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Biomass increment in mosses on the example of *Aulacomnium palustre* (Hedw.) Schwaegr.

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Abstract

The biomass increment of the moss *Aulacomnium palustre* growing on two meadows of the Kampinos National Park was studied. The state of the biomass and production in g/m² were compared on two different sites in two successive vegetation seasons.

INTRODUCTION

Within the framework of the theme "Biological productivity" investigations are conducted by the Group of Bryology and Pteridology of the Intsitute of Botany, Warsaw University on the productivity of mosses and their role in the production of organic matter. The present study is devoted to one moss species — *Aulacomnium palustre*.

The aim in view was to study the dynamics of growth of this moss species, calculate the production and state of its biomass in the years 1971 and 1972. The investigations were carried out from April to November in the vegetation season 1971 and from March to November in 1972 comparatively on two meadow habitats situated in the north-eastern part of the Kampinos National Park on the Strzeleckie and Sierakowskie meadows.

Localization of the sites under investigation

Both the meadows studied lie in the north-eastern part of the boggy Ciechowąż near the villages Sadowa and Dziekanów Leśny in the forest district Laski. These meadows are included into the reservation Sieraków in the Kampinos National Park. This reservation lies on the second dune terrace, in the morphology of which two dune belts are distinguished alternating with two belts of bogs (R. Kobendza, 1930).

The part of the Strzeleckie meadows from which samples were taken for analysis is covered with vegetation of the order *Molinietalia*, alliance *Stellario-Deschampsietum* (T. Traczyk, 1968). In the patches of this community water is always below the ground level and only exceptionally after long lasting rainfall does it ever reach the surface. In 1972 in April and September the meadows were completely innundated at the sampling sites, although the ground water level on the higher situated meadow patches, according to the amount and distribution of precipitation, is found at a depth of 40—80 cm (Z. Czerwiński, 1971).

On the other hand, the Sierakowskie meadows have a high ground water level, stagnant over nearly the whole of the vegetations season on the soil surface. pH examined by means of Hallige's reagent was about 9 on Strzeleckie and 7—8 on Sierakowskie meadows.

Strzeleckie meadows have not been exploited for 16 years, contrary to the Sierakowskie meadows which are regularly mown.

On account of the wide habitat differences of both meadows they were chosen for comparative studies and evaluation of the state of *Aulacomnium palustre* biomass and the production of organic matter by this moss species in the course of two vegetation seasons — 1971 and 1972.

METHODS

Measurements of the above-ground biomass of plant parts consisted in analysis of moss samples collected on the above mentioned sites. Surface areas covered with a one-species carpet were chosen for the investigations. Samples were collected at monthly intervals from April to November in 1971, and from March to November in 1972. On these areas samples were cut with a round blade 11 cm in diameter. In each month sampling was done 8 times (8×100 cm^2). A total of 64 samples was analysed in 1971 and 72 in 1972, that is 136 samples $\times$ 100 cm^2 in all. The collected moss was transferred in plastic bags to the laboratory where each sample was analysed separately, separated into single individuals, washed with water, and then the *Aulacomnium palustre* shoots were counted.

The length of the light green current-year segments and of the dark last-year ones was measured. From each sample from 100 cm^2 the length of 50 randomly chosen individuals was measured, that is in one month the length of 200 specimens was determined.

Then the light green part was separated from the last-year one and they were placed separately in paper bags. The material was dried at 80°C for 48 h. From one sample 50 individuals (10 in each bag) were weighed that is 200 individuals from one meadow. The last-year and present-year segments were weighed separately. For weighing the material an analytical scale with accuracy up to ± 0.0001 g was used.

The method applied in the present work is one of the direct methods for evaluation of production and is a modification of the harvest method. In investigations of the productions by the direct method, measurement of the biomass is indispensable.

It is best to obtain direct data on the value of the mass increament, and not base on the results of indirect methods, for instance the difference in the biomass values (Traczyk, 1967).

Direct analysis of the growth increment was performed in each month of the studies. This allowed to establish the maximum increment reached by the individuals in the given vegetation season. Growth was fastest from April to June, and the production of *Aulacomnium palustre* was calculated for this period (3 months).

The first step in this method was the determination of the average growth increment index G_i:

$$G_i = \frac{\sum \text{ of growth increments}}{n}$$

n — number of individuals weighed.

In the second step net production was calculated by the formula

$$P = G_i \times D$$

where P — net production in g/m^2

D — number of individuals per 100-cm^2 surface area.

The biomass was also calculated in each season by multiplying the weight of one individual in the particular months by the mean number of *Aulacomnium* individuals on the studied sites.

Number of individuals

The results of calculation of the density of *Aulacomnium palustre* on both the meadows in both years of the study are shown in table 6.

The number of individuals per 100-cm^2 surface of Sierakowskie meadows was within the range of 541—128 in 1971 and 345—120 in 1972.

For the Strzeleckie meadows the corresponding values were somewhat lower for the vegetation season, in 1971 — 399—123 and in 1972 — 439—107.

It results from these data that the number of individuals per 100 cm^2 varies widely. On the basis of the analysis of 136 samples of *Aulacomnium palustre*, and a similar number of samples of other moss species, for instance *Polytrichum commune*, *Climacium dendroides* exhibiting a similar variability in numbers, it would seem that it is impossible to establish the number of individuals occurring on 100 cm^2. This number depends on many factors, the most important of which are precipitation, temperature, and also the month in which the sample was collected.

Length of individuals

The length of individuals from the samples taken each month was measured with a graded measure with an accuracy up to 1 mm. From March and April to July the current and last year's length increments were measured separately and from

Table 1

Mean lenth of individuals in 1971 and 1972, cm

Site studied	Year	March			April			May			June			July			August	September	October	November
		this year's increment	last year's part	total	this year's increment	last year's part	total	this year's increment	last year's part	total	this year's increment	last year's part	total	this year's increment	this year's part	total	Entire lenth of the individuals			
Sierakowskie meadows	1971	—	—	—	1.0	9.2	10.2	1.4	10.4	11.8	2.1	10.1	12.2	2.4	9.4	11.8	11.8	11.4	9.6	9.0
	1972	0.4	6.5	6.9	1.3	5.7	7.0	1.6	6.1	7.7	3.1	4.1	7.2	2.5	4.0	6.5	5.8	6.4	8.5	6.8
Strzeleckie meadows	1971	—	—	—	0.8	8.4	9.2	1.3	10.1	11.4	3.0	10.7	14.0	2.0	9.9	11.9	10.9	9.8	9.3	8.8
	1972	0.5	7.7	8.2	—	—	—	2.8	6.4	9.2	2.7	5.7	8.4	1.7	4.4	6.1	6.0	—	6.8	5.5
		Results obtained on the basis of 200 measurements																		

August to November the entire length of the individuals was measured. This year's increment was easy to distinguish from that of the hibernating part, since the latter was dark green while the younger segments were of much lighter colour. Carl Olof Tamm (1954) applied such a division in his studies on the productivity of *Hylocomnium splendens*.

With the increase of green mass its decomposition starts; beginning with June the lower segments of this year's shoots begin to darken rapidly. The intensive growth of green mass ends, and it is no more clear whether the whole vividly green July growth increment is of this year. The results of measurements demonstrated (table 1) that the growth increments of the mosses on both meadows were more intensive in 1971 than in 1972.

In June 1971 on the Sierakowskie meadows the individuals reached a maximum length of 13.2 cm in which this years growth constituted 2.1 cm. In 1972 the maximum length was reached in May amounting to 7.7 cm, with this years increment of 1.6 cm.

On Strzeleckie meadows in 1971 most intensive growth occurred up to June. In this month the length of the individuals was 14 cm, 3 cm falling to this year's growth. The maximum increament in 1972 occurred like on the other meadows in May amounting to 2.8 cm, the whole individuals measuring on the average 9.2 cm.

Beginning with June the length of the individuals decreased. This may be attributed to the more intensive process of disintegration of the lower parts of the shoots, as compared to the elongation growth. At the end of the vegetation season the mean length of the moss shoots on Sierakowskie meadows was in 1971 9 cm and in 1972 6.8 cm, on Strzeleckie meadows the corresponding values were 8.8 and 5.5 cm.

From the length measurements in the particular months of the two years the linear ratio of the growth increment to last year's segment was calculated (table 2,

Table 2

Linear ratio of this year's growth to last year's parts

Site studied	Month Year	III	IV	V	VI	VII
Sierakowskie	1971	—	0.11	0.14	0.31	0.27
meadows	1972	0.06	0.23	0.28	0.76	0.63
Strzeleckie	1971	—	0.10	0.12	0.28	0.19
meadows	1972	0.07	—	0.44	0.48	0.39

fig. 1). The curves show a very similar course, indicating a similar dynamics of moss growth on both meadows in both years. The higher values of this ratio in 1972 both on Sierakowskie and Strzeleckie meadows are evidence of higher values of this year's growth increments with at the same time reduced last year's segments in 1972 as compared with 1971.

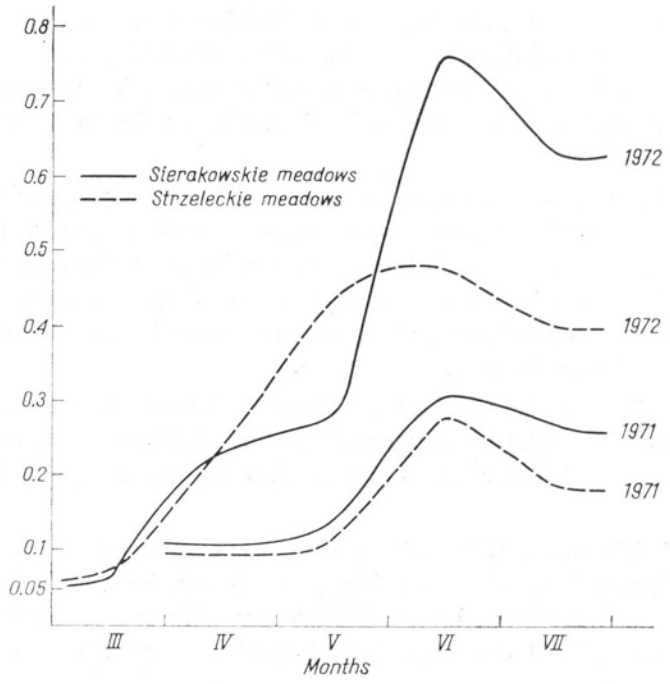

Fig. 1. Linear ratio of growth increment to the last year's parts in individuals of *Aulacomnium palustre*

Weigth of individuals

Table 3 presents the mean weight of 10 moss individuals in grams, taking into account the monthly variations. These changes in the particular months are graphically shown in fig. 1.

From the beginning of the vegetation season up to June in 1971 and to May in 1972 an increase in dry weight of the mosses occurred. The same was observed on the Strzeleckie meadows with the difference that in 1971 the maximum increment

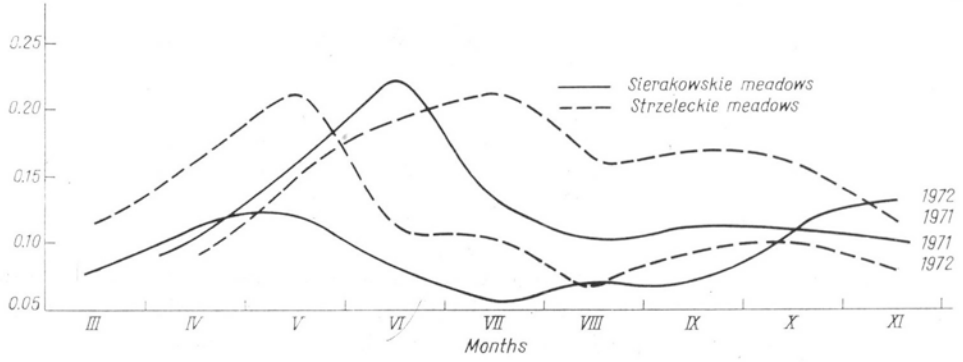

Fig. 2. Mean weight of 10 *Aulacomnium palustre* individuals on Sierakowskie and Strzeleckie meadows in 1971 and 1972

Table 3

Mean weight of 10 individuals in 1971 and 1972, g.

Site studied	Month Year	Mean weight of 10 individuals									Mean weight of 10 this year's growth increments					Mean weight of 10 last year's parts				
		III	IV	V	VI	VII	VIII	IX	X	XI	III	IV	V	VI	VII	III	IV	V	VI	VII
Sierak. meadows	1971	—	0.1009	0.1635	0.2217	0.1284	0.0989	0.1110	0.1127	0.0965	—	0.0128	0.0320	0.0560	0.0134	—	0.0881	0.1315	0.1617	0.1150
	1972	0.0865	0.1155	0.1319	0.0832	0.0539	0.0691	0.0693	0.1123	0.1286	0.0021	0.0137	0.0193	0.0247	0.0169	0.0844	0.1018	0.1126	0.0585	0.0370
Strzel. meadows	1971	—	0.0932	0.1531	0.1926	0.2100	0.1577	0.1718	0.1596	0.1244	—	0.0073	0.0208	0.0315	0.0216	—	0.0859	0.1323	0.1611	0.1884
	1972	0.1151	—	0.2141	0.1052	0.0702	—	0.1009	0.0785	0.0011	0.1010	—	0.0335	0.0241	0.0299	0.1050	—	0.1806	0.0850	0.0753
	Results obtained on the basis of 200 measurements																			

fell to July and in 1972 to May. After reaching its peak the biomass decreases, this lasting till September. In this month the weight of the individuals begins to increase somewhat, but then an irreversible decrease in the given season occurs.

Similarly as in the case of elongation growth, the linear ratio of the growth increment to last year's parts was determined, as was the ratio of the weight increment to the last year's weight calculated (Table 4 and fig. 3).

Table 4

Weight ratio of this year's growth increment to last year's parts

Site studied	Month / Year	III	IV	V	VI	VII
Sierakowskie meadows	1971	—	0.15	0.25	0.37	0.12
	1972	0.03	0.13	0.17	0.42	0.46
Strzeleckie meadows	1971	—	0.08	0.18	0.28	0.13
	1972	0.06	—	0.19	0.27	0.40

The character of the curves on this diagram indicates that the dynamics of increase in the amount of green mass is similar on both meadows in the same year. In 1971 an intensive growth was observed from the beginning of the vegetation season till June, and then the value of the ratio began to decrease. In 1972, on the contrary, the value of the weight ratio increased from March to July (figs. 4 and 5).

State of biomass

a. Production

Net production is the increase in biomass in a definite time period per surface area unit. Production and the current state of the biomass, that is the dry mass of the organisms in the given time period on a definite surface area should be distinguished (Odum, 1963). The production value is expressed in grams of dry mass per square meter of surface area (Table 5).

In the present study as green mass production was assumed the growth increment in the given vegetation season, and since these increments were distinguished to July inclusively, the production is shown in 1971 for four and in 1972 for five months.

Essential for the production value (P) is the number (density) of the individuals. Production is directly proportional to the number of individuals present. More representative is, therefore, the comparison of the G_i index (index of average individual growth).

On the Sierakowskie meadows production was 2.2 times greater in 1971 than in 1972. Maximum of growth fell in both years to June.

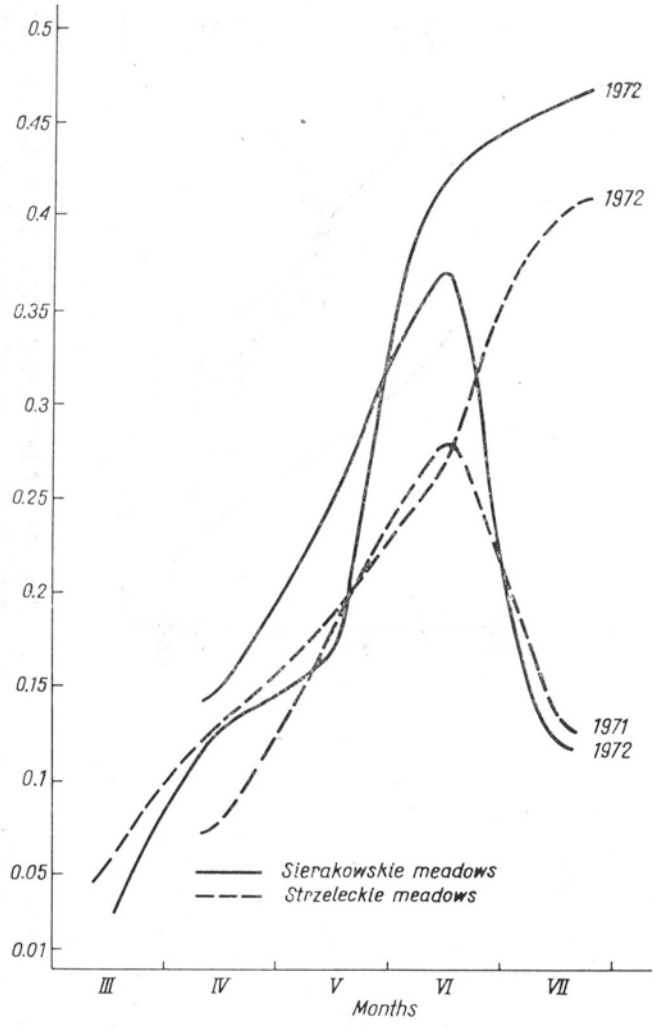

Fig. 3. Ratio of the weight of this year's growth to the weight of last year's parts in *Aulacomnium palustre* individuals

On the Strzeleckie meadows, on the other hand, the production maximum fell in 1971 to June and in 1972 to May.

b. State of biomass

Inasmuch as the G_1 index corresponds to the maximal growth increment in one vegetation season and is, therefore, calculated for the period in which this maximum increment occurred, the state of the biomass as the total dry mass of the individuals is presented for the entire vegetation season (Table 6).

The biomass value depends directly on the weight in the particular months of the individuals and on their number on the given sites.

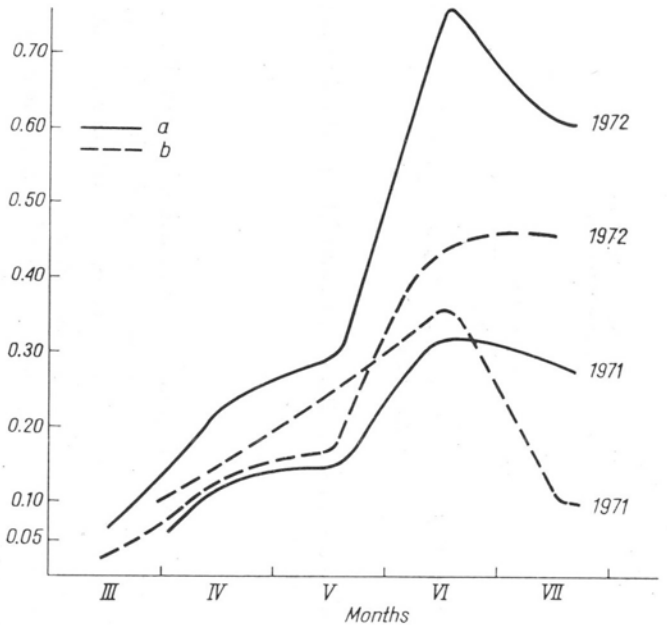

Fig. 4. Comparison of the linear and weight ratios of this year's growth to last year's parts on Sierakowskie meadows in 1971 and 1972: (a) linear ratio, (b) weight ratio

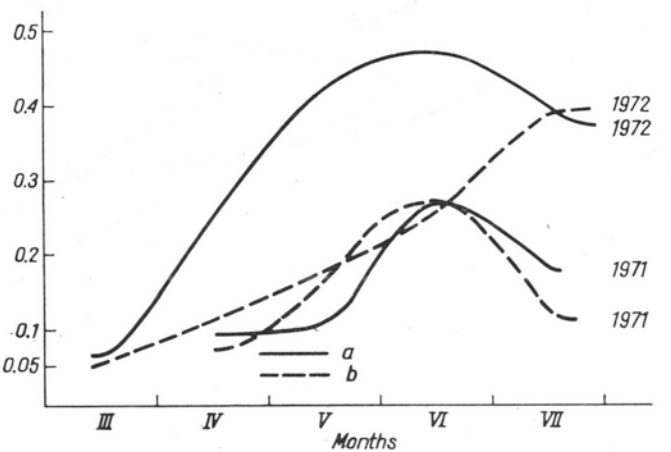

Fig. 5. Comparison of the linear and weight ratios of this year's growth to last year's parts on Strzeleckie meadows in 1971 and 1972: (a) linear ratio, (b) weight ratio

Table 5

Net production of *Aulacomnium palustre* on Sierakowskie and Strzeleckie meadows in 1971 and 1972, g/m²

Year	Sierakowskie meadows				Strzeleckie meadows			
	month	G_i	D	P	month	G_i	D	P
1971	IV	0.0013	541	70.30	IV	0.0007	399	27.93
	V	0.0032	312	99.84	V	0.0021	284	59.64
	VI	0.0056	472	264.32	VI	0.0032	358	114.56
	VII	0.0013	204	26.52	VII	0.0022	343	75.46
1972	III	0.0002	218	6.36	III	0.0010	135	13.50
	IV	0.0014	208	29.12	IV	—	—	—
	V	0.0019	148	28.12	V	0.0034	375	127.50
	VI	0.0025	345	96.25	VI	0.0024	214	51.36
	VII	0.0017	120	20.40	VII	0.0030	107	32.10

Table 6

State of biomass in particular month in 1971 and 1972

Year	Month	Sierakowskie meadows			Strzeleckie meadows		
		Mean weight of 1 individ.	Number of individ.	State of biomass	Mean weight of 1 individ.	Number of individ.	State of biomass
1971	IV	0.0101	541	546.41	0.0093	399	341.07
	V	0.0164	312	511.69	0.0153	284	431.45
	VI	0.0222	472	1047.84	0.0193	358	690.94
	VII	0.0128	204	261.52	0.0210	343	720.30
	VIII	0.0099	165	133.31	0.0158	309	488.22
	IX	0.0111	224	248.64	0.0196	227	444.92
	X	0.0113	251	283.63	0.0160	188	300.80
	XI	0.0097	128	124.16	0.0124	123	152.52
1972	III	0.0087	218	189.86	0.0115	135	155.25
	IV	0.0116	208	241.28	—	—	—
	V	0.0132	148	195.36	0.0214	375	801.56
	VI	0.0083	345	286.35	0.0109	214	233.26
	VII	0.0054	120	64.80	0.0106	107	112.35
	VIII	0.0069	243	176.67	0.0070	204	142.80
	IX	0.0069	230	158.70	—	—	—
	X	0.0112	284	318.08	0.0101	439	443.39
	XI	0.0129	297	383.13	0.0079	393	310.47

CONCLUSIONS

The total biomass is composed, beside the green mass of the current year, of last year's biomass, and partly of the dead fragments. Therefore in the present study production and the state of the biomass were investigated separately. In the

production this year's green increments were taken into account; they were treated separately only in the course of the four months of intensive growth. The state of the biomass, on the other hand, was determined for the whole vegetation season by investigating the whole living moss material.

Two year's investigations demonstrated that production on the Sierakowskie meadows was two times higher in 1971 than in 1972. On the Strzeleckie meadows there were hardly any differences between the results in the two years.

In 1971 the biomass value of mosses was on the Sierakowskie and Strzeleckie meadows 395 and 446 g/m^2, respectively, and the corresponding values for 1972 were 224 and 314 g/m^2. The biomass values for the mosses *Dicranum undulatum*, *Entodon schreberi* and other plants (grasses, Traczyk, 1968, 1970) from the Kampinos National Park are given in Table 7 for comparison.

Table 7

Comparison of state and production of biomass of moss *Aulacomnium palustre* and of the same values for grasses on two different sities in two vegetation seasons

Site studied	*Aulacomnium palustre*				Other mosses	Grasses
	Sierakowskie mead.		Strzeleckie mead.		Kampinos National Park	
	1971	1972	1971	1972	1973	1970
Production	144,82	51.16	67.38	64.12	109.01	—
State of biomass	395	224	446	314	202	105.8

The production value of the mosses *D. undulatum* and *E. schreiberi* are given for a 100 per cent covering like in the case of *Aulacomnium palustre*. The biomass value of mosses is three times higher than that of grasses.

The present paper reports preliminary results for two vegetation seasons.

I wishes to express my thanks to professor Irena Rejment-Grochowska for advice concerning the methods of investigation

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Przyrost biomasy mchów na przykładzie Aulacomnium palustre (Hedw.) Schwaegr.

Streszczenie

W skład biomasy ogólnej oprócz masy zielonej z danego roku wchodzi zeszłoroczna biomasa a także częściowo fragmenty martwe. Dlatego w pracy niniejszej badano oddzielnie produkcję i stan biomasy. Przy produkcji wzięto pod uwagę zielone przyrosty tegoroczne; wyodrębniono je tylko w ciągu czterech miesięcy ich gwałtownego wzrostu. Stan biomasy natomiast oznaczono dla całego sezonu wegetacyjnego, badając całość żywego materiału mchów.

Dwuletnie badania wykazały, że produkcja na Łąkach Sierakowskich była dwukrotnie wyższa w roku 1971 niż w 1972. Na Łąkach Sierakowskich wartość produkcji w obu latach pokrywa się.

W roku 1971 na Łąkach Sierakowskich oraz Strzeleckich wartość biomasy mchów wynosiła 395 i 446 g/m^2, zaś w r. 1972 odpowiednio 224 i 314 g/m^2.

Praca niniejsza zawiera wstępne wyniki badań przeprowadzonych w dwóch sezonach wegetacyjnych.