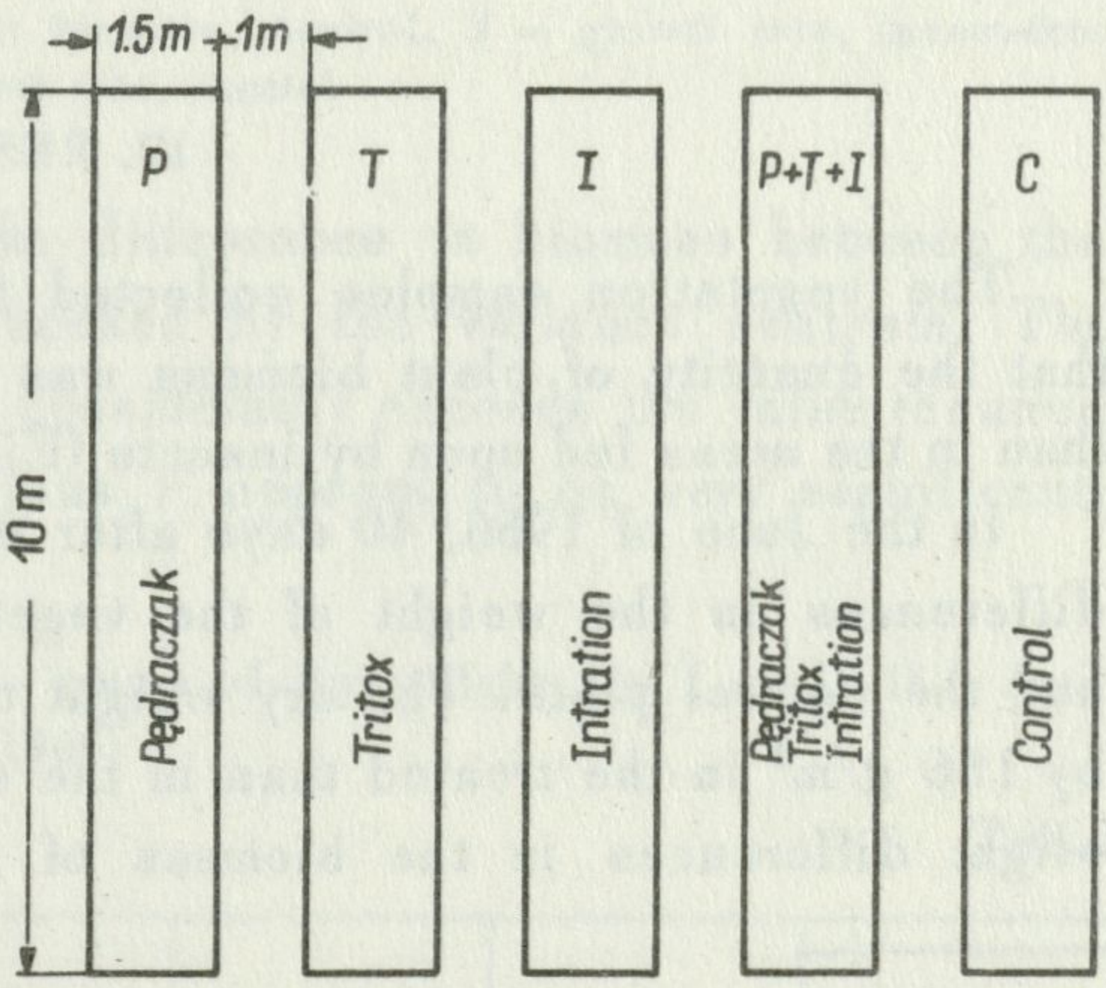

Fig. 1. Scheme of location of the experimental plots in meadow

The estimation of biomass was based on the measurement of samples. A sample consisted of all the plants, including dead parts, collected from a sample area – 1000 cm^2; the plants were cut as close to the ground as possible; from each plot five samples were taken. The plant material was

subsequently dried and weighed. The efficiency of the insecticides in relation to the invertebrates investigated, and the rate at which insects reappeared in the insecticide-treated areas were checked by control samples collected with a biocenometer of the size 0.3 × 0.3 m, from under which insects were sucked off.

In 1966, the first treatment with insecticides was applied on June 11, immediately after mowing the grass and at the beginning of the mass hatching of the phytophagous insects. In about six weeks (40 days) plant samples were collected from the experimental plots for the measurement of the plant biomass. Subsequently, the insecticides were again sprayed on the full-grown, unmown plants, and next samples were taken on August 3 and 17.

The same experiment was repeated in 1967, but then from a half of each plot the deposits of dead plants were removed in the spring, since, as has been found, if perimitted to remain, the dead deposits may affect the growth of new plants[1].

In 1968, Pędraczak was the only insecticide used. This substance does not cause any damage even to the plants growing back afresh. In the growing season of that year Pędraczak was sprinkled for the first time on May 3, before the first hatching period of the phytophagous insects.

III. RESULTS

The vegetation samples collected from the experimental areas indicated that the quantity of plant biomass was usually larger in the insect-free plots than in the areas fed upon by insects (Fig. 2).

In the June of 1966, 40 days after the mowing of the meadow, considerable differences in the weight of the vegetation were found between the treated and the control plots. The dry weight of vegetation was higher on an average by 166 g/m² in the treated than in the control areas. There occured also some slight differences in the biomass of plants between the plots treated with

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[1] This effect is clearly visible in places with a large quantity of dead material In the nature reserve meadow SM, from which the deposits of dry plants of the preceding year removed in May, an average of 314 g of dry weight of green plants per 1 m² was harvested at the and of June, and only 230 g/m² in areas in which the dead plant deposits had been premitted to remain. In the cultivated meadow at Kazuń, where the amount of deposited dead plants was much smaller no significant differences could be seen there between the biomass of the green parts of plants in the areas from which the dead matter had been removed, and that in the plots in which the dead matter had been allowed to remain (Tab. II).

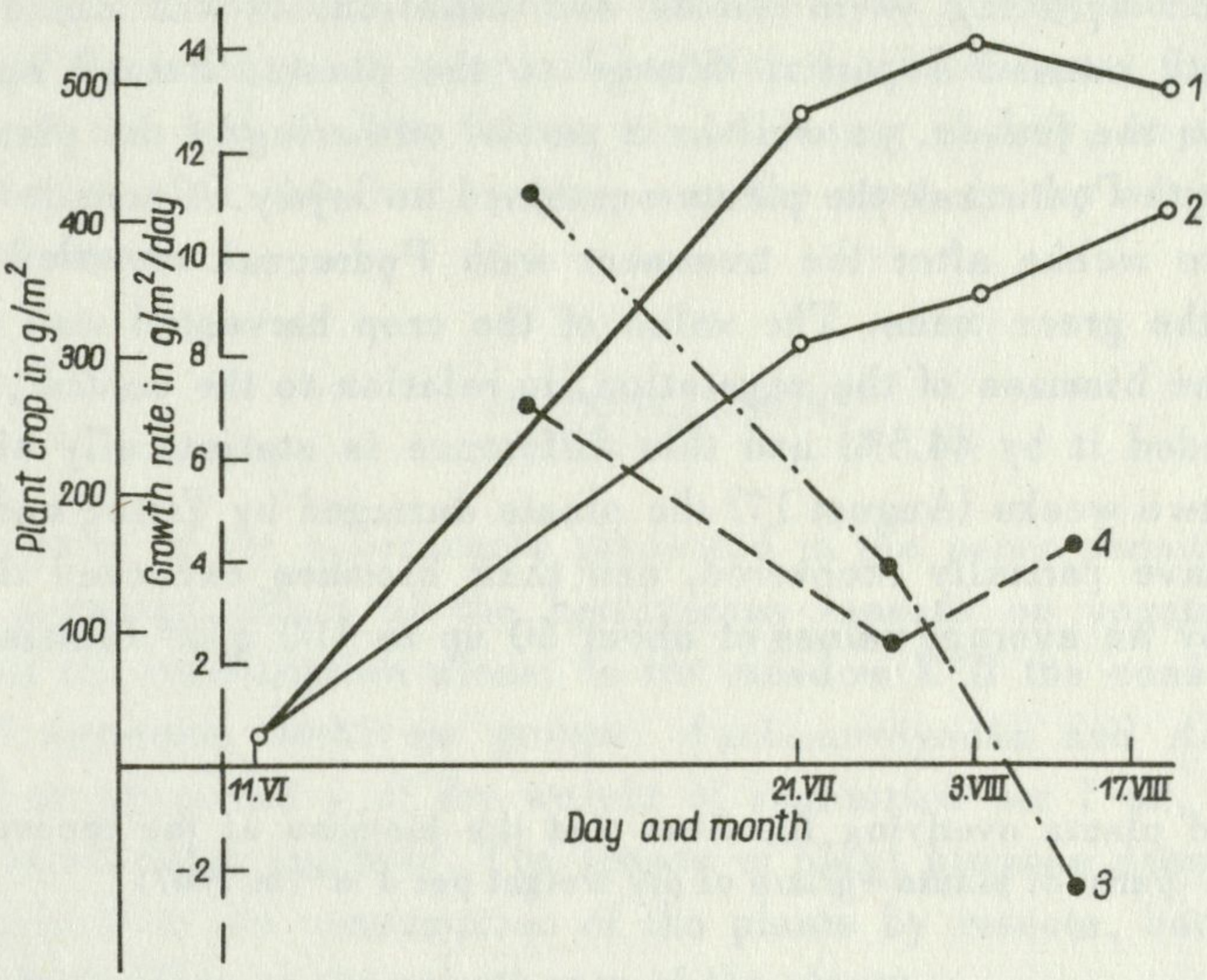

Fig. 2. Crop of vegetation harvested from experimental plots, an the growth rate of their biomass (data for meadow K II, in 1966)

1 – plant biomass, insect-free area, *2* – plant biomass, control, *3* – growth rate, insect-free area, *4* – growth rate, control

the different insecticides (Tab. I). The differences in biomass between the treated and the control plots were checked by the variance analysis. The obtained statistic value of F ($F = 23.8$) considerably exceeds the value required at the level of 0.05 ($F_{0.05} = 4.26$), thus F appears to be very significant.

Crop of vegetation in experimental areas – grams of dry weight per 1 m² (K II – data for 1966)

Tab. I

Insecticide / Date of taking plant samples	Control area	P Pędraczak	T Tritox	I Intration	P + T + I
June 11*	25	25	25	25	25
July 21*	312	479	478	457	500
August 3	344	529	336	336	404
August 17	404	494	456	501	461

* Data of treatment with insecticide.

The second spraying, with Tritox and Intration, of the stand after its recovery growth caused a partial damage to the plants. Burned spots could be observed on the leaves, as well as a partial withering of the plants. In the area treated with Pędraczak the plants sustained no injury. A sample of vegetation taken two weeks after the treatment with Pędraczak revealed a further increment of the green mass. The value of the crop harvested was 529 g/m². At that time the biomass of the vegetation, in relation to the control, was even greater (exceeded it by 44.5%) and this difference is statistically significant. After another two weeks (August 17) the plants damaged by Tritox and Intration appeared to have partially recovered, and their biomass exceeded that in the control area by an average values of about 50 up to 100 g/m² (statistically no significant).

Amount of dead plants overlying the litter and the biomass of the recovering green parts of plants—grams of dry weight per 1 m² (in 1967)

Tab. II

		Natural meadow SM	Cultivated meadow K II
Amount of dead plants on May 11		75	19
Crop of vegetation harvested on June 20 from plots	free of dead matter	314	352
	with overlying dead matter	230	357

Due to the scarce rainfall and the hot weather prevailing in the June and July of 1967 the vegetation in the meadow, and particulary in the insecticide--treated areas, began earlier to turn yellow and wither. As of all the insecticides used Pędraczek is the least harmful to plants, the plant biomass of the areas treated with it could be compared with the control. During the first harvesting in June the value of the biomass of plants in the treated areas was greater on an average by 26%, and in August (eight weeks after the cutting of the grass) – by 35%, and after another four weeks, in September – by 41%, as compared with the vegetation fed upon by insects.

In 1968 Pędraczak was the only insecticide used for the killing of insects in the experimental areas. The first treatment was applied on May 3, before the emergence of the first numerous phytophagous insects. The first vegetation sample was collected at the time of maximum growth in biomass, i.e. on June 19. At that time, in the areas devoid of fauna the biomass of the vascular plants was on an average higher by about 21%, as compared with the control

area. Insecticide-treatment applied at the beginning of May had no effect on the hatching of the subsequent groups of herbivores, which appear to be particularly numerous at the end of June and at the beginning of July, so the biomass of the vegetation after the first mowing was the same in the experimental as in the control areas.

IV. CONCLUSIONS

The results of the experiments presented in the paper permit the statement that the reducing effect of the herbivorous insects on vegetation does not result from the consumption alone. In the meadow K II the consumption of the two most numerous herbivore groups: *Auchenorrhyncha* and *Acridoidea*, was estimated at about 6.3 g of dry weight of vegetation per 1 m^2, throughout the season June-October in 1966[2]. The losses of plant biomass does not, therefore, result solely from the consumption of the plants by insects, but also from the effect of the feeding on the growth rate of the plants.

The quantity of plant biomass is usually larger in insect-free areas than in the control areas. The differences are most marked 40 days after the mowing of the meadow (June 11) when the dry weight of the plants in the insect-free areas is about 500 g/m^2, thus approaching the maximum value attainable under these soil conditions. As time elapses, the differences in the biomass of vegetation gradually become less conspicuous, but about 10 weeks after the harvesting of the meadow the dry weight of grass in the insect-free areas is still higher by 50 up to 100 g/m^2, in comparison with the control area. The differences in the biomass of vegetation were diminished because the plants free of insects grow faster, attain the biomass maximum at an earlier time – after 7–8 weeks, whereafter their rate of growth, as well as their biomass, gradually decrease (Fig. 2). Their biomass increment rate (during the period following the harwesting) is from 10.1 to 11.9 g dry weight/m^2/day (Tab. III).

[2] The average density of *Acridoidea* during the period June-October was 3.9 individuals/m^2, and their dry weight – 136.5 mg. Taking, as a basis, the food rations previously calculated (Andrzejewska, Wójcik 1970), the consumption by these insects may be estimated at about 4 g dry weight of plants per 1 m^2. The average density of *Auchenorrhyncha* in the same meadow was 27 individuals per 1 m^2, i.e. about 32 mg dry weight. The total amount of sap, they will have sucked during the season, may be estimated, on the basis of earlier data on the consumption of this group of insects (Andrzejewska 1967), at about 1700 g per 1 m^2 of the meadow. Assuming the average calorific value of the sap to be about 6 cal/ml (the mean from the values published by Wiegert 1964), the approximate calorific aquivalent of the dry weight of grass is above 2.3 g.

The control plants (fed upon by insects) grow more slowly. The increment in grass biomass was 7.2 g dry weight/m²/day (Tab. III). About 10 weeks after the mowing of the biomass of the plants in the control area still not attained its maximum and continues to grow (Fig. 2).

Growth rate of vegetation biomass in experimental plots (K II – data for 1966)

Tab. III

Growth rate of plant biomass in g/m²/day	Days after mowing	*C* Control	*P* Pędraczak	*T* Tritox	*I* Intration	*P* + *T* + *I*
	40	7.2	11.4	11.3	10.1	11.9
	53	3.2	3.8	-10.9	-7.0	-9.6 *
	67	4.3	-3.5	8.6	9.6	4.1

* Green plant biomass losses due to injuries caused by insecticides.

The statement that the quantity 450 to 500 g dry weight of plants/m² is the maximum value for this meadow may be inferred from the variation of the increment rate of plant biomass. Plant growth appears to be faster during the first period after the mowing of the meadow, when the plants are recovering;

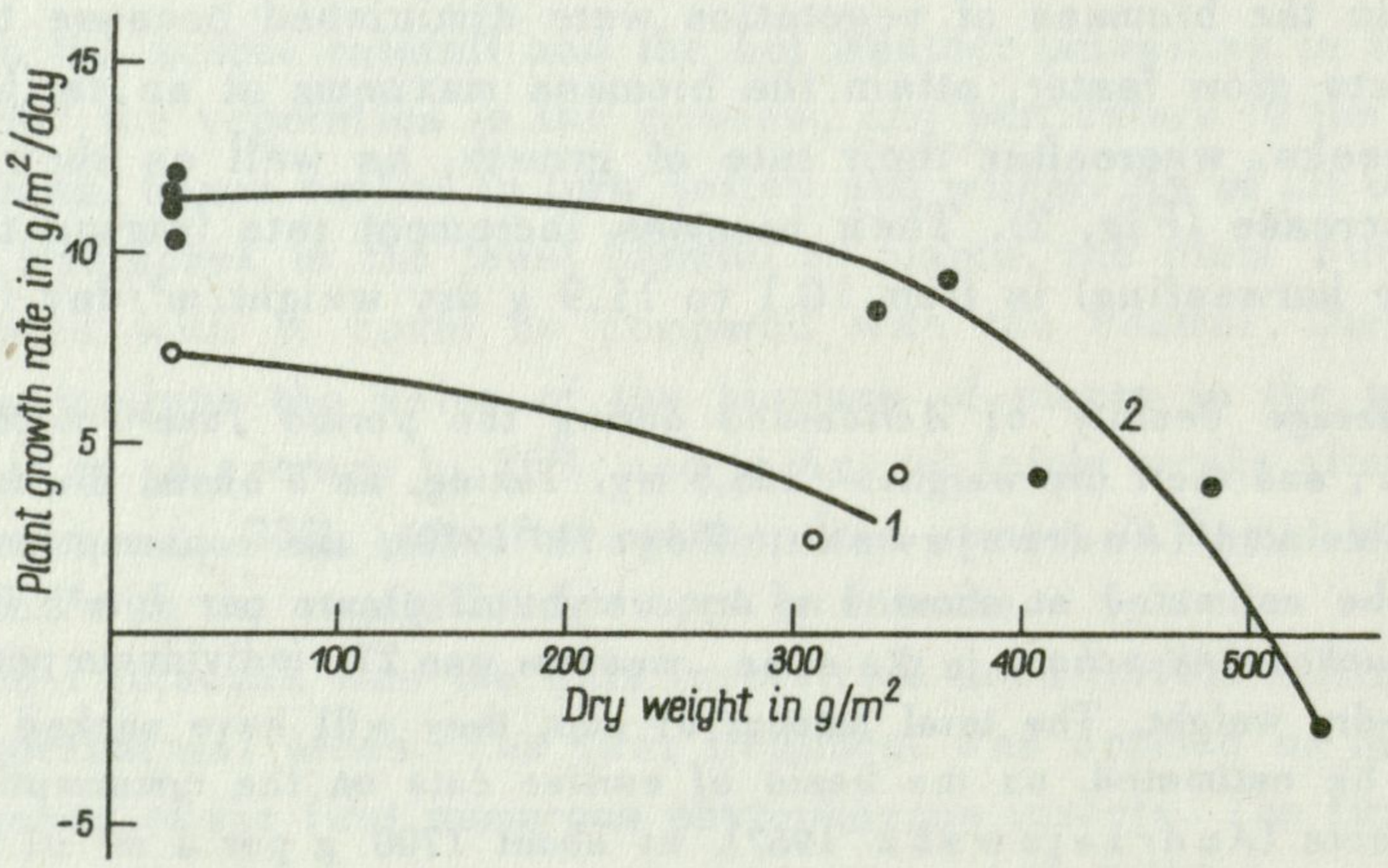

Fig. 3. Biomass growth rate in relation to the initial condition of the vegetation
1 – control, *2* – insect-free area

afterwards the biomass increment rate falls gradually down. Eventually the standing crop biomass atteins the value of 300–350 g dry weight/m^2, whereafter the rate of growth falls down much more rapidly. After the biomass has reached a maximum of about 500 g/m^2 it begins to decrease (Fig. 3).

It may, therefore, be presumed that the phytophagous insects affect the vegetation of a meadow chiefly by lovering its growth rate and delaying the attainment of biomass maximum. This leads on to a several weeks' delay in the second harvesting of the meadow and affects the recovery growth of the vegetation. The crop harvested from the meadow during the whole growing season is consequently lower. The losses of plant production are many times higher than the actual amount of food eaten by the herbivores.

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BADANIA PRODUKTYWNOŚCI DWÓCH TYPÓW ŁĄK W DOLINIE WISŁY

VII. OCENA WPŁYWU ROŚLINOŻERNYCH OWADÓW NA BIOMASĘ ROŚLIN NACZYNIOWYCH ŁĄKI

Streszczenie

Metodą eksperymentu terenowego przeprowadzono ocenę wpływu całej bezkręgowej fauny roślinożernej na biomasę roślinności łąkowej. Wpływ ten oceniano porównując biomasę roślin wyprodukowanych na powierzchniach bez owadów z biomasą roślin, na których żerowały roślinożerce. Owady z powierzchni eksperymentalnych zostały usunięte przy użyciu insektycydów; termin zastosowania trucizn związany był z okresami wylęgu owadów i pojawianiem się ich na łące. Biomasę roślin na powierzchniach doświadczalnych oceniano badając próby roślinności pobierane kilkakrotnie w ciągu sezonu.

Stwierdzono, że biomasa roślin na powierzchniach doświadczalnych była zwykle większa niż na powierzchniach kontrolnych. Największe różnice biomasy wystąpiły w okresie, kiedy rośliny na powierzchni pozbawionej owadów osiągały maksimum biomasy na danej łące (po ok. 40 dniach od skoszenia trawy w czerwcu). Wówczas ich biomasa była o 58% wyższa niż na powierzchni kontrolnej. Następnie tempo przyrostu roślin szybko spadało i następowało ubywanie ich biomasy.

Rośliny na powierzchni kontrolnej rosły wolniej nawet w okresie początkowym po skoszeniu trawy. Tempo ich przyrostu było o 4.7 g suchej masy/m²/dzień wolniejsze niż na powierzchniach bez owadów. W efekcie jeszcze po ok. 10 tygodniach od skoszenia trawy nie uzyskały maksimum biomasy właściwej na danej łące.

Można więc przypuszczać, że wpływ roślinożernej fauny bezkręgowców na roślinność łąkową polega głównie na zwolnieniu tempa wzrostu roślin i opóźnieniu osiągnięcia przez nie maksimum biomasy. W efekcie daje to znaczne obniżenie plonu roślin zbieranego z łąki w całym sezonie wegetacyjnym.

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