Ekológia (Bratislava) Vol. 28, No. 2, p. 113–126, 2009
doi:10.4149/ekol_2009_02_113

VEGETATION STRUCTURE AND ABOVEGROUND BIOMASS AT MOUNT SALATÍN LONG-TERM ECOLOGICAL RESEARCH SITE, THE WEST TATRA MTS, SLOVAKIA

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Abstract

Halada Ľ., David S., Halabuk A.: Vegetation structure and aboveground biomass at Mount Salatín long-term ecological research site, the West Tatra Mts, Slovakia. Ekológia (Bratislava), Vol. 28, No. 2, p. 113–126, 2009.

A detailed characteristic of vegetation in the long-term ecological research site using quantitative methods is provided. Plant species composition, frequencies and aboveground biomass of 25 research plots are reported. Additionally, inter-species relations and spatial pattern of vegetation are analysed.
Plant community at Mt. Salatin research site belongs to the association *Juncetum trifidi* S z a f e r et al. 1923 em. K r a j i n a 1933 (alliance *Juncion trifidi* K r a j i n a 1933). Main dominants are represented by *Oreochloa disticha, Festuca supina* and *Cetraria islandica*, that are evenly distributed throughout the plots with mean frequencies of 39%, 38% and 57% respectively. Significant correlations have been detected between several species what might imply their competition or coexistence. The mean aboveground biomass of vascular plants at Mt. Salatin was estimated to 109.4 g.m^{-2}. At plot level, grasses (91.02 g.m^{-2}) and *Juncus trifidus* (32.52 g.m^{-2}) account for substantial proportion of the biomass. Values of constancy, frequencies and biomass amount together with an analysis of the spatial pattern contribute to a complex understanding of the vegetation structure at Mt. Salatin research site.

Key words: alpine grasslands, ILTER, point intercept method, fine scale monitoring, Carpathians

Introduction

Alpine ecosystems are generally considered to be vulnerable and sensitive to the pressure of global environmental changes. In particular, alpine grasslands may react to climate change as they are determined by specific climatic factors that comprise snow cover duration, wind speed, soil moisture regime, etc. In the Tatra Mts, a direct impact of acidification on alpine grassland ecosystem (e.g. on plant species composition and vegetation structure) was demonstrated by Rusek (1993). The author introduces several reasons for considering alpine ecosystems as “early warning systems” of environmental change.

However, there is a continuous need to have more impact studies in different alpine ecosystems to get broader knowledge on processes within them. This could be done only in precisely designed research sites with long-term data series that allow a multi-site comparison and further generalizations. In this respect, Mt. Salatin long-term ecological research site (LTER) was established in 2002 based on Slovak and US cooperation in the research of nutrient deposition impact on alpine meadows. Permanent monitoring plots and a meteorological station with continual measuring of basic climatic variables, soil moisture and soil water potential represent a good basis for long-term studies on the impact of climate on alpine grassland ecosystem. There have been only few such long-term experimental sites established in alpine grassland ecosystems recently in the Tatra Mts (eg. Rusek, 1993; Boltižiar, 2003, 2009; Kanka et al., 2005). On the contrary, in forest ecosystems, many permanent plots had been established there since the 50-ies (see Strnka, 1970; Fleischer, 2001).

In this paper, we describe the vegetation structure of Mt. Salatin research site based on 2002 and 2003 field surveys. Rejmánek (1977) has emphasized three groups of vegetation structure characteristics: 1) qualitative, 2) quantitative and 3) relational. Qualitative characteristics of vegetation (species presence or absence) are quite well reported in many vegetation studies from the Tatra Mts. Quantitative characteristics are included mainly in phytosociological studies where species abundance is estimated (e.g. Dúbravcová et al., 2005; Šomšák et al., 1981). Plant aboveground biomass in the Tatra Mts was estimated mainly in forest ecosystems (e.g. Kubíček, 2001). There is still lack of studies on spatial pattern of alpine vegetation though knowledge of this phenomenon can serve for the proper understanding of the processes in plant communities (Kubíková, Rejmánek, 1973). We report on species composition, species frequency and aboveground biomass of vascular plants in this paper. Additionally, we analysed some relations between species and describe the spatial pattern of the vegetation at Mt. Salatin research site (Hreško, Boltižiar, 2001).

Materials and methods

The Mount Salatin is situated in the Western Tatra Mts (49°13’00” N, 19°40’32” E), within the Tatra National Park. The research was performed on a west-facing ridge top ca 2 km west of the summit, in altitude 1900 m, in gentle slope (Fig. 1). Soils are humic-ferruginous podzols, derived from biotite granodiorite parent material (Hreško, Bugár, 2001; Hreško et al., 2008). Soils are shallow, max. 10–15 cm deep, strongly acid. Short grassland plant community is dominated by graminoid species, including *Oreochloa disticha*, *Festuca supina*, and *Agrostis pyrenaica* with lower cover of forbs and shrub species.

In 2002, 25 2x2 m permanent plots were established at the Mount Salatin for long-term research activities. Research plots were selected in the way they could represent a homogenous units allowing proper experimental research (LeMay, Robinson, 2004). Because of comparability, we used the same sampling methods applied in the parallel research in

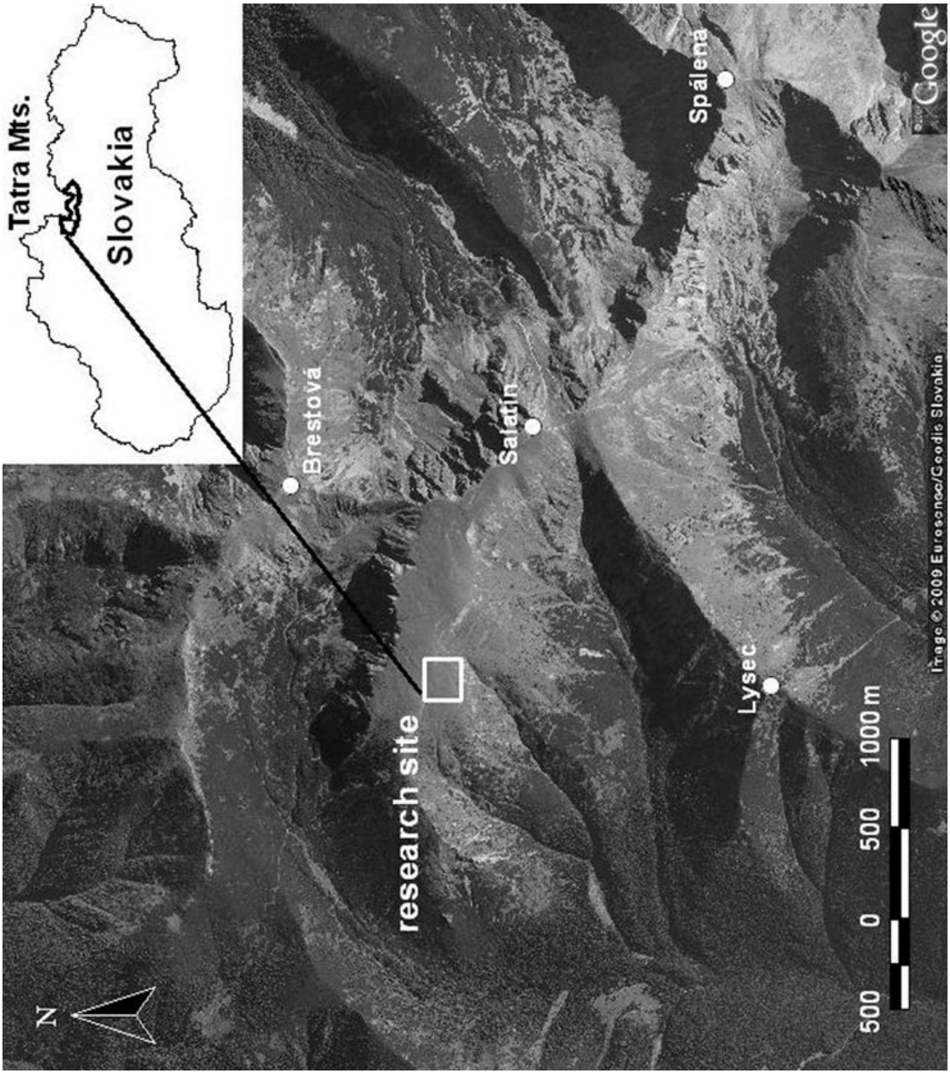

Fig. 1. Location of the Mt. Salatin long-term research site.

LTER site Niwot Ridge, South Rocky Mountains, CO, USA (see Bowman et al., 2006). Five treatments were used: addition of 2 g $N.m^{-2.year-1}$ (N2); 6 g $N.m^{-2.year-1}$ (N6); 15 g $N.m^{-2.year-1}$ (N15); 8 g $P.m^{-2.year-1}$ (P); and control (C).

The plant species composition was studied using both phytosociological records and point intercept method (PIM). Phytosociological records were taken using standard phytosociological methods (Braun-Blanquet, 1951).

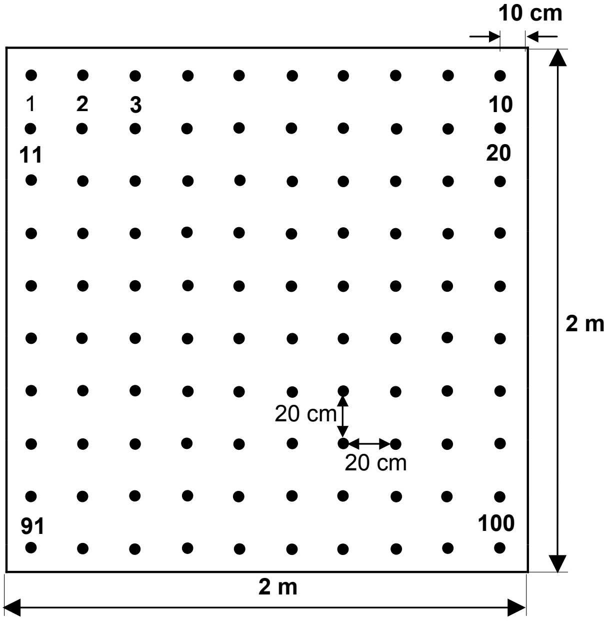

Fig. 2. Sample design for point intercept method in the permanent plots.

The enlarged 9-degree version of the Braun-Blanquet scale (Westhof, van der Maarel, 1978) was used for estimation of species abundance. The PIM method (Kubíková, Rejmánek, 1973) is particularly suitable for vegetation monitoring and allows detailed analysis of plant species composition. It is broadly used in different types of ecosystems, for application in alpine grasslands see Bråthen, Hagberg (2004). In each 2x2 m permanent plot, 100 sample points were distributed in regular, 20x20 cm grid (Fig. 2). Occurrence of vascular plants, lichens and mosses was recorded in each sample point. We tested the method in August 2002 when the site was instrumentalized. In this paper however, we used data from August 2003, representing records in 2,500 sample points in total. Data were stored in GIS database allowing visualization of spatial pattern of vegetation. The species nomenclature follows Marhold and Hindák (1998).

The aboveground biomass was sampled in August 2004 when maximal development of aboveground biomass was expected. A standard destructive method for aboveground biomass estimation using 30x30 cm quadrates was used (Jakrlová, 1987). Vascular plants were carefully clipped just above the soil surface with razor blade and necromass was removed consecutively. Each research plot was sampled by 3 randomly localized quadrates, i.e. 75 quadrates in total. Plant material was determined later on in laboratory. Because of difficult determination of grass species in biomass, grasses were merged and analysed as one group. Plant material was then oven-dried at 85 °C to constant weight.

A standard descriptive statistics was used to see a general view of species composition and aboveground biomass of the site and correlation matrix using Pearson “r” to see possible inter-species relationships.

Results

The vegetation of the permanent plots in the Mt. Salatin research site represents a species-poor plant community of the alliance *Juncion trifidi* Krajina 1933. The phytosociological records are in Table 1, we recorded totally 17 species in 25 plots with range of 9–14 species

Table 1. Phytosociological records in Salatin permanent plots – year 2003.

Treatment	**N2**					**N6**					**N15**					**P**					**C**				
Replication	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Cover E_1 [%]	85	65	80	80	85	75	75	70	80	85	75	65	80	60	70	85	90	85	85	80	80	65	80	75	70
Cover E_0 [%]	70	70	50	50	30	60	60	60	65	40	70	75	50	70	65	60	40	40	40	40	75	75	60	60	55
Herb layer E_1																									
Oreochloa disticha	7	7	7	8	6	7	7	8	8	7	7	7	8	7	7	8	7	8	8	7	7	7	8	8	7
Juncus trifidus		6	6	6	6		6	5	5	5		7	5	6	6		5	6	7	5		6	6	6	6
Agrostis rupestris	5	4	6	4	2	4		5	5	7	5	5	6	4	4	4	7	7	5	6	5	6	6	5	2
Festuca supina	5	5	6	5	8	6	6	6	6	5	5	6	5	6	6	6	6	7	6	7	6	6	5	6	6
Carex nigra	4	4		4	4	4		4	5	5	2	2	4	6	5		5	5	5	4		5	5	6	4
Hieracium alpinum agg.	5	5	5	5	6	6	5	4	5	4	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5
Campanula alpina	5	4	5	6	5	2	2	5	7	5	5	4	4	5	4	6	6	6	6	6	6	4	5	6	4
Homogyne alpina				4					2	2							2								
Bistorta major					2				1	2				3		2	3								2
Vaccinium vitis-idaea		2	2	2	2		4		2	2				2	2		2	2	4					2	
Trisetum alpestre										2	4						5					2			
Avenula versicolor				2							2										4				
Moss layer E_0																									
Cetraria islandica	8	8	7	7	6	7	8	8	8	7	8	8	7	8	8	8	7	7	7	7	8	8	8	7	8
Polytrichum alpinum	4		4	2		2	4	2	2	2	4	4	2	6	5	4					5	2	2	4	
Polytrichum sexangulare	2																								
Cladonia sp.	2	5	4	2	4	4	5	2		4	4	2	2	2	4	2	4	4	2	4	2	4	2	5	4
Alectoria ochroleuca								1												1				2	1

Date of sampling: 24.8.2003. Abundance scale – Westhoff, van der Maarel (1978)
Abbreviations in Tables 1, 2 and 6 see in the text

and mean 10.7 species per plot. By PIM (Table 2), we recorded 14 plant species in total: 6 gramnoids, 4 herbs, 1 ericoid and 3 lichens and mosses. The most constant (100%) throughout the plots were *Oreochloa disticha*, *Festuca supina* and *Cetraria islandica*, followed by *Campanula alpina* (96%), *Hieracium alpinum* agg. (96%), *Agrostis pyrenaica* (92%), *Juncus trifidus* (80%), *Carex nigra* (72%), *Polytrichum alpinum* (72%), *Cladonia* sp. (60%) describing their even distribution at the Mt. Salatin research site. The low constancy (site frequency) throughout the site had *Vaccinium vitis-idaea* (28%), *Bistorta major* (16%) and *Poa chaixii* (4%). The mean species richness in the research plots was 7.6 with the range of 4–11 species. The mean value of species diversity using Shannon-Wiener index was 1.0 with the range of 0.5–1.6.

Based on the plot frequency of the species, the most dominant plants in the herb layer at Mt. Salatin research site are *Oreochloa disticha* and *Festuca supina* while in the moss layer lichen *Cetraria islandica* dominates. The lowest variability of their frequencies indicates that these species are stable throughout the plots and really dominate in the vegetation. Plot frequencies that take into account only the plots where respective species occurred were analysed to see the frequencies of the species with low constancy and irregular distribution (Table 3).

T a b l e 2. Plot frequencies (%) of species occurrence recorded by the point intercept method.

	N2					N6					N15					P					C				
Species/Plot No.	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Oreochloa disticha	46	28	38	52	26	48	47	40	48	44	61	47	30	20	33	38	35	26	26	30	54	46	38	44	39
Festuca supina	46	40	40	26	52	36	38	23	34	24	28	21	35	48	37	54	18	41	59	44	36	35	44	47	53
Juncus trifidus	.	18	12	3	14	.	8	4	2	3	.	20	5	4	9	.	4	7	14	7	.	5	5	6	7
Agrostis pyrenaica	2	3	20	3	7	.	.	5	3	45	4	1	23	3	2	2	37	16	5	12	11	12	14	5	4
Campanula alpina	7	1	4	19	12	4	.	4	26	17	6	4	7	4	1	14	17	21	16	15	10	1	11	6	3
Hieracium alpinum agg.	6	4	8	13	5	5	3	.	7	2	9	2	3	2	2	9	5	8	2	8	1	10	2	2	4
Carex nigra	4	7	.	1	.	3	.	18	28	25	.	.	5	30	19	.	9	9	21	8	.	11	1	17	2
Poa chaixii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.
Bistorta major	.	.	.	.	1	.	.	.	.	3	.	.	.	2	.	.	1	.	.	.	.	.	.	.	.
Homogyne alpina	.	.	.	6	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vaccinium vitis-idaea	.	.	.	2	.	.	1	.	2	.	.	.	.	.	.	.	1	1	1	.	.	.	1	1	.
Cetraria islandica	58	58	65	52	42	51	68	67	73	40	58	65	62	64	55	61	39	73	55	55	57	63	53	49	53
Polytrichum alpinum	1	.	3	13	2	2	.	6	1	2	2	10	5	5	4	1	.	2	.	.	12	.	21	2	.
Cladonia sp.	.	6	3	2	5	1	.	7	.	1	1	.	.	.	4	.	.	1	2	4	1	1	.	.	6

T a b l e 3. Descriptive statistics of species plot frequencies (%).

Species	All plots (N = 25)				Plots with respective species presence				
	Mean	me-dian	SD	CV (%)	N	mean	me-dian	SD	CV (%)
Oreochloa disticha	39.36	39.0	10.25	26.03	25	39.36	39.0	10.25	26.03
Festuca supina	38.36	38.0	10.89	28.39	25	38.36	38.0	10.89	28.39
Agrostis pyrenaica	9.56	5.0	11.37	118.96	23	10.39	5.0	11.49	110.59
Campanula alpina	9.20	7.0	7.20	78.26	24	9.58	7.0	7.09	73.97
Carex nigra	8.72	5.0	9.74	111.65	18	12.11	9.0	9.50	78.48
Juncus trifidus	6.28	5.0	5.58	88.84	20	7.85	6.5	5.13	65.38
Hieracium alpinum agg.	4.88	4.0	3.33	68.30	24	5.08	4.5	3.24	63.79
Homogyne alpina	0.40	0.0	1.41	352.50	2	5.00	5.0	1.41	25.20
Vaccinium vitis-idaea	0.40	0.0	0.65	162.50	8	1.25	1.0	0.46	36.80
Bistorta major	0.28	0.0	0.74	263.25	4	1.75	1.5	0.96	54.71
Poa chaixii	0.16	0.0		.	1	4.00	4.0	.	.
Cetraria islandica	57.44	58.0	9.11	15.86	25	57.44	58.0	9.11	15.86
Polytrichum alpinum	3.76	2.0	5.16	137.19	18	5.22	2.5	5.43	103.97
Cladonia sp.	1.80	1.0	2.24	124.23	15	3.00	2.0	2.17	72.37

Notes: N – number of plots where respective species is presented; SD – standard deviation; CV – coefficient of variation

There have been some strong correlations between frequencies of the species in the plots revealed, however only three of them were significant (Table 4). A relative strong positive correlation was found between *Vaccinium vitis-idaea* and *Oreochloa disticha*. Negative correlations were detected between *Oreochloa disticha* and *Festuca supina* as well as between *Agrostis pyrenaica* and *Cetraria islandica.* Positive correlations might indicate a mutual benefit from co-existence (or common sharing of the environmental niche) while negative correlations could indicate between-species competition.

The mean value of 109.39 g. m^{-2} of vascular plant aboveground biomass was assessed from the Mt. Salatin research site. A dominant portion of the biomass is represented by grasses (83%). Lower values of biomass proportion of some species (*Carex nigra* – 3.3%, *Campanula alpina* – 4.0%; *Hieracium alpinum* – 2.0%) compared to their plot frequencies could reflect their low growth form. Exception is *Juncus trifidus*, which takes the bigger portion of the biomass than its frequency in the plots where it is presented (Table 5). In comparison with PIM results, *Bistorta major* was not detected in the biomass samples; in addition *Homogyne alpina* was detected. Substantially lower value of constancy of *Juncus trifidus* (24%) could be caused by a patchy distribution of *Juncus trifidus* at plot scale. Higher variability of biomass data of *Juncus trifidus* compared to plot frequencies may reflect the different sampling strategy and involved sampling errors. Only one significant strong negative correlation ($r = 0.96$; $p < 0.001$) between *Juncus trifidus* and grass species aboveground biomass data has been detected. This may imply their strong competition for living space at plot scale. We provide source data of the species frequencies and aboveground biomass in order to make possible future comparisons and change detection (Tables 2, 6).

Three representative examples of spatial patterns of vegetation in research plots were identified in the sense of their biggest similarity to the mean frequencies values (Fig. 3). Almost 100% cover of *Cetraria islandica* really dominate in the low E0 layer (moss layer). Tussocks of grass species are monodominant in individual micro-spaces and are evenly distributed throughout (across) the plots. On the other hand a patchy structure (clusters of *Juncus trifidus*) is characteristic at 2x2 m dimension.

T a b l e 4. Correlation matrix of species plot frequencies using Pearson r.

Species	*OD*	*FS*	*JT*	*AP*	*CA*	*HA*	*CN*	*BM*	*VV*	*CI*	*PA*	*C*
Oreochloa disticha	1.00	-0.48*	-0.25	-0.08	-0.02	0.25	-0.22	0.47	0.65	0.02	0.13	-0.47
Festuca supina	-0.48*	1.00	0.22	-0.40	-0.05	-0.13	-0.01	-0.22	-0.41	0.03	-0.21	0.22
Juncus trifidus	-0.25	0.22	1.00	-0.34	-0.37	-0.26	-0.14	-0.59	-0.56	0.04	-0.01	0.32
Agrostis pyrenaica	-0.08	-0.40	-0.34	1.00	0.29	-0.13	0.02	0.40	-0.49	-0.44*	-0.03	-0.43
Campanula alpina	-0.02	-0.05	-0.37	0.29	1.00	0.27	0.17	0.03	0.62	-0.05	-0.02	-0.39
Hieracium alpinum agg.	0.25	-0.13	-0.26	-0.13	0.27	1.00	-0.36	-0.90	0.75*	0.20	-0.20	-0.20
Carex nigra	-0.22	-0.01	-0.14	0.02	0.17	-0.36	1.00	0.73	0.15	0.20	-0.45	-0.08
Bistorta major	0.47	-0.22	-0.59	0.40	0.03	-0.90	0.73	1.00	a	0.15	0.00	-1.00
Vaccinium vitis-idaea	0.65	-0.41	-0.60	-0.49	0.62	0.75*	0.15	a	1.00	0.24	-0.08	0.50
Cetraria islandica	0.02	0.03	0.04	-0.44*	-0.05	0.20	0.20	0.15	0.24	1.00	-0.08	0.02
Polytrichum alpinum	0.13	-0.21	-0.01	-0.03	-0.02	-0.20	-0.45	0.00	-0.08	-0.08	1.00	-0.02
Cladonia sp.	-0.47	0.22	0.32	-0.43	-0.39	-0.20	-0.08	-1.00	0.50	0.02	-0.02	1.00

Notes: * – correlation is significant at the 0.05 level (2-tailed); a – cannot be computed because at least one of the variables is constant

T a b l e 5. Distribution of plant species aboveground biomass at Mt. Salatín (g.m^{-2}).

Species	All sample quadrates (N = 75)				Quadrates with respective species presence				
	mean	me-dian	SD	CV (%)	N	mean	me-dian	SD	CV (%)
Grasses	91.02	81.45	55.47	60.95	75	91.02	81.45	55.47	60.95
Carex nigra	3.63	1	5.72	157.82	43	6.33	4.00	6.34	100.28
Juncus trifidus	7.81	0	26.73	342.49	18	32.52	21.73	47.54	146.16
Campanula alpina	4.37	0.45	7.22	165.32	44	7.45	4.51	8.15	109.35
Hieracium alpinum	2.19	0.34	3.65	166.53	39	4.22	2.67	4.15	98.37
Vaccinium vitis-idaea	0.35	0	0.84	240.30	18	1.46	1.23	1.17	80.19
Homogyne alpina	0.04	0	0.27	643.93	3	1.04	0.67	1.05	100.73
Total	109.40	93.7	58.24	53.23					

Notes: N – number of plots where respective species is presented; SD – standard deviation; CV – coefficient of variation

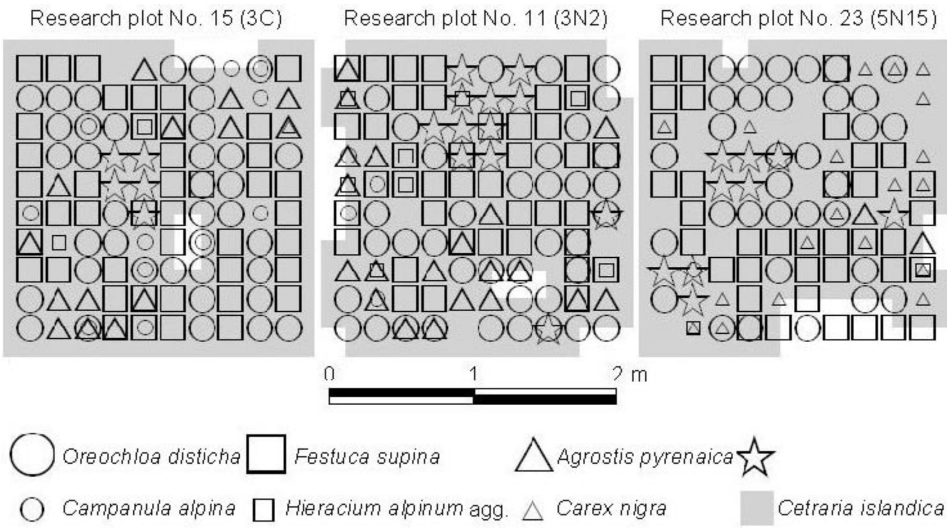

Fig. 3. Schematic representation of spatial vegetation pattern in 3 representative plots.

T a b l e 6. Aboveground vascular plant biomass (g/ plot), plot = 2x2 m.

Treatment	**N2**					**N6**					**N15**		
Replication	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**
Grasses	401.9	377.4	425.9	399.7	402.2	388.7	237.9	315.0	400.3	202.8	314.2	239.4	190.1
Carex nigra	29.6	0	0	2.4	0	11.4	0	0	15.7	24.2	0	28.7	11.7
Juncus trifidus	0	0	0	0	0	7.7	46.8	69.5	0	48.2	283.4	28.2	3.1
Campanula alpina	48.0	0	4.2	48.7	48.7	0	0	13.9	44.6	0	18.1	0.6	3.3
Hieracium alpinum agg.	33.5	9.8	2.1	16.9	4.6	15.0	0	0	37.3	16.4	9.2	2.8	1.9
Vaccinium vitis-idaea	0	0	0	0	0	0	1.9	0	2.5	0	1.6	0.4	3.3
Homogyne alpina	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	513.0	387.3	432.2	467.7	455.6	422.8	286.7	398.4	500.4	291.6	626.5	300.2	213.3

Treatment	**N15**		**P**					**C**				
Replication	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Grasses	245.5	245.6	515.6	387.3	332.6	614.8	649.6	581.6	211.9	273.2	320.6	427.3
Carex nigra	8.0	3.4	0.9	48.3	70.4	21.3	16.4	0	47.7	9.6	12.7	0
Juncus trifidus	48.7	0	67.7	0	0	93.8	0	0	0	66.5	11.4	5.5
Campanula alpina	20.6	6.4	49.6	24.3	0.7	18.5	8.0	21.2	14.4	4.3	38.7	0
Hieracium alpinum agg.	0.2	12.9	15.0	11.1	0	0	0	13.5	0.4	0	3.3	13.3
Vaccinium vitis-idaea	2.2	3.1	7.9	0	0.9	3.1	6.2	0	0	0	1.6	0
Homogyne alpina	0	0.3	3.9	0	0	0	0	0	0	0	0	0
Total	325.2	271.7	660.4	471.0	404.6	751.6	680.3	616.3	274.4	353.6	388.3	446.1

Discussion

The vegetation of the permanent plots in the Mt. Salatin research site belongs to the alliance *Juncion trifidi* K r a j i n a 1933, the plant community is composed by species typical for this alliance. This type of vegetation was classified in the past in the association *Juncetum trifidi* Szafer et al. 1923 em. K r a j i n a 1933 (e.g. Dúbravcová, 1982; Háberová, Šoltésová, 1989). The recent classification of the alliance (Dúbravcová, Jarolímek, 2007), distinguishes in Slovak mountains two closely related associations: above-mentioned *Juncetum trifidi* and *Junco trifidi-Festucetum supinae* K r a j i n a 1933. Their diagnostic species occur in both communities, differences are in their constancy: while *Juncus trifidus* has 100% constancy in *Juncetum trifidi* and significantly lower (69%) constancy in *Junco trifidi-Festucetum supinae*, *Festuca supina* has 100% constancy in *Junco trifidi-Festucetum supinae* and slightly lower constancy (83%) in *Juncetum trifidi*. Because of lower constancy (80%) of *Juncus trifidus* and also its lower abundance, the plant community in the permanent plots seems to be related to *Junco trifidi-Festucetum supinae* K r a j i n a 1933. This classification is supported also by high constancy of *Festuca supina, Agrostis pyrenaica, Hieracium alpinum* agg., *Cetraria islandica* and low constancy of *Vaccinium vitis idaea*. However, recorded high constancy of *Oreochloa disticha* (100%) and *Campanula alpina* (96%) is typical rather for the association *Juncetum trifidi.*

We recorded by PIM method totally 14 species in 25 permanent plots with range of 4–11 species per plot and mean 7.6 species per plot and totally 17 species with range of 9–14 species and mean 10.7 species per plot by phytosociological records. These are very low values; the published papers indicate higher species richness of the community. For *Juncetum trifidi*, Dúbravcová (1982) reported average species richness 24.8 and range 15–33 species/record based on 20 records; Háberová and Šoltésová (1989) mean 22.4 and range 16–30 species/record (5 records); and Dúbravcová and Jarolímek (2007) mean species richness 19 species (243 records). Dúbravcová and Jarolímek (2007) reported mean species richness 20 species for *Junco trifidi-Festucetum supinae* (based on 36 records). There are several possible (at least 4) reasons for recorded low values of species richness in the permanent plots. 1) Lichens of the genus *Cladonia* were not determined to species level; several species of this genus grow in the permanent plots. 2) The species richness can be influenced by small area of records: 4 m^2 used are much smaller than minimal area of grassland plant communities (16–20 m^2). However, total species richness of all permanent plots (14 species recorded in 100 m^2) is significantly lower than reported values from the literature. 3) Subjective selection of location of phytosociological records can represent other reason. The record should be representative for the plant community and there is tendency to include as much as possible species typical for the community. Therefore the species-poor parts of the community stands can be avoided. 4) Extremely acid soils (pH between 3.0 and 3.5) can operate as the selection factor allowing growth only to limited number of tolerant species.

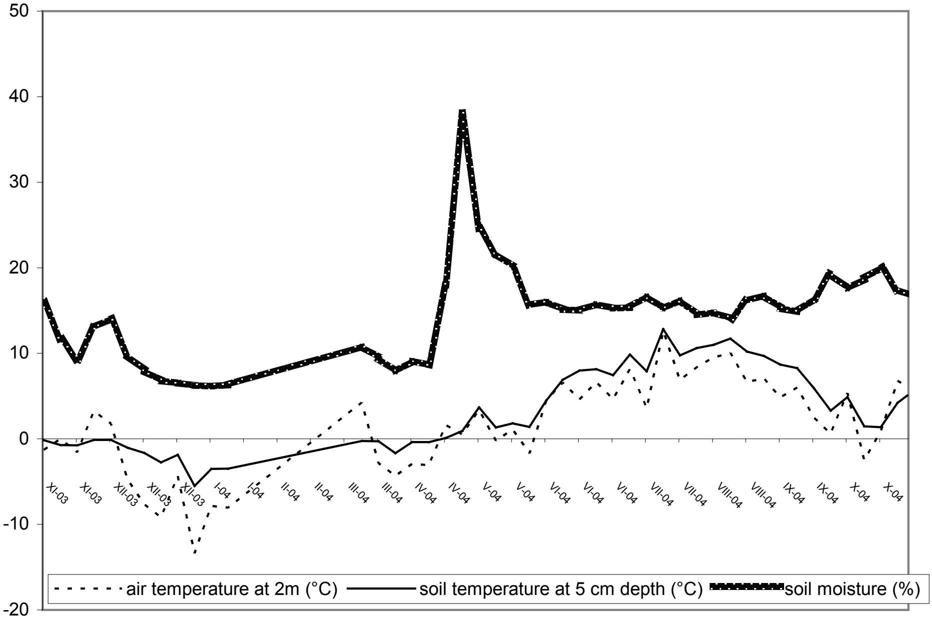

Fig. 4. Selected climatic variables at Mt. Salatin in 2003/2004.

There are many methodological and terminological discrepancies while comparing different productivity data. Körner (2003) summarised main methodological and terminological discrepancies of production studies in alpine ecosystems leading up to conclusion that only a small fraction of literature published is readily comparable. There is also no biomass data of alpine meadows in Slovakia. In order to minimize the possible negative effect of destructive method used on permanent plots, we avoid a more year sampling. In this respect, a climatic condition in 2004 should be considered while presented results are interpreted (Fig. 4). Körner (2003) also concluded that the year-to-year variation is much smaller than community differences which suggests that single year harvests of biomass can be considered as a reasonable site-typical estimate. According to this author the above-ground whole season biomass production may be anywhere between 100–400 $g.m^{-2}.year^{-1}$ for closed alpine vegetation in the temperate zone, with 200 $g.m^{-2}.year^{-1}$ representing a useful mean. Hitz et al. (2001) reported values between 100 and 172 $g.m^{-2}.year^{-1}$ from the alpine grasslands (*Caricetum curvulae*) in Vereina valley, Swiss Alps, Grabherr (1989) estimated the dry matter production of alpine grassland on acid soils (*Caricetum curvulae*) at 100–170 $g.m^{-2}.year^{-1}$. The length of the growing season and the percentage of ground cover are the two major determinants of alpine plant biomass and its rate of production (Körner, 2003).

In finer scale, maximum productivity is always found in moist places which permit season-long soil microbial activity (Scott, Billings, 1964). A relatively low value of aboveground biomass at the Mt. Salatin may be caused by the fact that we did not estimate lichens and moss biomass in our study. Grabherr (1989) indicated that lichens may represent up to 64% of total aboveground biomass in high alpine grasslands. An important fact is that not productivity but its accumulative biomass production per year is low, but this fact is not caused by „stressful environment“, „low temperature“ „adverse life condition“ etc., but simply by the short growing season and partly by incomplete ground cover (Körner, 2003). Future studies on species-specific productivity and its response to spatial and seasonal variation thus are necessary.

Conclusion

The plant community composition, its spatial structure and aboveground biomass were studied in the permanent plots in the Mt. Salatin. We present the quantitative data from this study. Because the permanent plots in the Mt. Salatin were established in order to study the reaction of the alpine grassland ecosystem to increased inputs of nitrogen and phosphorus, the results presented in the paper should be considered as a basic data that should serve for comparison in the following years. However, further development and testing of non-destructive methods for canopy structure and biomass estimation have to be involved in order to maintain long-term ecological research allowing future comparisons.

Translated by the authors

Acknowledgements

This research was supported by the grant agency VEGA, project No. 2/0166/08 and 2/0217/09. We would like to thank to all colleagues who were involved in demanding fieldwork.

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