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ASPECTS OF BIOMASS AND PRIMARY PRODUCTION STABILITY
 IN A FERTILIZED STAND OF *HIERACIO-NARDETUM STRICTAE*
 ASSOCIATION

ABSTRACT

The study was performed in the forest glade "Stare Wierchy" (49° 33'N, 20°02'E. altitude 1001 m a.s.l.) in the Gorce Mountains (Western Carpathians) in a stand of *Hieracio-Nardetum*: 1. in the unfertilized plot, 2. in the plot fertilized by folding. On both plots the changes in the occurrence of species were studied by the phytosociological method. Variations of the state of biomass were determined on the basis of series of random samples of the above-ground and underground organs.

During the period of study the floristic composition and space structure had remained almost unchanged on the unfolding plot. On the contrary, in the fertilized plot qualitative and quantitative changes in the occurrence of species and the structure were observed. The variations in the floristic composition were accompanied by the biomass changes of particular components of the community. Immediately after the folding the state of equilibrium was disturbed. It could be seen in the biomass increase of above-ground and underground organs of plants and in the accumulation of twice as much of dead material as on the unfertilized plot. However, in the next year, in the maximum growth period, the state of equilibrium was reached again. The decrease of bryophytes and lichens biomass was compensated by the increase of vascular plant biomass and surplus of dead material was decomposed. Total values of above-ground biomass and values of live and dead parts remained at the level of corresponding biomass values of the unfolded plot. The production of the underground parts of plants on both the plots was also similar.

PURPOSE, AREA AND METHODS OF THE STUDY

In 1973 and 1974 the studies were made on the seasonal variations of the plants and on the succession tendencies in a stand of *Hieracio-Nardetum strictae* in the Gorce Mountains on an unfertilized plot and as a plot which was fertilized by folding [4, 5]. When comparing the results of these studies, some similarities in the biomass and primary production values were noticed, despite the differences in quantitative relations of species due to the folding.

The studied meadow is situated in the ridge part of the Gorce Mountains in a vast clearing of Stare Wierchy (49°33'N, 20°02'E) at the altitude of about 1000 m a.s.l., 9 km N from Nowy Targ. From the floristic and structure point of view and with respect to the environmental condition it represents a typical stand of *Hieracio-Nardetum strictae*. It grows on an acid brown soil, developed on the flysh sandstone.

At the beginning of July 1973 a part of 900 m² of studied meadow was fertilized and the rest of 1600 m² left alone. The fertilization was made by application of folding — 1 sheep per day and night per surface of 2 m².

On both areas the qualitative and quantitative changes in the occurrence of species were studied by phytosociological method of Braun-Blanquet [7]. Every two or three weeks the phytosociological records were made from the surface of 100 m² and then from 750 m². The biomass changes were determined from a series of random samples of the above-ground and underground parts of plants. The samples were taken several times during the vegetation season. The obtained above-ground material was first separated into the live and dead parts then the live parts divided into fractions: *Nardus stricta*, *Festuca rubra*, other monocotyledonous, dicotyledonous, bryophytes and lichens.

The soil monoliths with the underground parts of plants were slashed into layers of 0—5, 5—10, 10—20 and 20—30 cm and then washed on a set of soil sieves with the mesh diameter of 2.0, 1.0, 0.5 and 0.25 mm. The obtained material was then dried at the temperature of 65°C and weighted.

THE INFLUENCE OF FOLDING ON THE ENVIRONMENTAL CONDITIONS

Until recently the folding was a frequent agricultural resource performed to improve the soil conditions on mountain meadows. It damages mechanically the turf by treading and enriches the soil in the mineral components by fertilizing it.

The soil in the studied areas was characterized before the folding by a relatively low content of mineral components: nitrogen, phosphorus and potassium. In the first year after the folding one finds that the content of total nitrogen, phosphorus, potassium and calcium has increased in the surface layer of soil at the depth of 0—10 cm [2].

THE INFLUENCE OF FOLDING ON THE QUALITATIVE AND QUANTITATIVE OCCURRENCE OF SPECIES AND THE SPATIAL STRUCTURE OF THE COMMUNITY

Before the folding the stand counted 42 species and had a two-layer structure. The layer of vascular plants (C) consisted of low grasses and herbs that covered altogether 85 per cent of surface. Among them the species *Nardus stricta* (4.4) was dominating and the rest of species were much less numerous. *Festuca rubra* (2.2) appeared in bigger concentrations only in the more fertile places at the ant mounds. The fraction of bryophytes was big. They covered 70 per cent of the surface. Among them dominated the species of *Rhacomitrium canescens*. The underground organs showed the vertical stratification. Their most dense layer occurred at the depth of 0—6 cm. The roots of plants reached the depth of 70 cm.

At the unfertilized plot which remained in equilibrium with the slowly varying environmental conditions, no changes in the floristic composition, the quantitative relations and the spatial structure were found during the three years long study period (Tab. 1). On the other hand, on the folded plot the normal development of plants was perturbed and distinct changes in the qualitative and quantitative occurrence of species and in the spatial structure of the community appeared. Because of the folding the plot started to change into a different plant community. The most striking changes were found in the abundance of the floral components of the meadow, connected with the expansion of *Festuca rubra* and with the recession of *Nardus stricta* and *Rhacomitrium canescens* (Tab. 1).

After the observations of the changes in the floristic composition of the above-ground plant parts, one could distinguish several stages of the development of vegetation on this plot: 1. The stage of the intensive expansion of *Festuca rubra* immediately after the folding when the tufts of *Festuca rubra* overgrew the tufts of *Nardus stricta* and the rest of the treated plants; 2. The stage of complete domination of *Festuca rubra* with the number of other species of the stand decreased to a half of the previous value during one year after the folding; 3. The stage when *Festuca rubra* still dominates but does not expand any more. There appear again the above-ground parts of the species of the *Molinio-Arrhenatheretea* class and also two species not found before characteristic for the association of *Gladiolo-Agrostietum* (*Crocus scepusiensis* and *Arabis halleri*). The fraction of species the *Nardo-Callunetea* class and bryophytes and lichens keeps decreasing.

Table 1. Phytosociological records from the *Hieracio-Nardetum strictae* stand:

A — unfolded plot, B — folded plot.

Ch. — characteristic species, loc. — locally

Locality Stare Wierchy, altitude: 1001 m a.s.l., exposure: NNW, slope: $\pm 15-20^\circ$								
Date	3.07.1973 before folding B		11.09.1973		5.07.1974		9.07.1975	
Area	A	B	A	B	A	B	A	B
Plant cover in % (total)	98	98	98	100	95	100	95	100
cover of herbs C	85	85	80	100	70—80	100	85	100
cover of bryophytes D	70	50	70	50	70	5—10	50	5—10
Area of sample plot in m ²	100 (750)	100 (750)	100 (750)	100 (750)	100 (750)	100 (750)	100 (750)	100 (750)
Height of the main plant layer in cm								
C ₁	—	—	—	—	—	96	—	85—100
C ₂	5	5	5	10	10	25—30	12	25—30
Herbs (C):								
Ch. loc. <i>Hieracio-Nardetum</i> :								
<i>Carex pilulifera</i>	+	+	+	.	+	.	+	+
<i>Hieracium lachenalii</i> ssp.	+	+	1.1	2.1	2.2	2.1	2.2	1.2
<i>Carex pallescens</i>	+	+	.	.	+	+	.	.
<i>Carex leporina</i>	.	.	.	.	+	.	+	+
Ch. <i>Nardetalia</i> :								
<i>Nardus stricta</i>	4.4	4.4	4.4	4.4	4.4	3.2	4.4	2.2
<i>Polygala vulgaris</i>	+	+	+	.	+	+	+2	.
Ch. <i>Nardo-Callunetea</i> :								
<i>Potentilla erecta</i>	1.2	1.2	2.2	2.1	2.1	2.1	2.2	2.2
<i>Luzula multiflora</i>	2.1	2.1	1.2	+	2.2	1.1	2.2	2.2
<i>Antennaria dioica</i>	+2	+2	+2	.	2.2	+	1.2	+
<i>Sieglingia decumbens</i>	1.2	1.2	1.2	2.1	1.1	+	1.1	+
<i>Veronica officinalis</i>	+	+	+	+	+	+	1.1	+
<i>Lycopodium clavatum</i>	+	+	+	.	.	+	.	.
Ch. <i>Gladiolo-Agrostietum</i> :								
<i>Agrostis vulgaris</i>	+	+	+	1.1	+	1.1	1.1	2.2
<i>Alchemilla crinita</i>	1.2	1.2	+	+	+	+	+	1.2
<i>Alchemilla micans</i>	+	+	+	+	+	+	+	+
<i>Stellaria graminea</i>	.	.	.	.	+	.	.	.
<i>Arabis halleri</i>	+	.	.	.	+	+	+	1.2
<i>Crocus sczepusiensis</i>	+	.	.	.	+2	.	+	+
Ch. <i>Arrhenatheretalia</i> :								
<i>Chrysanthemum leucanthemum</i>	1.2	1.2	1.2	+	1.2	+	1.1	+
<i>Campanula patula</i>	+	+	.	+	+	+	.	+
<i>Trifolium repens</i>	+	+	+	.	+	+	.	+
<i>Centaurea jacea</i>	+	+	+	.	+	+	+	.
<i>Knautia arvensis</i>	+	+	1.1	.	+	+	+	+
<i>Carum carvi</i>	.	.	.	.	.	.	.	+
<i>Phleum pratense</i>	+	.	.	.	.	.	.	+
<i>Heracleum sphondylium</i>	+	.	.	.	+	+	+	+

Locality: Stare Wierchy, altitude: 1001 m a.s.l., exposure: NNW, slope: $\pm 15-20^\circ$									
Date	3.07.1973 before folding B,		11.09.1973		5.07.1974		9.07.1975		
	Area	A	B	A	B	A	B	A	B
<i>Achillea millefolium</i>	+	.	+	.	+	.	+	+	
Ch. <i>Molinio-Arrhenatheretea</i> :									
<i>Plantago lanceolata</i>	+	+	+	+	+	+	.	.	
<i>Ranunculus acer</i>	+	+	1.2	+	+	+	.	.	
<i>Anthoxanthum odoratum</i>	2.2	2.2	1.2	.	+	1.1	1.1	1.1	
<i>Rumex acetosa</i>	+	+	+	+	+	1.2	+	1.2	
<i>Trifolium pratense</i>	+2	+2	1.2	.	+2	+	+	+	
<i>Rhinanthus minor</i>	+	+	.	.	+	+	+	+	
<i>Cerastium caespitosum</i>	.	.	.	.	+	.	.	.
<i>Briza media</i>	+	+	.	+	.	+	+	.	
<i>Deschampsia caespitosa</i>	.	.	.	.	+	+2	+2	+2
<i>Poa trivialis</i>	.	.	.	.	.	.	.	+
Ch. <i>Calamagrostietalia</i> :									
<i>Hypericum maculatum</i>	+	+	1.2	+	+	1.2	+	1.2	
<i>Chaerophyllum hirsutum</i>	.	.	.	.	+	+	+	+
Others:									
<i>Festuca rubra</i> ssp. <i>commutata</i>	2.2	2.2	2.2	4.4	2.2	5.5	2.2	5.4	
<i>Veronica chamaedrys</i>	.	.	.	.	.	+	.	.
<i>Carlina acaulis</i>	+	+	+	.	.	+	.	+	
<i>Galium vernum</i>	+	+2	+	.	+	+2	+	+	
<i>Lotus corniculatus</i>	+	1.2	+	+	+	+	+	1.2	
<i>Plantago media</i>	.	.	.	.	.	+	.	+
<i>Hieracium pilosella</i>	2.2	2.2	2.2	+	+	+	+	+	
<i>Thymus pulegioides</i>	+2	+2	+	.	+2	+	+2	+	
<i>Equisetum arvense</i>	+	+	+	.	+	+	.	+	
<i>Trifolium montanum</i>	+	+	1.2	.	.	.	.	+
<i>Gymnadenia conopsea</i>	+	+	.	+	+	+	+	+	
<i>Coeloglossum viride</i>	+	+	+	.	+	+	+	+	
<i>Phyteuma spicatum</i>	.	+	.	.	+	+	+	+	
<i>Vaccinium myrtillus</i>	1.2	1.2	1.2	1.2	2.2	+	2.2	+	
<i>Gentiana asclepiadea</i>	1.2	1.2	+	+	+	+2	1.2	+	
<i>Thymus alpestris</i>	.	+2	+2	.	+	+	+	+	
<i>Cirsium palustre</i>	.	.	.	.	+	+	+	+
<i>Equisetum silvaticum</i>	.	.	.	.	+	+	+	+
<i>Salix silesiaca</i>	.	+	.	+	.	.	+	+	
<i>Lathyrus niger</i>	.	.	.	.	.	.	+	.
Bryophytes and lichenes (D):									
<i>Entodon schreberii</i>	+	+	+	+	+	+	+	+	
<i>Rhacomitrium canescens</i>	4.3	3.3	4.3	3.3	4.3	+	3.3	+	
<i>Polytrichum</i> sp.	+	+	+	+	+	+	+	+	
<i>Plagiochila</i> sp.	+	+	+	+	+	+	+	+	
<i>Cladonia</i> sp.	+	+	+	.	+	+	+	+	
<i>Cetraria</i> sp.	+	+	+	.	+	+	+	+	

THE SIGN OF STABILITY OF THE BIOMASS AND OF THE PRIMARY PRODUCTION

The folding stopped the normal development of the association and consequently the normal cycle of the seasonal biomass changes. Immediately after the folding one could see a perturbation in the equilibrium state of the circulation of matter. The perturbation consisted of an increase in biomass of the above-ground and underground parts and then in storing about twice as much of the dead material as on the unfolded plot. But already in the subsequent vegetational season in the maximum plant development stage the situation returned to normal. The qualitative and quantitative changes in the occurrence of species which were caused by folding, influenced the changes in biomass of the individual components of the association, e.g. the vascular plants and bryophytes (Fig. 1) but caused no changes in global values of biomass of the above-ground live and dead parts. The reduction of the biomass of bryophytes by almost a factor of three was compensated by the increase of the biomass of vascular plants and the surplus of the dead material was decomposed. Consequently, the total values of biomass of the above-ground live and dead parts were kept at the level of the corresponding values from the unfolded plot (Figs 2 and 3).

In the following year the state of equilibrium was maintained. One could also see that despite the similar values of the biomass of vascular plants at the beginning of the vegetational season, the values on the folded plot has increased by a factor of two due to the fertilization. Consequently, the fertilization greatly influenced the hay crop.

If one sums together the production of vascular plants and the increase of biomass of bryophytes (the latter values has unfortunately a big statistical error about 20 per cent) one obtain quite similar values of global production of the above-ground parts: 542 g/m² on the unfolded plot and 528 g/m² on the folded plot.

The underground biomass was more influenced by the environmental conditions than the above-ground biomass. Before the folding it was 1335 ± 55 g/m² on the unfolded plot and 1379 ± 50.0 g/m² on folded plot. Immediately after the folding it increased by 35 per cent on the folded plot and was maintained a higher level (Fig. 3). The primary production of the underground parts was, however, almost unchanged. The sum of the biomass increases of the individual fractions of the underground organs in the soil layer of 0—30 cm has similar values, on the unfolded plot 257 g/m² as on the folded plot 269 g/m².

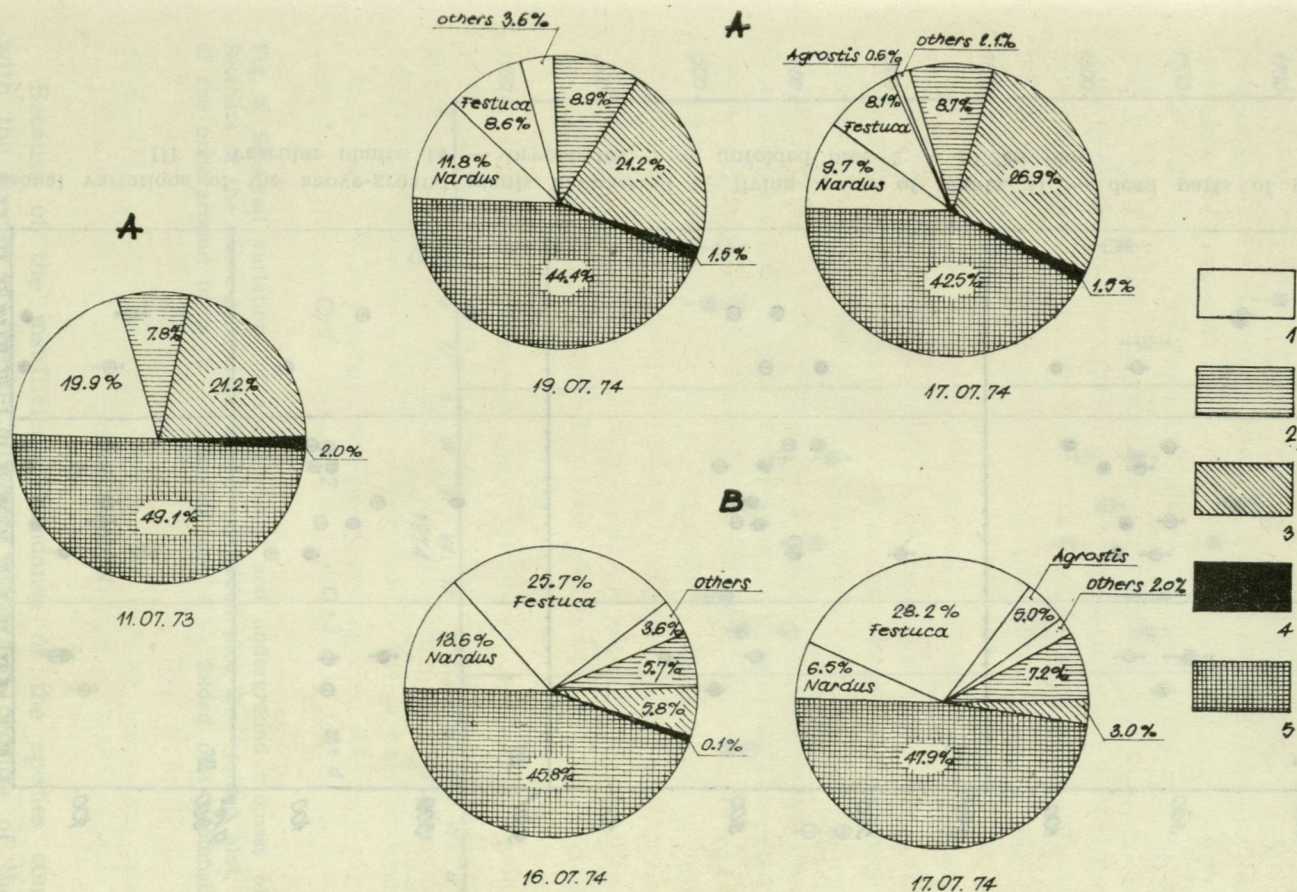


Fig. 1. Changes in the percentage share of various plant groups in the period of 1973–1975: A — unfolded plot, B — folded plot 1 — Monocotyledones, 2 — Dicotyledones, 3 — Brophyta, 4 — Lichenes, 5 — dead material; 11.07.1973 — before folding, (Kotanińska 1976)

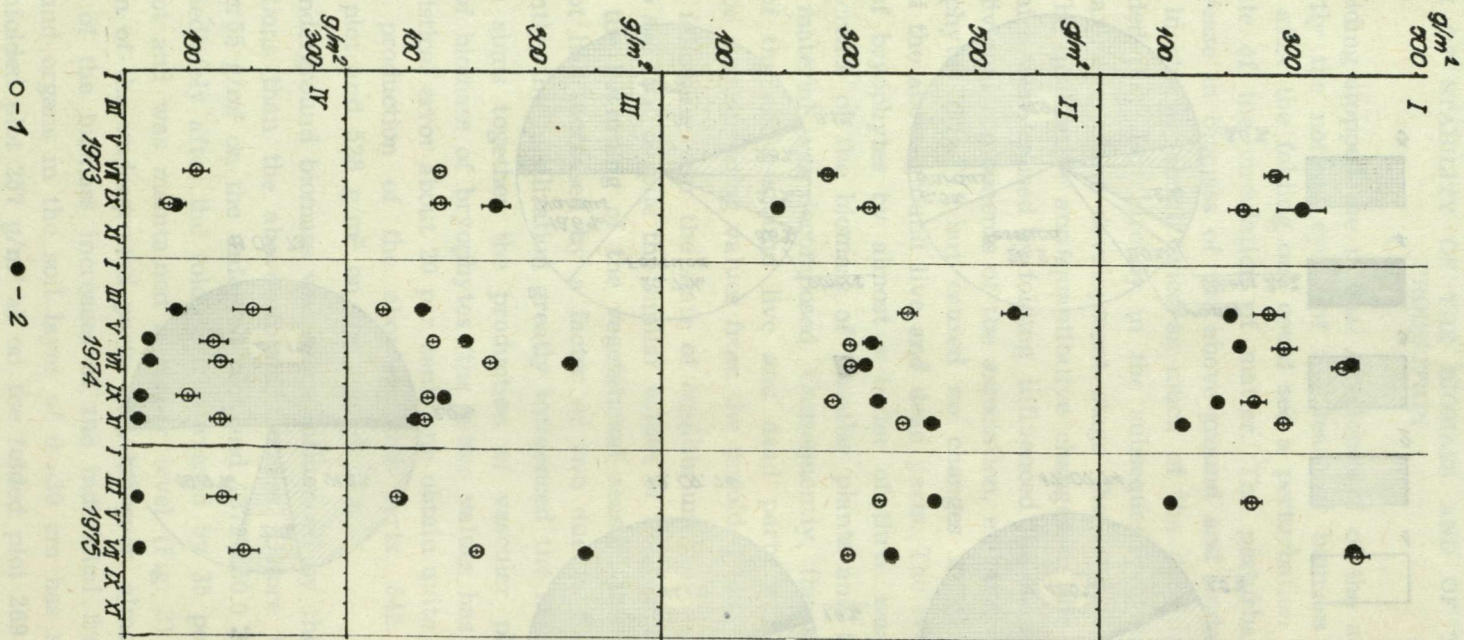


Fig. 2. Seasonal variations of the above-ground plants biomass: I — living parts of plants, II — dead parts of plants, III — vascular plants, IV — bryophytes; 1 — unfolded plot, 2 — folded plot.

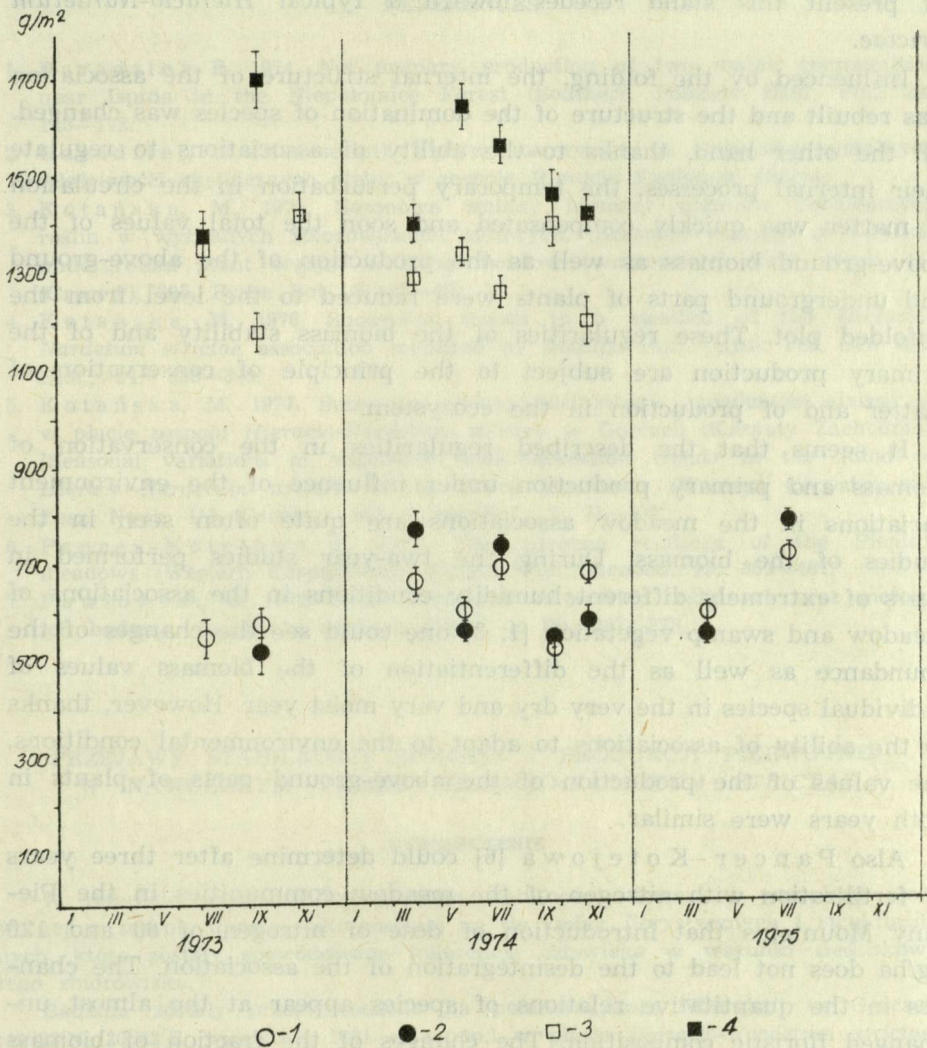


Fig. 3. Seasonal variations of above-ground and underground biomass of plants. Biomass of the above-ground parts: 1 — unfolded plot, 2 — folded plot; biomass of the underground parts: 3 — unfolded plot, 4 — folded plot (Kotárska 1977).

DISCUSSION

Because of the insufficient abundance of the species competing with the species of *Nardo-Callunetea* class and because of the relatively weak fertilization (the folding was performed only once), the folded plot of *Hieracio-Nardetum strictae* transformed only into a stand intermediate between *Hieracio-Nardetum* and *Gladiolo-Agrostrietum*.

At present this stand recedes toward a typical *Hieracio-Nardetum strictae*.

Influenced by the folding, the internal structure of the association was rebuilt and the structure of the domination of species was changed. On the other hand, thanks to the ability of associations to regulate their internal processes, the temporary perturbation in the circulation of matter was quickly compensated and soon the total values of the above-ground biomass as well as the production of the above-ground and underground parts of plants were reduced to the level from the unfolded plot. These regularities of the biomass stability and of the primary production are subject to the principle of conservation of matter and of production in the ecosystem.

It seems that the described regularities in the conservation of biomass and primary production under influence of the environment variations in the meadow associations are quite often seen in the studies of the biomass. During the two-year studies performed in years of extremely different humidity conditions in the associations of meadow and swamp vegetation [1, 3] one could see the changes of the abundance as well as the differentiation of the biomass values of individual species in the very dry and very moist year. However, thanks to the ability of associations to adapt to the environmental conditions, the values of the production of the above-ground parts of plants in both years were similar.

Also Pancer-Kotejowa [6] could determine after three years of fertilization with nitrogen of the meadow communities in the Pieńiny Mountains that introduction of dose of nitrogen of 60 and 120 kg/ha does not lead to the desintegration of the association. The changes in the quantitative relations of species appear at the almost unchanged floristic composition. The changes of the fraction of biomass of the individual species do not cause the significant changes of the total biomass of the above-ground and underground parts of plants. Only at the dose of 240 kg/ha the domination structure of species changes significantly and the species which are characteristic for the association give way to the nitrophilous species even if the total biomass remains almost unchanged.

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PRZEJAWY STABILNOŚCI BIOMASY I PRODUKCJI PIERWOTNEJ
W NAWOŻONYM PŁACIE *HIERACIO-NARDETUM STRICTAE*

STRESZCZENIE

W referacie przedstawiono problem stabilności biomasy i produkcji pierwotnej w zespole ubogiej łąki górskiej na tle zmian florystycznych i strukturalnych, które zostały spowodowane ingerencją człowieka w warunki siedliskowe tego zbiorowiska.

Badania zostały przeprowadzone na polanie „Stare Wierchy” w Gorcach (49°33'N, 20°02'E, wysokości 1001 m n.p.m.) w płacie *Hieracio-Nardetum strictae*, na dwóch powierzchniach: 1. nienawożonej, 2. nawożonej przez koszarzenie. Na obu powierzchniach obserwowano zmiany jakościowe i ilościowe w występowaniu gatunków stosując metodę fitosocjologiczną. Zmiany w stanach biomasy określano na podstawie serii prób losowych części nadziemnych i podziemnych roślin.

Podczas 3-letniego okresu badań skład florystyczny i struktura przestrzenna na powierzchni nienawożonej pozostała prawie niezmienną. Natomiast na powierzchni nawożonej obserwowano zmiany jakościowe i ilościowe w występowaniu gatunków i strukturze przestrzennej zbiorowiska. Wyróżniono kilka etapów rozwoju roślinności na tej powierzchni. Zmianom w składzie florystycznym towarzyszyły zmiany poszczególnych komponentów zbiorowiska.

Bezpośrednio po koszarzeniu stan równowagi w obiegu materii na powierzchni koszarzonej został zaburzony. Uwidoczniło się to we wzroście biomasy organów nadziemnych i podziemnych roślin i następnie nagromadzeniu 1,5 raza większej ilości obumarłego materiału niż na powierzchni niekoszarzonej. Jednak już w roku następnym w okresie maksymalnego rozwoju roślinności stan rów-

nowagi został osiągnięty ponownie. Obniżenie biomasy mszaków i porostów zostało skompensowane przez wzrost biomasy roślin naczyniowych (przede wszystkim biomasy *Festuca rubra*) a nadmiar obumarłego materiału rozłożony. Całkowite wartości biomasy nadziemnej, wartości biomasy nadziemnej części żywych i obumarłych utrzymane zostały na poziomie odpowiednich wartości biomasy z powierzchni niekoszarzonej. Również produkcja pierwotna części nadziemnych i podziemnych roślin w rok po koszarzeniu posiadała podobne wartości na obu badanych powierzchniach.

ПРОЯВЛЕНИЯ СТАБИЛИЗАЦИИ БИОМАССЫ И ПЕРВИЧНОЙ ПРОДУКЦИИ В УДОБРЯЕМОЙ СТАЦИИ СООБЩЕСТВА *HIERACIO-NARDETUM STRICTAE*

РЕЗЮМЕ

В докладе представлена проблема стабильности биомассы и первичной продукции в ассоциации скудного горного луга на фоне флористических и структурных изменений, вызванных вмешательством человека в биотические условия этого сообщества.

Исследования проводились на поляне „Старе Верхи” в Горцах (49°33'N, 20°02'E, высота 1001 м над у.м.) на участке *Hieracio-Nardetum strictae* на двух площадках: 1. неудобренной, 2. удобренной путем скашивания.

На протяжении 3-летнего периода исследований видовой состав растений и пространственная структура на неудобренной площадке почти не изменились. На удобренной площадке наблюдались количественные и качественные изменения видового состава и пространственной организации сообщества.

Первоначально, непосредственно после скошения нарушилось состояние равновесия и круговорота, что проявилось в росте биомассы наземных и подземных органов растений и накопление в 1,5 раза большего количества отмершего материала. Однако, уже в следующем году было снова достигнуто состояние равновесия. Снижение биомассы мхов и лишайников было компенсировано ростом биомассы высших растений, а избыток отмершего материала разложился. Величина всей биомассы удержалась на уровне, соответствующем величине биомассы с некосенной площадки. Величина первичной продукции по прошествии года характеризовалась сходными величинами на обеих исследованных площадках.