OPERA CORCONTICA 38: 89–121, 2001

VEGETATION DYNAMICS IN DWARF PINE ECOSYSTEMS IN THE WESTERN GIANT MTS.

Dynamika vegetace kosodřeviny v ekosystémech západních Krkonoš

HANA PAŠŤALKOVÁ[1], STANISLAV VACEK[2], KAREL MATĚJKA[3], JITKA MÁLKOVÁ[4]

[1] Ústav ochrany životního prostředí, Univerzita Pardubice, 530 05 Pardubice
[2] VÚLHM, VS Opočno, Na Olivě 550, 517 73 Opočno
[3] IDS, Na Komořsku 2175/2a, 143 00 Praha
[4] Univerzita Hradec Králové, Víta Nejedlého 517, 500 03 Hradec Králové

Four young dwarf pine (*Pinus mugo* Turra) stands were studied with regard to a possible influence of pine shrubs on several herb species. These plots were monitored each year during 1995–2000. The main method used in this study is based on distances between an herb plant and the nearest dwarf pine shrub. A set of these distances was evaluated by special statistical procedure.
The distribution of *Hieracium alpinum* agg., *Pulsatilla scherfelii*, *Hypochoeris uniflora*, *Calluna vulgaris* and several other herbs was evaluated as affected by young pine plantings: the influence of dwarf pine shrubs on the distribution of all species under study was great. The ecotonal effect in the dwarf pine surroundings is constituted by a belt about 100 cm wide (this distance roughly corresponds to dwarf pine height) and is species-specific. This zone often positively influences not only the number of plants of the species concerned but also its flowering intensity. Plant browsing is influenced by dwarf pine shrubs, too.
The vegetation dynamics and growth of dwarf pine are compared among mentioned plots and four older stands (studied between 1981–1997). Changes in vegetation on the older dwarf pine stands was not accelerated very much during years 1981–1995. Greater changes occurred in the period to 1987 than in the next period since 1987. Dwarf pine expansion is fast under favourable conditions. The area increment in younger stands was 6–38 % per annum, which corresponds to an annual increase in shrub diameter by ca. 3–18 %.

Keywords: Giant Mts., alpine tundra, *Pinus mugo*, spatial structure, distance method, shrub-herb influence, *Calluna vulgaris*, *Hieracium alpinum* agg., *Hypochoeris uniflora*, *Pulsatilla scherfelii*.

INTRODUCTION

Since 1992 it has been adverted to negative impacts of high-elevation reforestation with dwarf pine (*Pinus mugo* Turra) on frost soil forms and ecosystems associated with them in the Giant Mts. There exists a conflict of interests of foresters and environmentalists on an area of approximately 200 ha (at an altitude about 1350 m) out of the total area 2179 ha of dwarf pine stands in the Giant Mts. The foresters argue that the existence of dwarf pine stands above the timberline is essential for the fulfilment of hydrological, soil conservation and climate protection functions (Lokvenc 1997). The environmentalists point out the decreasing intensity of frost processes in soil, changes in the temperature, wind and snow conditions as well as in the vegetation cover due to reforestation (Kociánová et al. 1995).

The dwarf pine as a dominant tree species of these ecosystems substantially influences their environment and processes in these ecosystems. All these impacts induce changes in growth conditions for many other plants that can display different responses. Therefore this article tries to elucidate such impacts. To clarify the influence of dwarf pine on plant communities permanent research plots (PRP) were established in the western part of the Giant Mts. on which research has been conducted since 1995. The objective of investigations was an exact evaluation of the influence of dwarf pine stands on some species of the herb layer. The results for the first year of investigations were evaluated in the paper by PAŠŤALKOVA et al. (1996). The situation development until 2000 is analysed now. The results of long-terms observations of vegetation dynamics in older dwarf pine stands (carried out since 1981 to 1998) are also included in this article.

METHOD

The territory in question is situated in the 1st zone of Krkonoše National Park in the western Giant Mts. Four permanent research plots (PRP) were established for research purposes, and other four PRP (8 plots in total) at the localities Krkonoš, Harrachova louka, Pančavská louka and Labská louka were used (Fig. 1.). Dwarf pine stands are of different origin, age and canopy density, growing on high-elevation mat grass meadows of the alliance *Nardo-Caricion rigidae* (cf. PAŠŤALKOVA et al. 2001). Table 1 shows the basic description of these localities.

Plant coenological relevés were recorded for the whole research period using seven-degree Braun-Blanquet combined scale for dominance and abundance. Relevés on PRP P1–P4 (established in 1981; 100–4000 m^2 in size) were taken in 1981, 1987, 1995 and 1998. Relevés on PRP J, K, N and V (established in 1995; 200 m^2 in size) were taken in 1995 and 1998. The nomenclature of plants is consistent with ROTHMALER et al. (1990), of mosses with CORLEY et al. (1981) and plant associations with MORAVEC et al. (1995).

The representations of particular species were expressed by average values of coverage for the relevé processing. It enabled to process all recorded storeys at once. A hierarchical agglomerative classification (average linkage method) was used (ORLÓCI 1978). A DCA method was applied to establish ordination (HILL 1979).

Data from four plots (J, K, N and V) with young dwarf pine stands 20 x 10 m in size were processed. On these plots exact mapping of dwarf pine shrubs and contingent spruce trees (both was mapped as periphery line) was carried out in 1995–2000. Distribution of selected herb species (*Hieracium alpinum agg.*, *Hypochoeris uniflora*, *Pulsatilla scherfelii*, *Veratrum album* subsp. *lobelianum* and *Senecio fuchsii*) was determined as set of points of occurrence of a single plant or a clump of several plants. Each point of occurrence has assigned several values - co-ordinates in the plot, number of plants (one or more), number of flowers (flowering plants), and number of browsed flowers (plants). The area of distribution of *Calluna vulgaris* was mapped as polygons.

Digitisation of stand maps in the TopoL software was the basic procedure of relevé processing. The areas of particular dwarf pine shrubs were calculated. Distance of a point of occurrence from the nearest shrub of dwarf pine (occurrence point-pine distance) was the basic measure of plant distribution for using in the next steps of data processing.

A new method of spatial analysis for a points-areas pattern study is introduced below. Its application in evaluation of relationship between several herb species and dwarf pine was applied. There are set of standard methods based on distances of spatial elements (compare CRESSIE 1991), the used method is similar. Distribution (in statistical sense) of occurrence point-pine distances is possible to compare with distribution of a random point from the nearest shrub of dwarf pine (random point-pine distance). This distribution of random point-pine distances is similar to one calculated on the base of a rectangular regular network of points (statistically, it is a sort of inaccuracy that can be tolerated due to the random distribution of all other elements observed on the plot). The used regular networks had spacing between

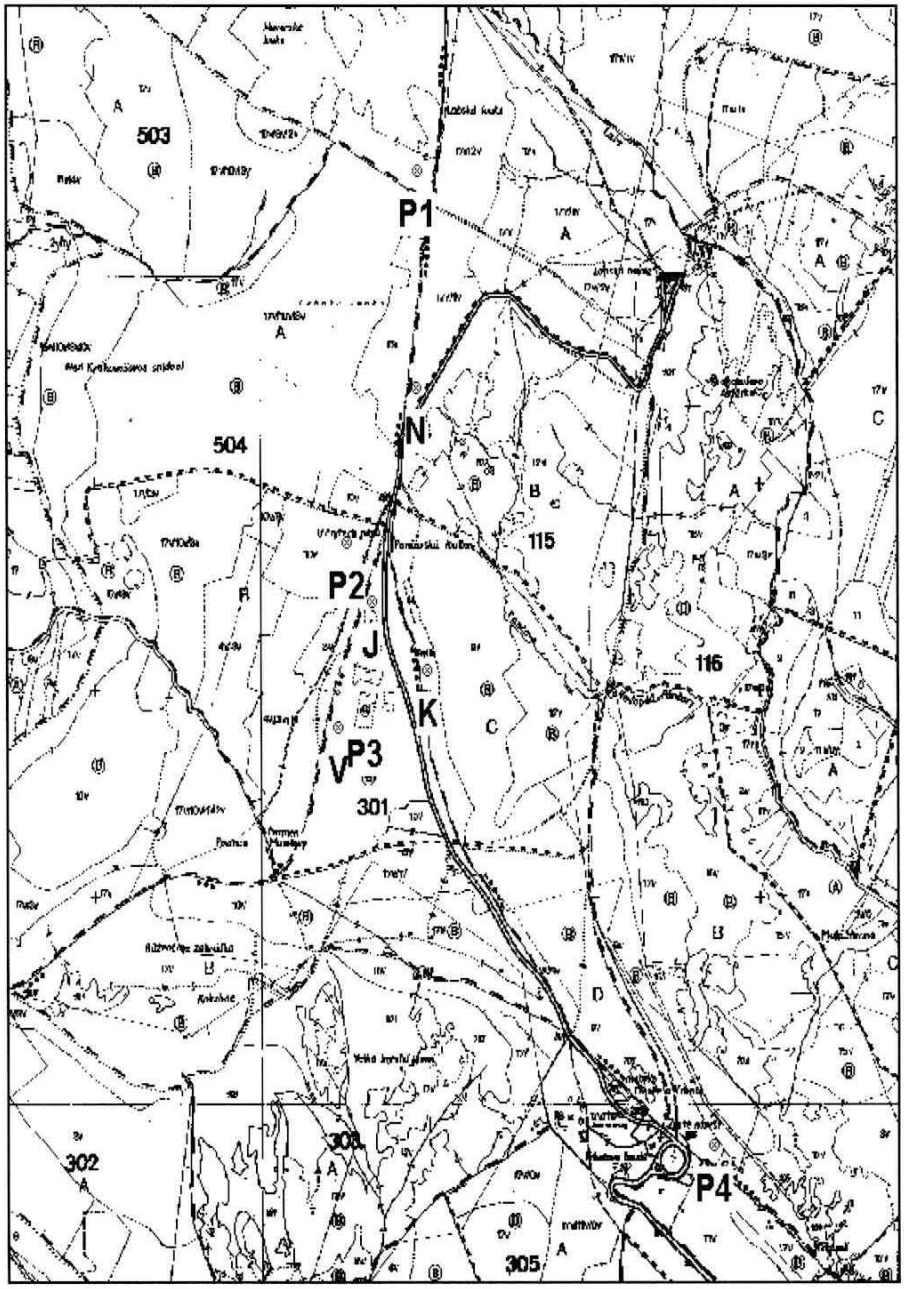


Fig. 1. Localisation of the permanent research plots in the western Giant Mts.

neighbouring points of 0.5 m in plots J, K, N and V, in the other plots this spacing was enlarged to 1–1.5 m in dependence on the plot size.

The frequencies of random point-pine distances should correspond to the frequencies of occurrence point-pine distances (and to the frequencies plant-pine, flowers-pine and browsed flowers-pine distances calculated on the base of number of plants, flowers, and browsed flowers respectively, at each point of occurrence) under assumption of their random distribution on the plot. The relative cumulative difference (d) in the frequency was calculated according to the equation

$$d = \sum_{i=1}^{k} (f_i/t - F_i/T),$$

where f_i is actual i-th frequency (i corresponds to the 0.25 m interval of distances, beginning with 0 m to the last interval 4 m and more; i = 0, distance 0 m corresponds to points inside the dwarf pine shrub, i = 1 to interval [0 m, 0.25 m], i = 2 to interval [0.25 m, 0.50 m], ...), F_i is relevant expected frequency, t is total frequency (sum of all f_i, i = 0,1,2,...), T is the number of the regular network points, k is a limit interval of the distance. Graphs of cumulative differences in dependence on the distance from dwarf pine were plotted. Evaluation of these graphs should indicate in what segment (in which distance from the nearest pine shrub) the values increase and where they decrease - showing the presence of more and/or fewer objects under study (points, plants, etc).

As different numbers of plants were studied in each species, cumulative differences shown in graphs cannot be directly compared in the terms of significance, but data could be tested statistically. It is possible to compare the frequencies of plant number (also for other objects under study) in relation to distances from the nearest dwarf pine shrub with the expected frequency that can be generated by the used network of points. χ^2-test of goodness of fit (comparing e.g. occurrence point-pine distance with generated random point-pine distance) was therefore employed.

The method of studying *Calluna vulgaris* was different from all other plant species because the investigations were not aimed at the particular plants (or plant clumps assigned to points) but the whole area covered with heather was plotted.

The area of heather cover was classified according to vitality:

a – more than 60 % of heather cover is in flower,
b – 30–60 % of heather cover is in flower,
c – less than 30 % of heather cover is in flower,
d – not flowering,
+ – dead part of heather cover.

Each homogenous area with *Calluna vulgaris* of the same vitality class was mapped separately as a polygon.

Evaluation was based on an analysis of the size of summary plot of dwarf pine (P_1), heather (P_2) and plot of dwarf pine with heather undergrowth (designated as a "mix", plot P_3). On condition that P is the size of the whole investigated plot and that heather grows independently to dwarf pine, the estimate for P_3 (marked $\mathscr{P}_3$) is expressed by the formula

$$\mathscr{P}_3 = P_1 * P_2 / P$$

Whole heather area as so as each area of separate vitality class was estimated and evaluated according to relative difference $(P_3 - \mathscr{P}_3)/\mathscr{P}_3$.

Transition matrices (sets of probabilities of transition of the plot with a certain class of vitality to other class of vitality) were calculated between the classes of vitality for pairs of the years 1996/1997, 1997/1998, 1998/1999, 1999/2000, separately for heather growing in the open space and for heather as dwarf pine undergrowth. One average transition matrix was calculated describing the processes of heather development in the period of observation (1996/1997–1999/2000).

RESULTS

Condition and development of phytocenoses

The object of the studies was dwarf pine stands that are not classified as dwarf pine community of the subalpine zone (see e.g. JIRÁSEK, 1996) but they are primarily subalpine grass communities of the association *Carici fyllae-Nardetum* (Zlatník 1928) Jeník 1961 (the alliance *Nardo-Caricion rigidae* Nordhagen 1937; Tab. 2.), locally with high frequency of *Nardus stricta*, *Calamagrostis villosa*, *Deschampsia flexuosa*, *Deschampsia cespitosa*, *Anthoxanthum odoratum* agg., *Homogyne alpina*, *Vaccinium myrtillus*, *Hieracium alpinum* agg., *Luzula luzuloides* and *Galium harcynicum*.

Phytocenological relevés recorded on the plots in particular years are quite homogeneous (Fig. 2.). In general, changes were greater in younger dwarf pine stands (plots J, K, N and V) than in older stands (plot P) even though the time of investigations was shorter (Fig. 3.).

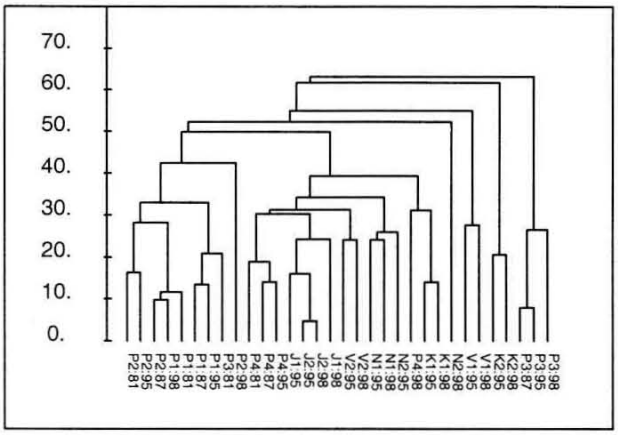


Fig. 2.
Classification tree of the relevés recorded in plots with dwarf pine. Hierarchical agglomerative classification - average linkage method are used. Plots (J, K, N, V) were divided in two sub-plots, sampling of each sub-plot (e.g. J1 and J2) was made separately. The last two digits represent year of sampling.

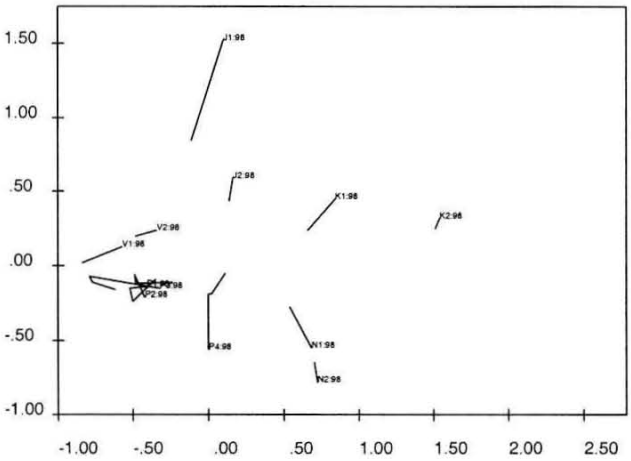


Fig. 3.
Ordination (with method DCA) of relevés recorded in plots with dwarf pine. First and second axes are drawn. Trajectories of single plots are given for period from starting year 1995 (plots J, K, N, V) or 1981 (plots P with older dwarf pine stands). The end of each trajectory is labelled using plot name and the last sampling year.

Tab. 2A. Relevés recorded in the research plots of the dwarf pine altitudinal belt.

Relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Plot	P2	P2	P2	P2	P1	P1	P1	P1	P3	P3	P3	P3	P4	P4	P4	P4
Altitude (m)	1350	1350	1350	1350	1380	1380	1380	1380	1370	1370	1370	1370	1390	1390	1390	1390
Orientation	NNW	NNW	NNW	NNW	SW	SW	SW	SW	N	N	N	N	NNE	NNE	NNE	NNE
Slope (°)	1	1	1	1	2	2	2	2	2	2	2	2	15	15	15	15
Area (m^2)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Year	1981	1987	1995	1998	1981	1987	1995	1998	1981	1987	1995	1998	1981	1987	1995	1998
E_2 - total cover (%)	30	40	50	55	35	45	55	60	40	50	55	60	5	10	10	15
E_1 - total cover (%)	85	87	89	90	80	79	76	75	90	90	90	90	95	95	96	97
Picea abies	1	+	+	+	1	+	+	+	+				1	1	1	1
Pinus mugo	3	3	3-4	4	3	4	4	4	3	3-4	4	4	2	2	2	2
Salix caprea																r
Salix silesiaca																+
*Sorbus * glabrata*	r												1	+	+	+
Rubus caesius													+	r	r	+
Agrostis capillaris													+			+
Agrostis rupestris																+
Alchemilla vulgaris									r							
Anthoxanthum odoratum agg.	1	1	+	2	1	+	+	+	1	1	+	+	2	2	1	1
Arnica montana	+	r			+											
Calamagrostis villosa						+	+	1	r	+	1	2	+	+	1	1
Calluna vulgaris	r			1					2	2	2	1	r	+	+	1
Campanula bohemica																+
Carex bigelowii	+	r		+	+				+	+			+	+		
Carex nigra	r	r			r				+	r			r			
Cerastium holosteoides																+
Deschampsia cespitosa	+	+	+		+	+	+	+	1	+	+		1	2	2	2
Deschampsia flexuosa	1	2	2	3	2	1	2	2	2	3	3	3	2	2	2	2

Diphasiastrum alpinum	r															
Dryopteris dilatata																+
Epilobium angustifolium																+
Festuca aizoides																+
Galium harcynicum	1	+	r	+	1	+	+	+	+	+	+	2	1	+	+	+
Gentiana asclepiadea	+	r			r				r				1	+	+	+
Hieracium alpinum agg.	+	r			1	+	r	r	+	r			1	+	+	+
Homogyne alpina	1	1	+	+	1	1	1	1	1	1	+	1	1	1	1	1
Huperzia selago					r								r			
Hypochoeris uniflora	+	r			+				r				+			
Luzula luzuloides	+	+	r	r	1	+	+	+	+	r			1	1	1	1
Luzula sudetica	r												1	+	+	+
Lycopodium clavatum													+	r		
Melampyrum pratense																+
Molinia caerulea						+	+	+					+	+	+	+
Nardus stricta	4	4	4	4	4	3	3	4	3	2	2	2	4	4	4	3
Polygonum bistorta	r					+	+	+	r				+	+	1	+
Potentilla erecta	r									r			r	+	+	+
Pulsatilla scherfelii													+	+	+	+
Rumex alpestris									+					+	+	+
Rumex obtusifolius										+						
Senecio fuchsii	+				+	r			+	r			+			1
Silene dioica																r
Silene vulgaris																+
*Solidago * minuta*									r			r	+	+	+	+
Taraxacum sec. *ruderalia*																+
Trientalis europaea	+	+	r	r	+	+	r	r	+	r			r			+
Vaccinium myrtillus	+	+	+	2	1	1	r	1	+	r		+	+	+	+	2
Vaccinium vitis-idaea	+	1	1	1	r	r							+	+	+	+
*Veratrum * lobelianum*	r				+	r				r	+	+	+	r		+

Tab. 2B.

Relevé	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Plot	J1	J1	J2	J2	N1	N1	N2	N2	V1	V1	V2	V2	K1	K1	K2	K2
Altitude (m)	1350	1350	1350	1350	1340	1340	1340	1340	1370	1370	1370	1370	1340	1340	1340	1340
Orientation	NNW	NNW	NNW	NNW	S	S	S	S	NNW	NNW	NNW	NNW				
Slope (°)	6	6	6	6	2	2	2	2	1	1	1	1	0	0	0	0
Area (m^2)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Year	1995	1998	1995	1998	1995	1998	1995	1998	1995	1998	1995	1998	1995	1998	1995	1998
E_2 - total cover (%)	5	10	5	10	10	20	10	20	10	20	10	20	15	20	10	15
E_1 - total cover (%)	100	100	100	100	100	95	100	95	100	95	100	95	100	95	100	98
Picea abies	+	+	1	1		+	+	+	+	+			+	+	+	+
Pinus mugo	1-2	2	1-2	2	2	2	2	2	2	2	2	2	2	2	2	2
Salix caprea									r	r						
Agrostis capillaris					1	+	1	1					1	1	1	1
Agrostis rupestistris																
Alchemilla vulgaris					1	+										
Anthoxanthum odoratum agg.	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	2
Arabidopsis thaliana							+									
Arnica montana			+		+	+	+									
Calamagrostis villosa	1	2	2	2	2	2	2	2	1	2	1	2	1	2	2	3
Calluna vulgaris									3	3	2	2				
Campanula bohemica																+
Carex bigelowii											+					+
Carex nigra	+	1					r	r	r	+	r	+				
Cerastium holosteoides	+	+	+	+			+	1								r
Deschampsia cespitosa	+	+	1	1			2	2	+		+		1	1	+	+
Deschampsia flexuosa	2	2	2	2	1	2	1	2	2	3	2	3	2	2	1	1
Epilobium alpestre						r										
Epilobium angustifolium					1	+			1	r						

Epilobium montanum							r	r								
Galium harcynicum	+	1		+	1	1	1	2			r			+		
Gentiana asclepiadea													+	+	+	1
Hieracium alpinum agg.	2	2	2	2	+	+			+	+	1	1	+	+	+	+
Hieracium tubulosum					+	+										
Homogyne alpina	1	1	1	1	1	1	+	2	1	2	+	1	1	1	1	1
Hypochoeris uniflora		+	1	1	1	1	1	1					+	1	2	2
Juncus effusus				+												
Luzula luzuloides	+	+	r	r	+	+	+	+			r	r				
Luzula sudetica					r	1	r	1						+		
Melampyrum pratense																
Molinia caerulea					1	+		+								
Nardus stricta	4	4	4	4	4	4	4	3	3	3	4	4	3	3	2	2
Poa subcoerulea					r	r										
Polygonum bistorta	r	+	r	r			+	+			r	r			+	+
Potentilla erecta					1	2	1	2							1	1
Pulsatilla scherfelii													2	2	2	2
Rumex alpestris							1	1								
Rumex obtusifolius	r	r														
Senecio fuchsii	+	+	+	+	1	2	2	2								+
Silene dioica								+								
*Solidago * minuta*	1	2	+	1						+	+	+	+	1	+	+
Taraxacum sec. *ruderalia*			r	r	r	r				r						
Trientalis europaea								r								
Vaccinium myrtillus				+	+	+	1	1	+	+	+	+			+	+
Vaccinium vitis-idaea					r				1	+	+					
*Veratrum * lobelianum*	1	2	r	+		+	r	r	+	r	r	r	r	+		+

Tab. 2C. List of the moss layer (E0) species according to the study plots (state of 1998).

	P1	P2	P3	P4	J	K	N	V
Brachythecium reflexum				•				
Ceratodon purpureus				(•)	•			
Cynodotium sp.				•				
Dicranella heteromalla	•	•		•				•
Dicranum fuscescens				•				
Dicranum montanum		•		•				
Dicranum scoparium	•	•	•					
Hylocomium splendens				•				
Plagiothecium curvifolium	•							
Plagiothecium denticulatum				•				
Pleurozium schreberi	•			•				
Pohlia drummondii				•				
Pohlia nutans		•	•	•	•	•	•	
Pohlia sp.	•	•						
Polytrichum alpinum				•				
Polytrichum commune				•				•
Polytrichum formosum	•	•	•		•	•		•
Polytrichum juniperinum							•	
Polytrichum strictum				•				•
Ptilidium pulcherrimum		•						
Racomitrium heterostichum				•				
Racomitrium sudeticum							•	
Rhizomnium punctatum				•				
Rhytidiadelphus loreus				•				
Rhytidiadelphus subpinnatus				•				
Sanionia uncinata				•				
Sphagnum girgensohnii				•				

Comment: Species with occurrence in plot P4 on the building of bunker only: *Amblystegium serpens, Brachythecium velutinum, Bryum argenteum, Didymodon rigidulus, Eurhynchium praelongum, Grimmia doniana, Polytrichum piliferum, Rhynchostegium murale, Schistidium apocarpum, Tortula muralis.* Similar behaviour by *Ceratodon purpureus* was recorded.

Vegetation dynamics in older dwarf pine stands was not accelerated very much in 1981–1998. Substantially greater changes occurred in 1981–1987 in comparison with 1987–1995. Vegetation dynamics was relatively highest on plots P3 and P4 in 1995–1998. On plot P3 (with the most different vegetation), it was a decrease in the cover of *Calluna vulgaris* and on the contrary, an increase in *Galium harcynicum* cover. On plot P4 the number of species (mostly anthropophyte species) considerably increased by 14.

Higher dynamics on plots with young plantings was recorded only on parts of plots J, N and K (phytocenological investigations were carried out within two square sub-plots 10 x 10 m within each of these plots). The cover of *Calamagrostis villosa*, *Solidago virgaurea* and *Veratrum album* subsp. *lobelianum* increased on plot J. Plots N and K are affected by progressive eutrophication and subsequent synanthropication from the road margins. So it can be deduced that vegetation dynamics can be influenced to a lager extent by anthropogenic load than by the expanding canopy of dwarf pine stands. It agrees e.g. with the effect of anthropogenic load on dwarf pine ecosystems in the Tatra Mts. (Kubíček et al. 1983).

THE EFFECT OF DWARF PINE ON PLANT COMMUNITIES

Numbers of occurrence points, plants, flowering plants, and browsed plants by studied species have varied prom plot to plot as well as during time (Tab. 3.). Table 4. shows the range of the cumulative difference values as a first look to describe relation between herb species and dwarf pine (e.g. highest values are calculated by *Hypochoeris uniflora* as probably one of the most sensitive species).

Tab. 3. Numbers of occurrence points, all plants, flowering plants (flowers) and browsed plants in the study plots during the monitoring period.

Species	Plot	Year	Points	Plants	Flowers	Browsed
Hieracium	J [1)]	1995	295	1171	919	307
alpinum agg.		1996	346	821	339	152
		1997	533	1561	749	349
		1998	932	3077	644	403
	K	1998	112	268	92	20
		2000	166	390	164	58
Hypochoeris	J	1995	37	145	14	6
uniflora		1996	28	72	15	7
		1997	28	98	16	10
		1998	41	143	16	5
		1999	40	127	3	1
		2000	43	149	34	33
	K	1998	609	1831	346	281
		2000	660	2152	382	303
	N	1995	48	235	45	40
		1996	46	155	38	21
		1997	49	202	40	27
		1998	61	208	73	24
		1999	64	214	28	14
		2000	63	237	81	71
Pulsatilla scherfelii	K	1995	417	1715	129	-
		1996	792	2363	78	54
		1997	822	3592	129	90
		1998	725	3523	115	36

Comment: [1)] In the year 2000, occurrence of *Hieracium alpinum* agg. was recorded in subplot J1, only.

All results of the χ^2-test of goodness of fit for difference between real and prospective frequency (with relation to distance from the nearest dwarf pine) are shown in Tab. 14. Interesting is e.g. low significant results in *Hypochoeris uniflora* on plot N. In general, data on plant number is more important than the number of frequency of points of occurrence.

Plot J

Figs. 4A-D and 5. show development of the dwarf pine horizontal structure and herb species distribution. Dwarf pine stand is of medium number of shrubs and degree of coverage (Tab. 5.). The most frequent distance of a random point from any dwarf pine shrub assessed by the mode of distribution was 50–75 cm (Fig. 6.).

Tab. 4. Ranges of values of relative cumulative difference (d; in per-cent) by occurrence points, all plants, flowering plants (flowers) and browsed plants for selected species according to plots and years.

Species	Plot	Year	Points	Plants	Flowers	Browsed
Hieracium	J	1995	7,3	11,8	13,7	17,5
alpinum agg.		1996	6,6	4,7	8,4	16,2
		1997	5,2	7,5	4,7	4,9
		1998	6,3	4,9	5,5	7,8
	K	1998	22,8	25,4	30,9	36,5
Hypochoeris	J	1995	53,1	63,5	29,6	46,2
uniflora		1996	51,3	50,9	53,7	79,2
		1997	49,0	55,6	51,0	78,5
		1998	48,4	57,4	27,1	50,9
	K	1998	11,9	12,4	12,3	18,2
	N	1995	15,9	17,4	19,5	24,1
		1996	12,0	7,8	11,7	20,1
		1997	8,4	12,9	11,8	15,9
		1998	6,5	11,6	10,8	23,0
Pulsatilla scherfelii	K	1995	11,3	7,8	14,4	-
		1996	13,7	13,9	12,9	19,4
		1997	12,2	14,3	7,5	10,6
		1998	13,7	15,0	9,4	25,1

A – 1995

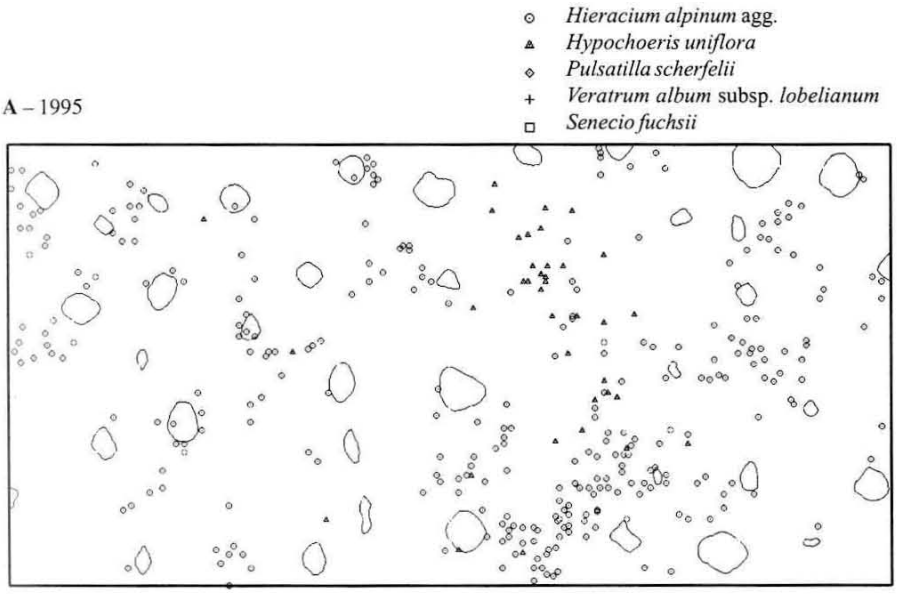
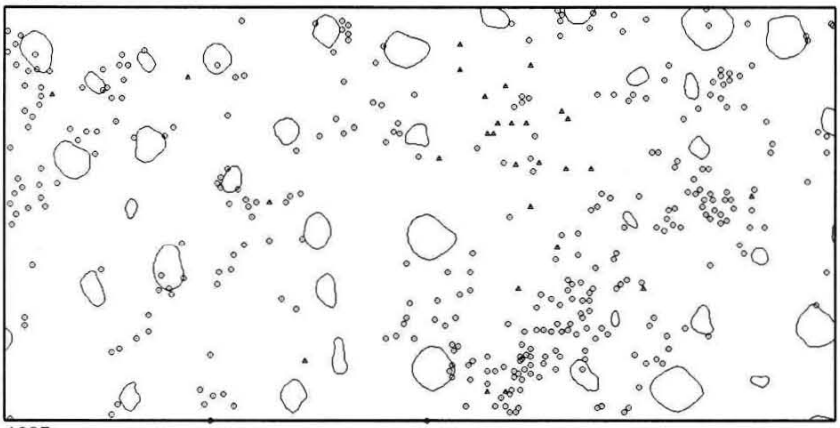
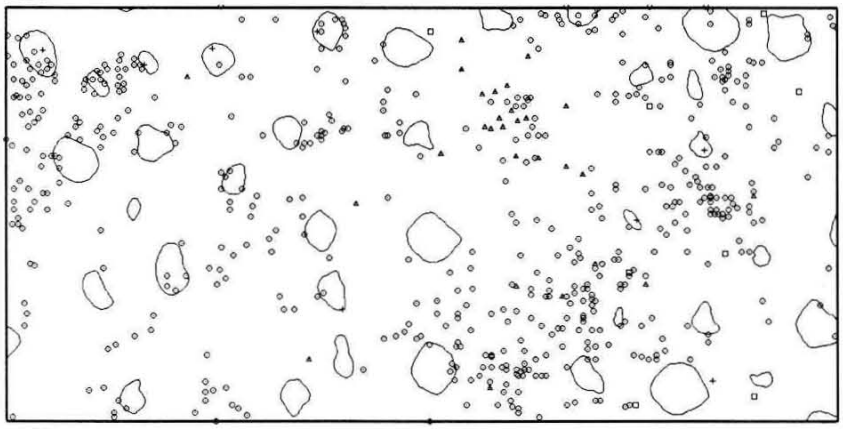


Fig. 4A-D. Plot J in years 1995-1998. Polygons represent shrubs of dwarf pine. Four small trees of Norway spruce are drawn only in the last year (1998). Plot size is 10 m x 20 m.

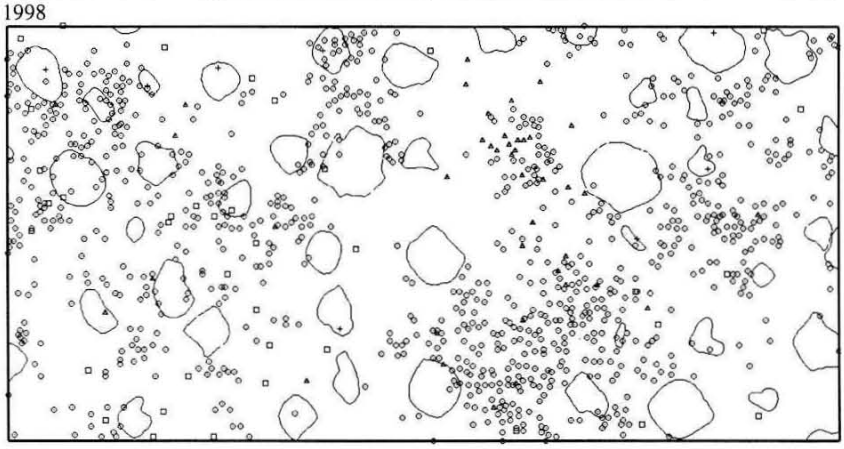
B – 1996



C – 1997



D – 1998



Tab. 5. Development of area of *Pinus mugo* shrubs in the plot J.

Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
number of shrubs *	38	40	41	42	42	42
area [m^2]	**10,753**	**13,910**	**17,796**	**24,598**	**27,942**	**33,065**
annual increment [%]		+29,4	+27,9	+38,2	+13,6	+18,3
pine coverage [%]	5,43	6,96	8,90	12,30	13,97	16,53

Comment: * It is number of all shrubs with any part trenching on the plot.

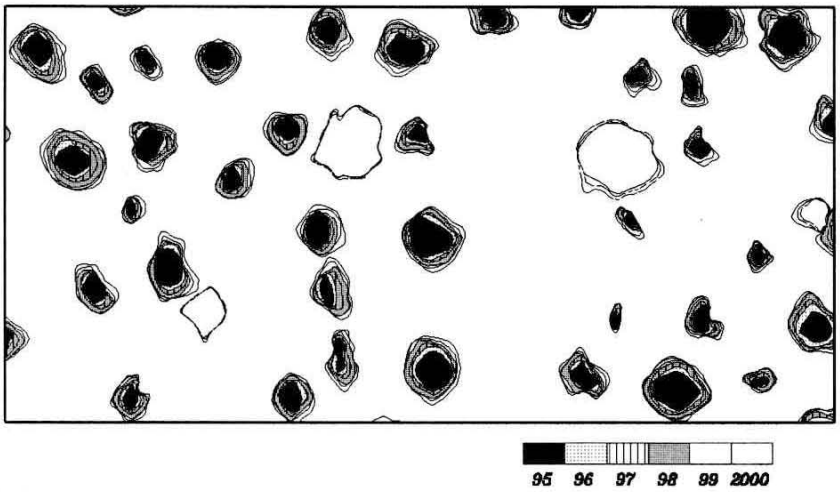


Fig. 5. Growing of dwarf pine in the plot J during period 1995-2000. Empty polygons represent Norway spruce trees.

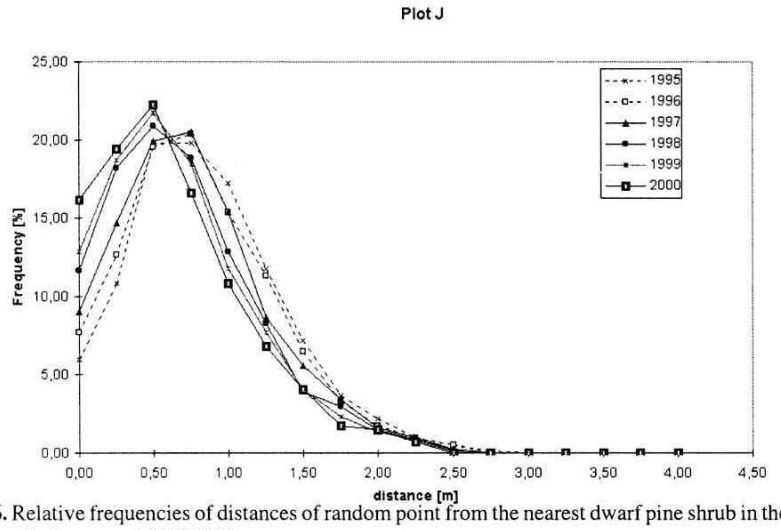


Fig. 6. Relative frequencies of distances of random point from the nearest dwarf pine shrub in the plot J during years 1995-2000.

***Hieracium alpinum* agg.:** There are few plants inside dwarf pine shrubs. But they are accumulated near the shrubs (with a distance of 50–100 cm). Fig. 7. shows the results of cumulative difference for particular variants in 1998. There are more flowering plants outside dwarf pine shrubs at medium intensity of flowering (evaluated as flowering percentage, i.e. the proportion of flowering plants). The spatial difference cannot be significant if the flowering percentage was higher. But there can be more flowering plants under the shelter of dwarf pine shrubs in adverse conditions.

Hypochoeris uniflora largely prefers gaps between dwarf pine shrubs. It seeks places with more than 100–150 cm distance from dwarf pine shrubs.

***Veratrum album* subsp. *lobelianum*:** In 1997 only 8 plants were found outside dwarf pine shrubs (with distance of 11–86 cm from the nearest pine shrub). In 1998 (52 plants) this species preferred gaps again.

***Senecio fuchsii*:** 16 plants of this species grew exclusively inside the dwarf pine stands in 1997–1998.

Tab. 6. Share of flowering plants of *Hieracium alpinum* agg. in the plot J.

Year	Share [%]	
	under pine cover	in gaps
1995	100 [1)]	79,5
1996	34,3	41,6
1997	47,8	48,0
1998	24,5	20,7
2000 [2)]	29,2	23,2

Comment: [1)] Only 3 plants under dwarf pine, all flowering. [2)] The sub-plot J1 was evaluated only.

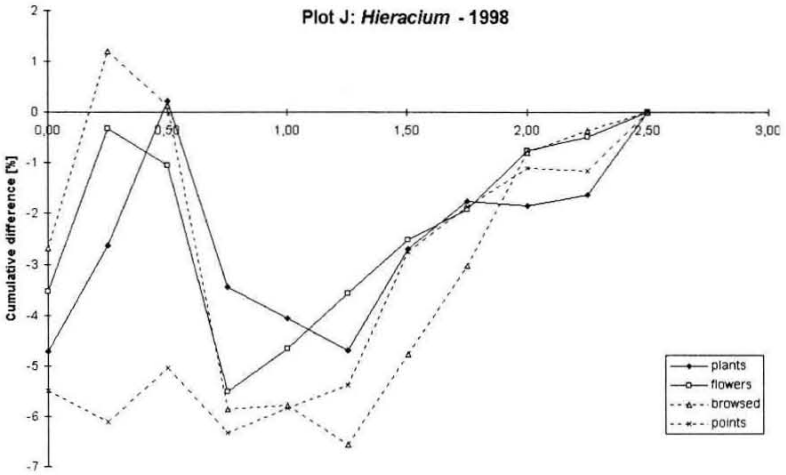


Fig. 7. Relative cumulative difference in the frequency of occurrence points, plants, flowering plants (flowers) and browsed plants by *Hieracium alpinum* agg. in the plot J - example of the 1998 year. Horizontal axis - distance from the nearest dwarf pine shrub (in m).

Plot K

Figs. 8A-D. and 9. show development of the dwarf pine horizontal structure and herb species distribution. The dwarf pine stand is of high number of shrubs and degree of coverage (Tab. 7.). The most frequent distance of a random point from dwarf pine is 25–50 cm (Fig. 10.).

Pulsatilla scherfelii: The frequency of plants is largely reduced inside dwarf pine shrubs and within a radius of 25 cm from dwarf pine. Fig. 11. shows the results of cumulative difference for particular

variants in 1998. Nevertheless, this species often produces more flowering plants inside dwarf pine shrubs (Tab. 8.). The zone of shrub surroundings has a very positive effect (within ca. 20–50 cm from dwarf pine shrubs) where plant browsing is also concentrated.

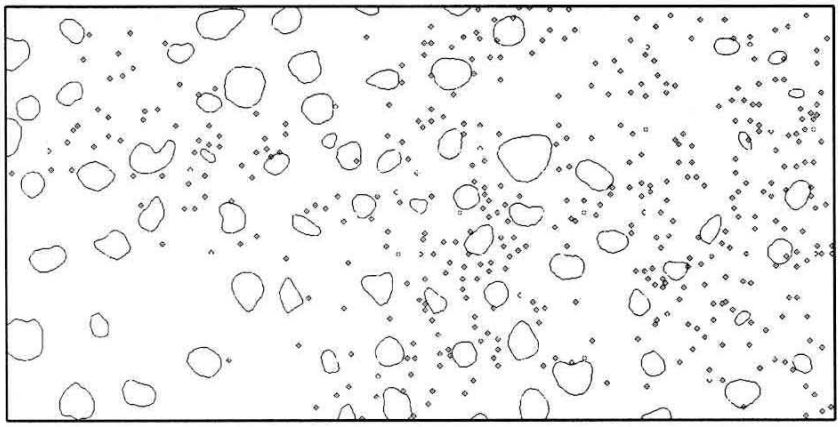
Hieracium alpinum agg.: There are markedly fewer plants and flowers inside dwarf pine shrubs and in their surroundings within a radius of ca. 50 cm. Flowering percentage inside dwarf pine shrubs was lower (29.6 %) than in the open space (34.9 %).

Hypochoeris uniflora: There are markedly fewer plants and flowers inside dwarf pine shrubs and in their nearest surroundings (within 25 cm). Flowering percentage inside dwarf pine shrubs and in the open space is equal (18.3 and 19.0 %, respectively).

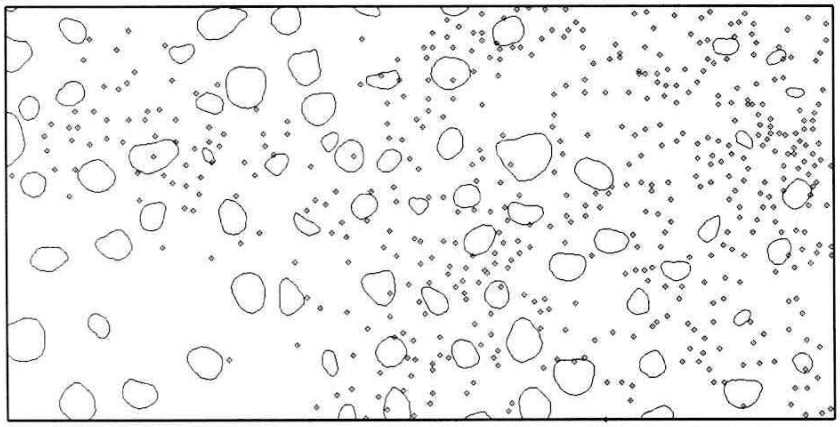
Tab. 7. Development of area of *Pinus mugo* shrubs in the plot K.

Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
number of shrubs	73	74	74	74	78	78
area [m^2]	**23,403**	**26,183**	**31,418**	**39,491**	**46,611**	**57,303**
annual increment [%]		+11,9	+20,0	+25,7	+18,0	+22,9
pine coverage [%]	11,89	13,09	15,71	19,75	23,31	28,65

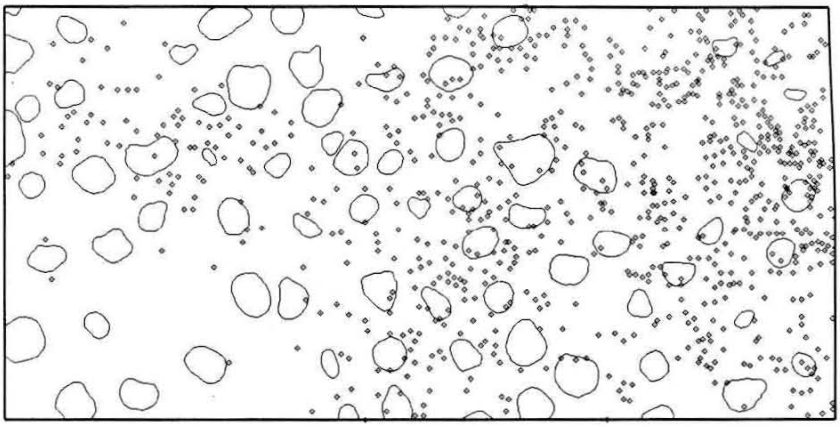
A – 1995



B – 1996



C – 1997



D – 1998

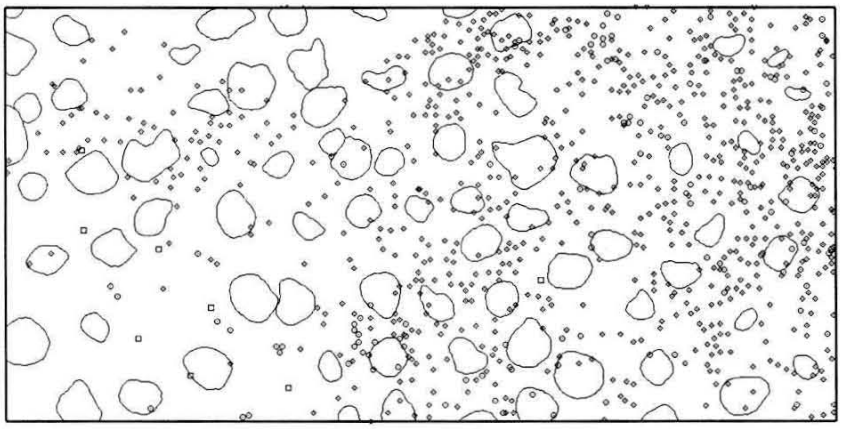


Fig. 8A-D. Plot K in years 1995-1998. Polygons represent shrubs of dwarf pine. See legend in Fig. 4.

Tab. 8. Share of flowering plants of *Pulsatilla scherfelii* in the plot K.

Year	Share [%]	
	under pine cover	in gaps
1995	7,9	7,5
1996	3,6	3,3
1997	6,8	3,4
1998	6,6	3,0

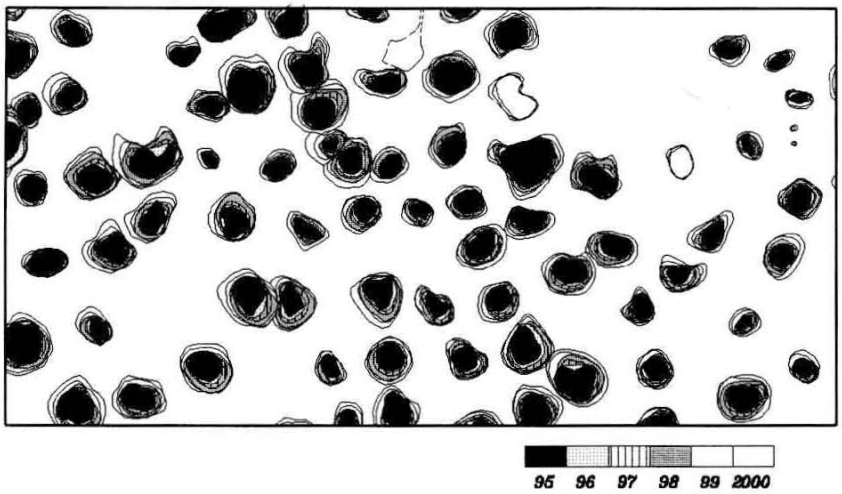


Fig. 9. Growing of dwarf pine in the plot K during period 1995-2000. Empty polygons represent Norway spruce trees.

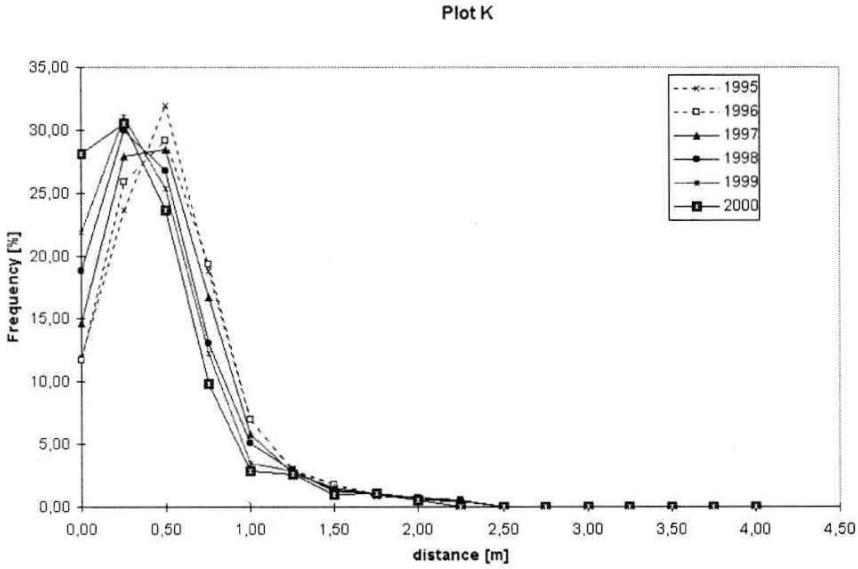


Fig. 10. Relative frequencies of distances of random point from the nearest dwarf pine shrub in the plot K during years 1995-2000.

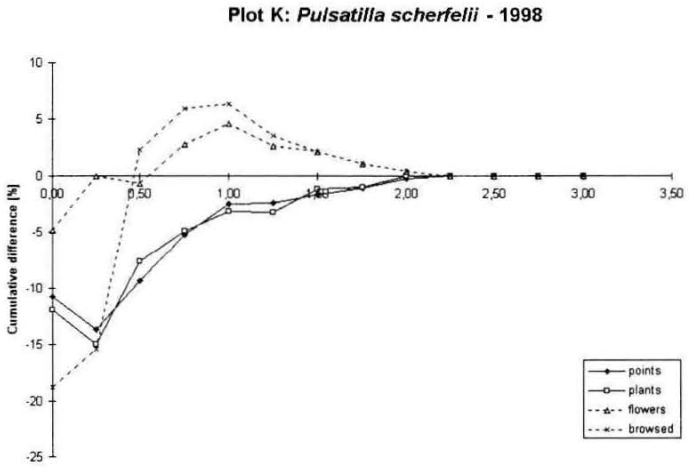


Fig. 11. Relative cumulative difference in the frequency of occurrence points, plants, flowering plants (flowers) and browsed plants by *Pulsatilla scherfelii* in the plot K – example of the 1998 year. Horizontal axis – distance from the nearest dwarf pine shrub (in m).

Plot N

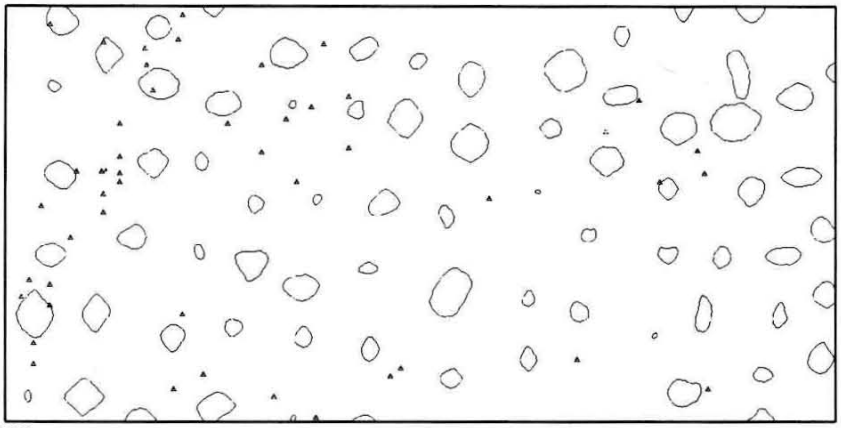
Figs. 12A–D. and 13. show development of the horizontal dwarf pine structure and herb species distribution. The most frequent distance of a random point from dwarf pine is 50 cm (Fig. 14.). Points at a distance of 1 m and more occur only sporadically, due to the more or less regular distribution of a higher number of smaller dwarf pine shrubs on the whole plot. The development of area grown with dwarf pine is shown in Tab. 9.

Hypochoeris uniflora: The number of plants and flowers inside dwarf pine shrubs and in the open space is balanced, contrarily to the preceding plots (compare Tab. 14c.). Dwarf pine probably protects plants from browsing here. The frequency of plants and flowers is substantially reduced in a narrow zone around dwarf pine shrubs (within 30–50 cm). Table 10 shows flowering of this species. The results of cumulative difference for particular variants in 1998 are represented in Fig. 15. Different behaviour of this species in comparison with preceding plots can be explained by the relatively high dwarf pine number of shrubs and degree of coverage (voids of small size between dwarf pine shrubs). It could also be supported by the fact that differences in the species behaviour (balanced frequency inside dwarf pine shrubs and in the open space) increase throughout the three years of observations – while size of the gaps continue to decrease.

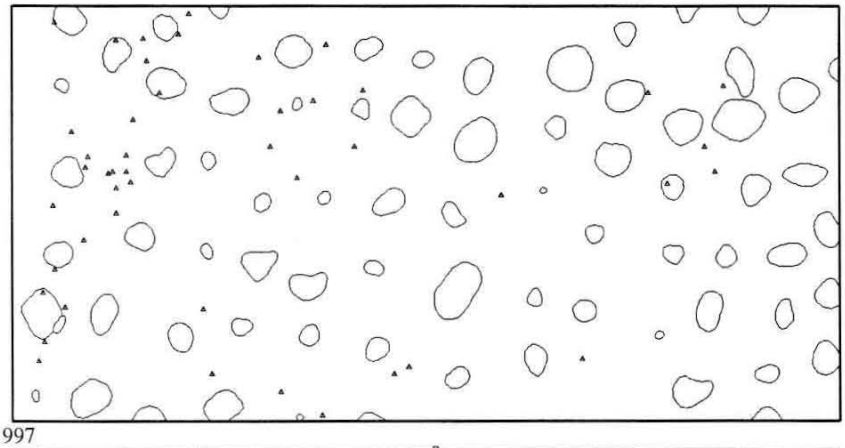
Veratrum album subsp. *lobelianum*: There were fewer plants inside dwarf pine shrubs than in the open space (-5.3 %). In general, the plant frequency is quite balanced (the statistical evaluation was a little difficult because there were only 62 plants on the whole plot). The maximum number of plants seems to be within the radius of 50 cm from dwarf pine shrubs.

Senecio fuchsii: The cover of this species has been increasing rapidly since 1997 as a result of progressive eutrophication from the margin of the road paved with limestone gravel. The highest number of plants is within the radius of 50 cm from dwarf pine shrubs (Fig. 15B–C.).

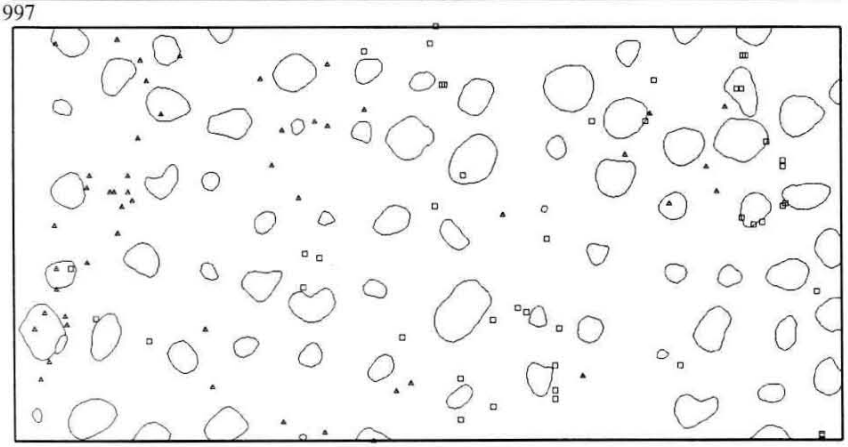
A – 1995



B – 1996



C – 1997



D – 1998

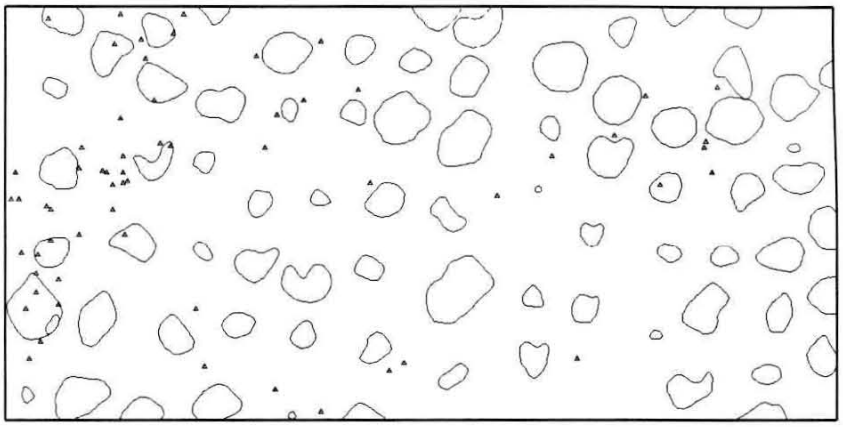


Fig. 12A–D. Plot N in years 1995-1998. Polygons represent shrubs of dwarf pine. See legend in Fig. 4.

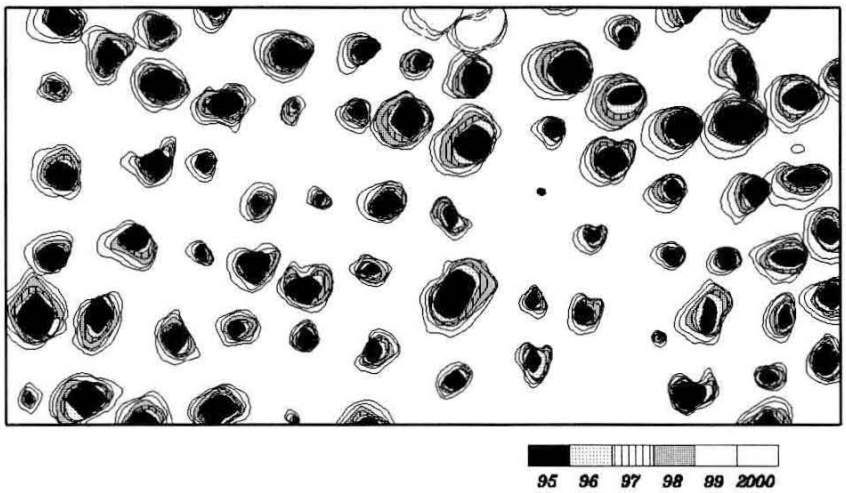


Fig. 13. Growing of dwarf pine in the plot N during period 1995-2000. Empty polygons represent Norway spruce trees.

Tab. 9. Development of area of *Pinus mugo* shrubs in the plot N.

Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
number of shrubs	74	74	74	74	75	76
area [m^2]	**19,477**	**25,102**	**30,837**	**38,739**	**48,806**	**64,047**
annual increment [%]		+28,9	+22,8	+28,9	+26,0	+31,2
pine coverage [%]	9,73	12,55	15,42	19,37	24,40	32,02

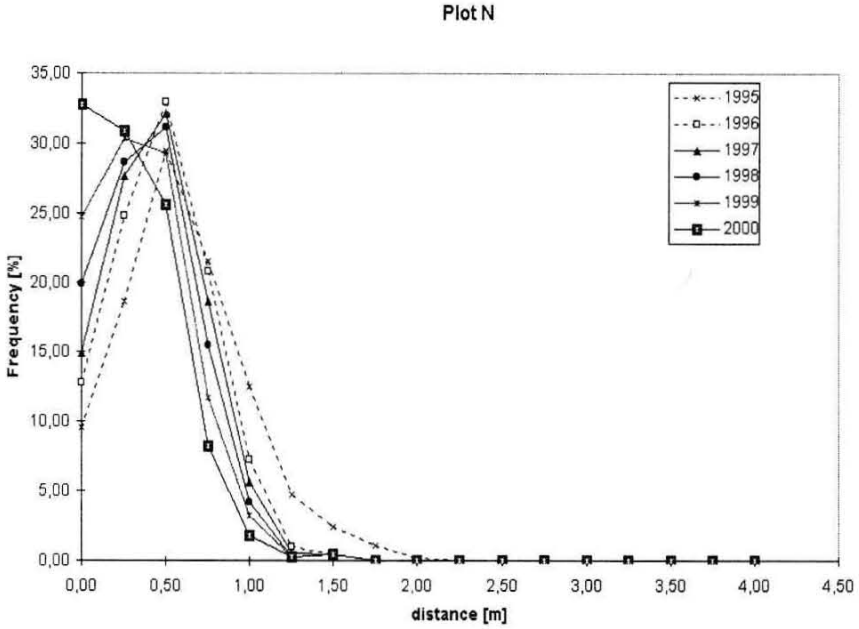
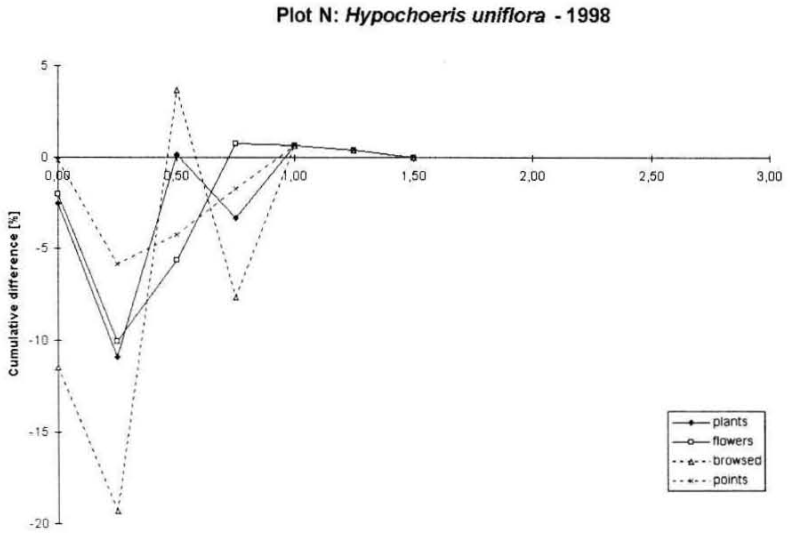
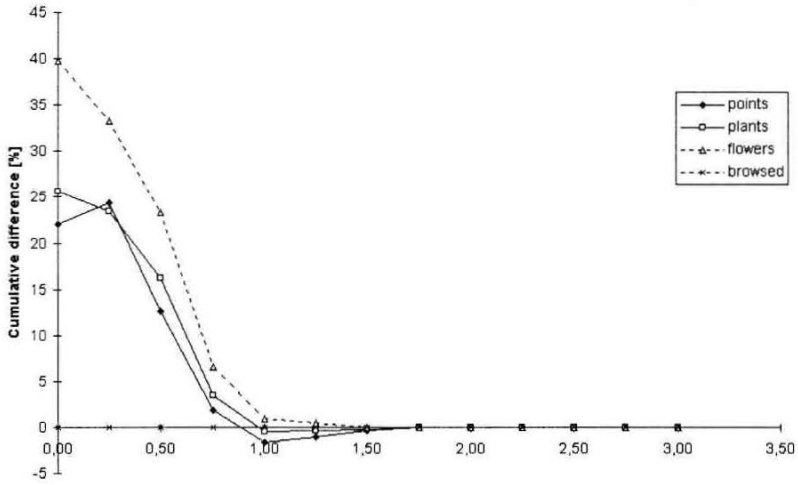


Fig. 14. Relative frequencies of distances of random point from the nearest dwarf pine shrub in the plot N during years 1995-2000.

A



B



C

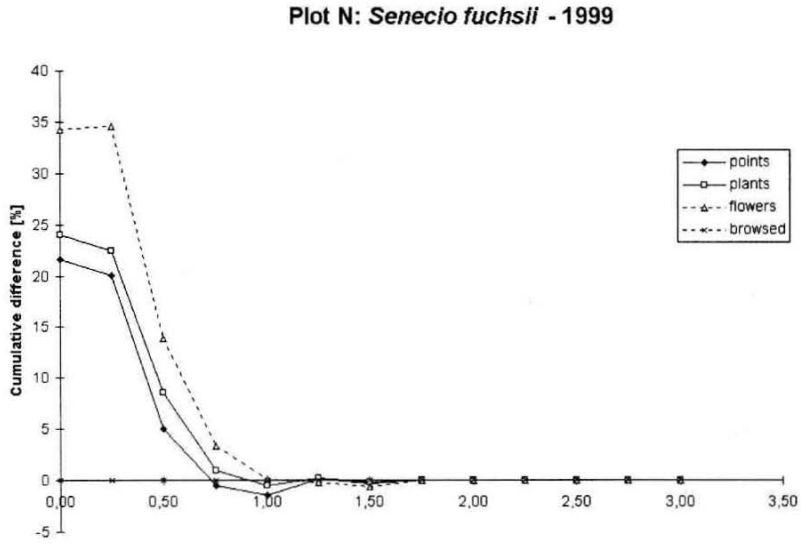


Fig. 15 (A-C). Relative cumulative difference in the frequency of occurrence points, plants, flowering plants (flowers) and browsed plants in the plot N: by *Hypochoeris uniflora* - example of the 1998 year (A), and *Senecio fuchsii* in 1997 (B) and 1999 (C). Horizontal axis - distance from the nearest dwarf pine shrub (in m).

Tab. 10. Share of flowering plants of *Hypochoeris uniflora* in the plot N.

Year	Share [%]	
	under pine cover	in gaps
1995	16,7 *	19,3
1996	33,3	23,4
1997	17,9	20,1
1998	36,1	34,9
1999	8,8	13,9
2000	33,3	34,5

Comment: * Only 12 flowering plants under dwarf pine.

Plot V

Figs. 16 A–D and 17 show development of the dwarf pine horizontal structure and herb species distribution. Dwarf pine stand is of low number of shrubs and degree of coverage (Table 11.). The most frequent distance of a random point from dwarf pine is 50 cm, but there are a lot of points at a distance of 2 m from dwarf pine shrubs (Fig. 18.).

***Hieracium alpinum* agg.** had low frequency here. It occurs in clusters in the open space.

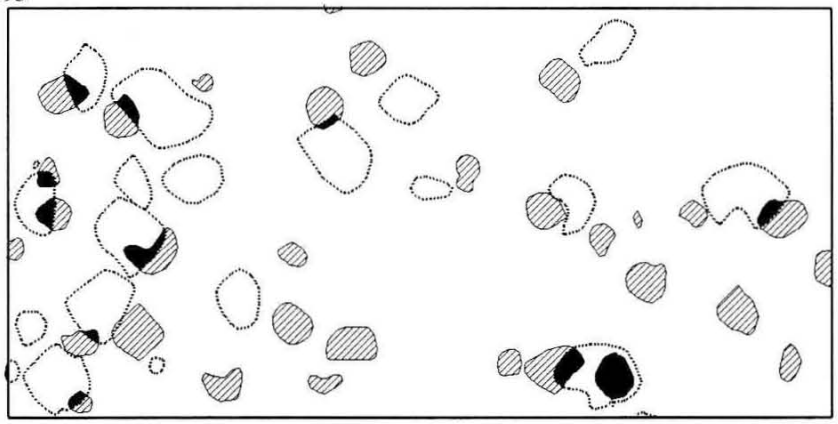
***Solidago virgaurea*:** This species was included additionally on one plot in the course of study. Its frequency looks peculiar in comparison with all preceding species because its frequency was reduced in the ecotone zone around dwarf pine shrubs (Fig. 19.).

***Calluna vulgaris*:** Heather frequency was analysed in a different way - the areas covered by heather, by dwarf pine shrubs and by dwarf pine with heather undergrowth (so called mix) were identified. Heather areas were evaluated by the classes of vitality (Table 12a–e). The frequency of heather inside dwarf pine shrubs is considerably higher than expected (+36 % in 1996 and 2000). This value reaches its maximum in 1997 and 1998 (ca. +26 %). If the classes of vitality (defined on the basis of flowering intensity) are compared, attention should be paid to the most frequent classes a, b, c. A decrease in the area of the highest vitality class was recorded within four years (class a; -19.4 % to -28.6 %), on the contrary, the area of class a largely increased in 1999 (+251 %), and there was a substantial increase in the area of class c within five years (+23.8 % to +155.0 %) in comparison with the expected areas. The enlargement of heather area in undergrowth can be attributed to dwarf pine expansion. Heather in the open space mostly belongs to the same class of vitality (classes a to c) in the next year. Non-flowering heather (class d) passes to class a in the next year. It documents a sort of cyclic flowering. The areas newly overgrown with heather are usually included in the highest classes of vitality (Table 13a.). The above findings do not describe heather as dwarf pine undergrowth. Its vitality gradually decreases (see e.g. frequent transition from class a to class c). The areas newly overgrown with heather are mostly included in lower class c under dwarf pine (Table 13b.). The results from 1996–2000 are consistent with the results from 1995 that were processed by a different method (PAŠŤALKOVA et al. 1996).

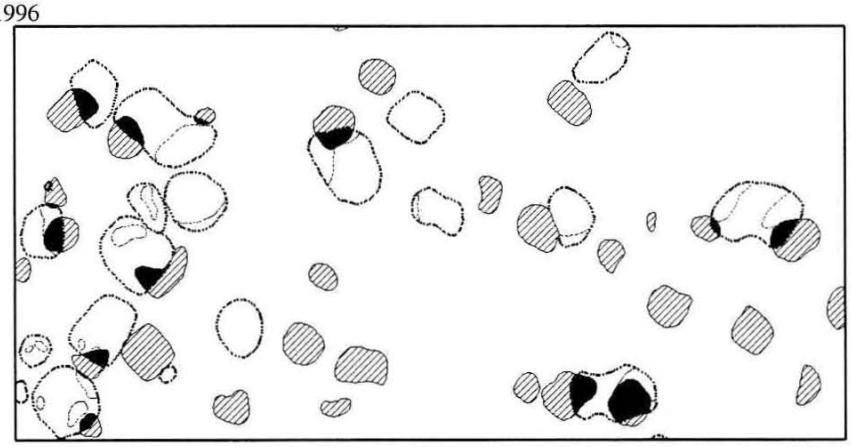
Tab.11. Development of area of *Pinus mugo* shrubs in the plot V.

Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
number of shrubs	32	32	32	32	32	32
area [m^2]	**16,557**	**17,521**	**19,185**	**23,087**	**27,166**	**33,719**
annual increment [%]		+5,8	+9,5	+20,3	+17,7	24,1
pine coverage [%]	8,28	8,76	9,59	11,54	13,58	16,86

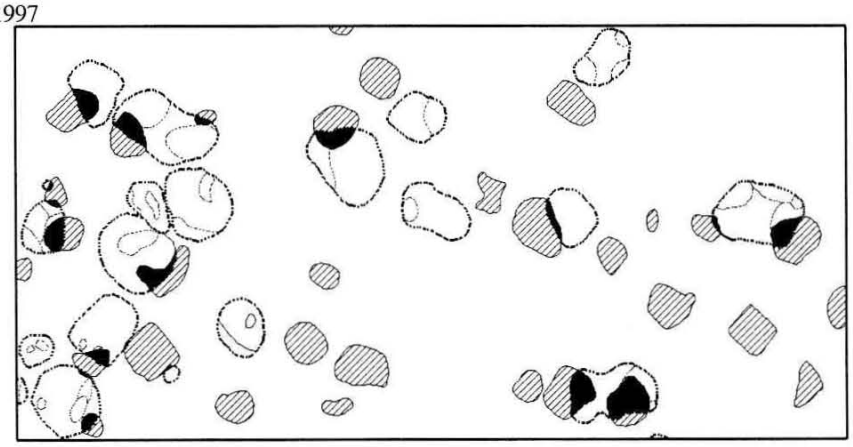
A – 1995



B – 1996



C – 1997



D – 1998

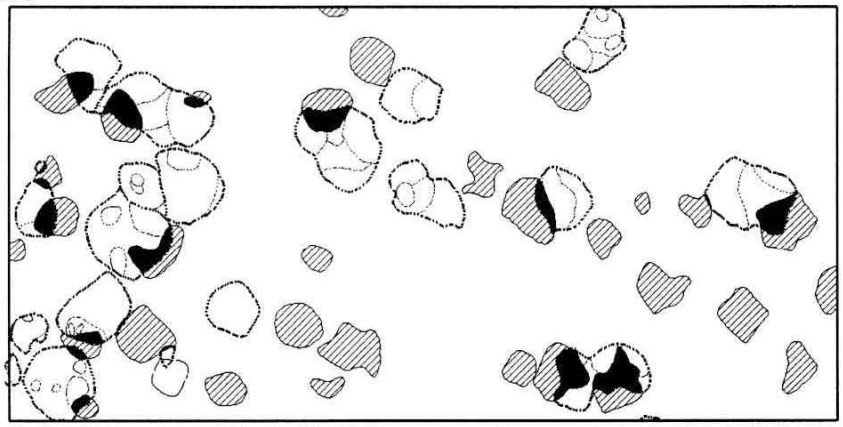


Fig. 16A–D. Plot V in years 1995–1998. Hatching polygons represent shrubs of dwarf pine, black areas are ones with *Calluna vulgaris* undergrowth. Empty polygons drawn with thick dotted lines show heather on free places. They can be divided into vitality classes by thin lines.

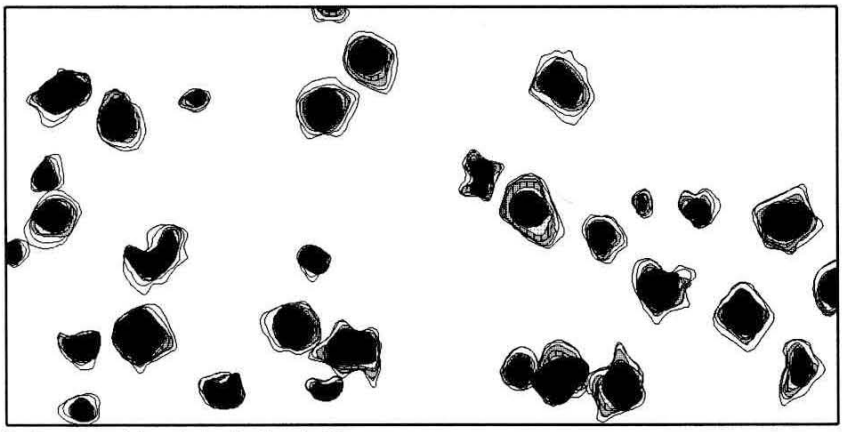
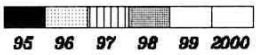


Fig. 17. Growing of dwarf pine in the plot V during period 1995–2000.



Tab. 12A. Analysis of the area occupied by *Calluna vulgaris* related to the vitality classes in the plot V at 1996.

vitality class	area of *P. mugo* [m^2]	area of *C. vulgaris* [m^2]	in under-growth [m^2]	total of *P. mugo* [m^2]	total of *C. vulgaris* [m^2]	expected under-growth [m^2]	difference [%]
+		0,503	0,082		0,585	0,051	60,02
a		5,659	0,430		6,089	0,533	-19,38
b		13,204	1,495		14,699	1,288	16,11
c		4,042	1,160		5,202	0,456	154,57
d		0,000	0,000		0,000	0,000	0,00
total	14,352	23,408	3,167	17,519	26,575	2,328	36,05

Tab. 12B. Analysis of the area occupied by *Calluna vulgaris* related to the vitality classes in the plot V at 1997.

vitality class	area of *P. mugo* [m²]	area of *C. vulgaris* [m²]	in under-growth [m²]	total of *P. mugo* [m²]	total of *C. vulgaris* [m²]	expected under-growth [m²]	difference [%]
+		0,691	0,093		0,784	0,075	23,66
a		8,279	0,665		8,944	0,858	-22,49
b		10,374	1,214		11,588	1,112	9,21
c		6,310	1,582		7,892	0,757	108,96
d		0,193	0,000		0,193	0,019	-100,00
total	15,632	25,847	3,554	19,186	29,401	2,820	26,01

Tab. 12C. Analysis of the area occupied by *Calluna vulgaris* related to the vitality classes in the plot V at 1998.

vitality class	area of *P. mugo* [m²]	area of *C. vulgaris* [m²]	in under-growth [m²]	total of *P. mugo* [m²]	total of *C. vulgaris* [m²]	expected under-growth [m²]	difference [%]
+		0,599	0,000		0,599	0,069	-100,00
a		14,487	1,301		15,788	1,822	-28,60
b		8,789	0,899		9,688	1,118	-19,60
c		4,189	1,747		5,936	0,685	154,99
d		0,191	0,841		1,032	0,119	606,05
total	18,296	28,255	4,788	23,084	33,043	3,814	25,54

Tab. 12D. Analysis of the area occupied by *Calluna vulgaris* related to the vitality classes in the plot V at 1999.

vitality class	area of *P. mugo* [m²]	area of *C. vulgaris* [m²]	in under-growth [m²]	total of *P. mugo* [m²]	total of *C. vulgaris* [m²]	expected under-growth [m²]	difference [%]
+		0,827	0,000		0,827	0,112	-100,00
a		0,412	0,376		0,788	0,107	251,38
b		6,586	0,754		7,341	0,997	-24,34
c		18,723	4,390		23,113	3,139	39,85
d		3,092	0,880		3,974	0,540	63,20
total	20,763	29,640	6,401	27,164	36,042	4,895	30,77

Tab. 12E. Analysis of the area occupied by *Calluna vulgaris* related to the vitality classes in the plot V at 2000.

vitality class	area of *P. mugo* [m²]	area of *C. vulgaris* [m²]	in under-growth [m²]	total of *P. mugo* [m²]	total of *C. vulgaris* [m²]	expected under-growth [m²]	difference [%]
+		1,736	0,004		1,740	0,294	-98,60
a		5,503	0,855		6,358	1,075	-20,49
b		9,662	3,091		12,752	2,157	43,29
c		11,354	3,009		14,362	2,429	23,84
d		2,793	2,326		5,120	0,866	168,65
total	24,544	31,048	9,285	33,829	40,333	6,822	36,10

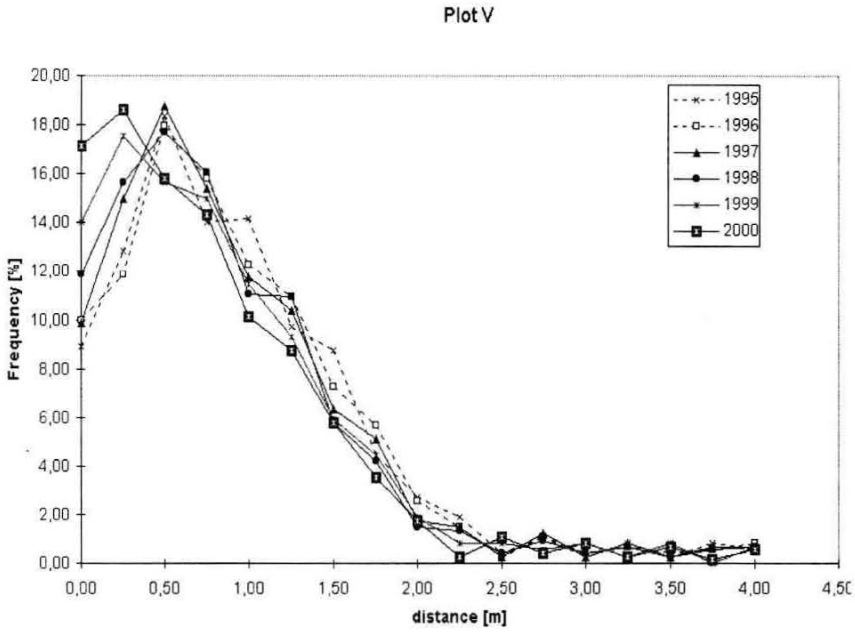


Fig. 18. Relative frequencies of distances of random point from the nearest dwarf pine shrub in the plot V during years 1995–2000.

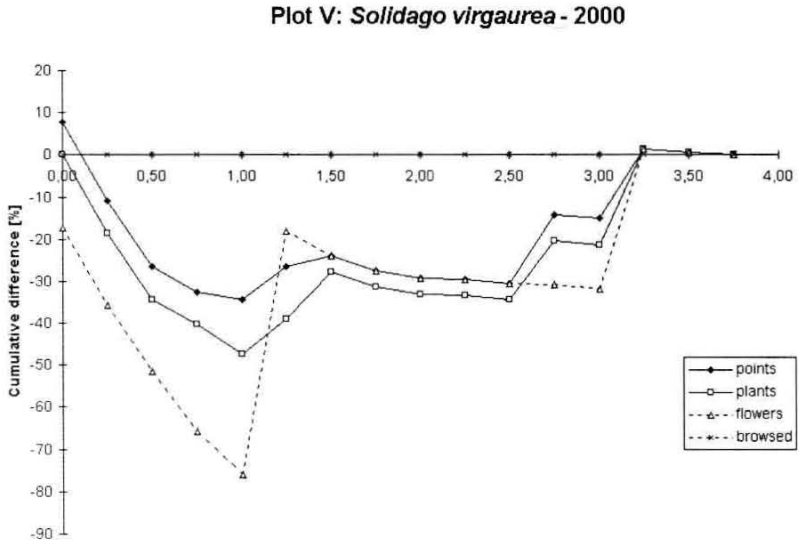


Fig. 19. Relative cumulative difference in the frequency of occurrence points, plants and flowering plants (flowers) by *Solidago virgaurea* in the plot V – example of the 2000 year. Horizontal axis - distance from the nearest dwarf pine shrub (in m).

Tab. 13A. Average transition matrix among different vitality classes of *Calluna vulgaris* in the plot V during period 1996/1997 to 1999/2000. Single value represents probability (in per-cent) within a part of plot without dwarf pine shrubs (gaps).

Transition matrix						
starting year	following year					
	a	b	c	d	+	without heather
a	33,8	29,1	28,9	3,4	1,6	3,2
b	31,6	34,0	28,9	1,0	1,5	3,0
c	10,6	26,4	45,7	12,1	2,8	2,3
d	3,7	29,6	60,8	2,6	2,0	1,2
+	12,9	12,5	14,6	1,8	56,9	1,2
without heather	24,1	33,1	33,0	7,0	2,7	–

Tab. 13B. Average transition matrix among different vitality classes of *Calluna vulgaris* in the plot V during period 1996/1997 to 1999/2000. Single value represents probability (in per-cent) within a part of plot under dwarf pine shrubs (undergrowth).

Transition matrix						
starting year	following year					
	a	b	c	d	+	without heather
a	19,2	15,3	49,0	10,4	1,0	5,0
b	20,4	42,7	28,1	2,8	0,0	6,0
c	6,2	17,3	49,4	22,0	0,0	5,0
d	3,7	12,0	45,7	35,4	0,0	3,3
+	2,3	11,4	26,3	14,3	32,0	13,7
without heather	20,3	28,2	37,6	13,8	0,2	–

Tab. 14A. χ^2-test of goodness of fit comparing occurrence point-pine (B) plant-pine (R), flowering plant-pine (K) and browsed plant-pine (O) distances with generated random point-pine distances, plot J. Number of degrees of freedom (n-2) is presented. Values of χ^2-test significant at level á < 0.1 % are bold, insignificant values at level á = 5.0 % are written in *italics*.

		Hieracium alpinum agg.				*Hypochoeris uniflora*				*Senecio fuchsii*			*Veratrum lobelianum*	
year	n-2	B	R	K	O	B	R	K	O	B	R	K	B	R
1996	9	21,3	**39,5**	**33,4**	**32,4**	**95,9**	**357,4**	**94,7**	**120,4**					
1997	9	25,8	**80,9**	*15,6*	18,4	**90,7**	**485,2**	**130,0**	**209,1**	**45,2**	**121,2**	**72,9**	*4,2*	*4,2*
1998	9	**140,7**	**743,4**	**39,1**	**39,8**	**158,4**	**729,9**	**36,6**	*12,6*	**60,9**	**121,9**	**76,2**	*5,6*	*10,3*
1999	9					**190,3**	**622,5**	21,3	**42,6**	**54,4**	**170,0**	**142,8**	*8,0*	*14,2*
2000	8	**33,2**	**488,0**	**180,0**	**132,0**	**178,0**	**765,0**	**218,3**	**216,7**	**35,4**	**148,4**	**129,4**	*8,1*	*13,8*

Tab. 14B. χ^2-test of goodness of fit - plot K (see Table 14A for details).

		Hieracium alpinum agg.				*Hypochoeris uniflora*				*Senecio fuchsii*		*Veratrum lobelianum*		*Pulsatila scherfelii*			
year	n-2	B	R	K	O	B	R	K	O	B	R	B	R	B	R	K	O
1996	8													**58,9**	**343,3**	15,8	16,5
1997	8													**91,2**	**497,4**	*6,0*	*8,0*
1998	8	**52,2**	**205,9**	**344,2**	**33,1**	**69,0**	**313,2**	**75,3**	**85,9**					**86,1**	**550,2**	*8,4*	*13,8*
1999	8									*6,1*	*5,0*	*11,4*	*11,4*				
2000	7	**66,8**	**167,0**	**150,5**	**47,9**	**63,7**	**308,1**	**77,9**	**100,8**	14,6	18,6	*10,5*	*10,5*				

Tab. 14C. χ^2-test of goodness of fit - plot N (see Table 14A for details).

		Hieracium alpinum agg.				*Hypochoeris uniflora*				*Senecio fuchsii*			*Veratrum lobelianum*	
year	n-2	B	R	K	O	B	R	K	O	B	R	K	B	R
1996	5					*3,7*	15,0	*10,6*	*6,0*					
1997	5					*2,1*	16,8	*3,4*	*4,1*	**127,5**	**291,0**	**137,4**	12,1	**43,3**
1998	5					*2,2*	**25,1**	*4,7*	12,3	**122,1**	**203,7**	**105,1**		
1999	5	*4,3*	*8,1*	*3,0*	*5,2*	*3,6*	19,8	*7,1*	13,7	**129,3**	**255,7**	**130,6**	15,5	**35,8**
2000	5	*6,9*	*6,8*	*3,2*	*2,9*	*1,8*	*6,9*	*7,7*	13,1				11,6	**29,7**

Tab. 14D. χ^2-test of goodness of fit - plot V (see Table 14A for details).

		Hieracium alpinum agg.				*Veratrum lobelianum*		*Solidago virgaurea*		
year	n-2	B	R	K	O	B	R	B	R	K
1999	14	**56,4**	**73,3**	*21,0*	*16,9*			**145,8**	**614,8**	**144,6**
2000	14	**43,4**	**64,3**	*13,5*	*23,3*	*22,8*	31,8	**204,9**	**856,4**	**135,7**

CONCLUSION

Research on localities in the dwarf pine altitudinal zone confirmed their extreme characteristics as regards environmental conditions and soil properties. The vegetation dynamics of older dwarf pine stands (plots P1–P4) was not accelerated very much during years 1981–1995. Substantially greater changes occurred in the years 1981–1987 than in 1987–1995. Vegetation dynamics was relatively highest on plots P3 and P4 in 1995–1998. On plot P3 it was a decrease in the cover of *Calluna vulgaris* and an increase in *Galium harcynicum* cover. On plot P4 the number of herb species markedly increased. Higher dynamics on plots with young dwarf pine plantings was recorded on relevés from subplots J1, N1 and K1. On subplot J1 it was an increasing cover of *Calamagrostis villosa*, *Solidago virgaurea* and *Veratrum album* subsp. *lobelianum*. Subplots N1 and K1 are influenced by progressive eutrophication and subsequent synanthropication from the road margins. It can be deduced that vegetation dynamics in dwarf pine stands depends on the level of air-pollution environmental load to a larger extent than on the increasing density of dwarf pine canopy.

The vitality of hawkweed (*Hieracium alpinum* agg.), pasque flower (*Pulsatilla scherfelii*), cat's-ear (*Hypochoeris uniflora*), heather (*Calluna vulgaris*) and other herbs was evaluated as affected by young plantings: the influence of dwarf pine shrubs on the distribution of all species under study was great. The ecotonal effect in the dwarf pine surroundings is constituted by belt of width about 100 cm (this distance roughly corresponds to dwarf pine height) and is species-specific. This zone often influences positively not only the number of plants of the species concerned but also its flowering intensity. Plant browsing is lower in the proximity of dwarf pine shrubs. This effect need not be obvious or it can be even opposite in some other herb species. Nevertheless, the most vital plants of hawkweed, pasque flower, cat's-ear and heather on the plots under study grow in the shrub proximity with distance up to 50 cm. Statistically significant correlation were calculated for hawkweed and pasque flower while the relations for cat's-ear and heather may be insignificant due to a low number of plants. The findings are influenced by the openness of dwarf pine stands on these plots, that means the plants do not suffer from the lack of light and benefit from a more favourable microclimate in the dwarf pine lee. It is an ecological lee-effect.

The tundra plant communities with dwarf pine plantation have a specific spatial structure with several different plant microcoenoses (in sense of MATĚJKA 1992) at least:

1. places under dwarf pine shrubs;
2. free gaps, which are equals to the original grass tundra community in the species structure;
3. an ecotone between first and second type.

There is necessary to study and discuss relation between two concepts: "plant microcoenose" (MATĚJKA 1992) and "niche". First one is a spatial structure unit, second one has been derived from coenose dynamics. Both approaches are full complementary, not self-contradictory.

Dwarf pine expansion is fast under favourable conditions. The area increment in younger stands was 6–38 % per annum, which corresponds to an annual increase in shrub diameter by ca. 3–18 %. The canopy of young dwarf pine plantings that ranged from 5.4 to 11.9 % in 1995 amounted to 16.9–30.0 % in 2000. The average annual area of the shrub increased by 2.84 % in older stands (plot P4 where the shrub growth is not limited by mutual contact). This accounts only for a 1.5 % increase in shrub diameter, but this value is very important because it indicates a reduction in small gaps between shrubs. Nevertheless, the portion of the open space on plots with older dwarf pine stands has been sufficiently high until now (45–90 %). These gaps are usually of very small size (mostly up to 2 m in diameter), therefore they do not behave like the open space. They may be insufficiently large for some species to survive.

It is suggested by the results that the management of dwarf pine stands should involve measures providing for sufficient spacing of shrubs from each other in order that the gaps for prosperous existence of the species under study (*Hieracium alpinum* agg., *Hypochoeris uniflora*, *Calluna vulgaris*, *Pulsatilla scherfelii*, *Arnica montana*, *Veratrum album* subsp. *lobelianum*) will be 4 m in diameter at least. The capacity of dwarf pine to expand should also be considered: it is highly variable in dependence on the spatial, age and genetic structure of stands and air-pollution environmental conditions. The above-mentioned minimum spacing of shrubs (4 m) cannot be generalised for the conditions of the dwarf pine forest altitudinal zone in the Giant Mts. because it is based on partial data acquired during six years of observations and on a limited number of plots. Hence further research on the optimisation of dwarf pine canopy in the species under study will be conducted to propose some regulatory measures in stands in the dwarf pine altitudinal zone on the basis of exact findings.

SOUHRN

Vegetační dynamika v ekosystémech kleče horské v Krkonoších

Významným a jedinečným ekosystémem Krkonoš je oblast nad horní hranicí lesa – klečový lesní vegetační stupeň – o rozloze 3470 ha. To dáno jeho specifickým charakterem, funkčním zařazením, posláním a genezí. Od roku 1992 je zde poukazováno na negativní vlivy vysokohorského zalesňování klečí horskou (*Pinus mugo* Turra) na mrazové půdní formy a s nimi spojené ekosystémy. Cílem práce proto bylo exaktní zhodnocení rozrůstající se kleče horské na vybrané druhy bylinného patra. K tomuto účelu byly v r. 1995 založeny 4 TVP a dále využity 4 další TVP (z r. 1981), tj. celkem 8 ploch v oblasti západních Krkonoš (na lokalitách Krkonoš, Harrachova louka, Pančavská louka, Labská louka). Na plochách byl kromě opakovaných fytocenologických záznamů sledován vývoj horizontální struktury kleče a rozmístění následujících druhů: *Hieracium alpinum* agg., *Hypochoeris uniflora, Calluna vulgaris, Pulsatilla scherfelii, Arnica montana, Veratrum album* subsp. *lobelianum a Senecio fuchsii*.

Z výsledků vyplívá, že ve starších porostech kleče (TVP P1–P4) nebyla v letech 1981–1995 zjištěna výrazně urychlená vegetační dynamika. K podstatně větším změnám došlo v letech 1981–1987 ve srovnání s lety 1987–1995. Relativně největší vegetační dynamika pak probíhala na plochách P3 a P4 v letech 1995–1998. Na ploše P3 to bylo způsobeno zejména poklesem pokryvnosti *Calluna vulgaris* a naopak nárůstem pokryvnosti *Galium harcynicum*. Na ploše P4 to bylo dáno výraznějším zvýšením počtu druhů (především antropofytů) o 14. Významnější dynamika na plochách s mladými výsadbami byla zaznamenána pouze u snímkovaného materiálu z dílčích ploch J1, N1 a K1. Na dílčí ploše J1 je to

dáno především narůstající pokryvností *Calamagrostis villosa, Solidago virgaurea* a *Veratrum album* subsp. *lobelianum*. Dílčí plochy N1 a K1 jsou značně ovlivňovány postupující eutrofizací a návaznou synantropizací od okrajů cest. Z toho lze usuzovat, že vegetační dynamika v porostech kleče je více závislá na intenzitě imisně ekologického zatížení, než na zvyšujícím se zápoji klečových porostů.

Z hodnocení vitality jestřábníku, koniklece, náholníku, vřesu i dalších bylin ve vztahu k mladým výsadbám kleče vyplynulo, že keře kleče značně ovlivňují rozmístění všech sledovaných druhů bylin. Ekotonální efekt v okolí keřů kleče má šíři okolo 100 cm (přibližně odpovídá výšce kleče), přičemž jeho vliv na jednotlivé druhy se projevuje specificky. Tato zóna často působí pozitivně nejen na počet rostlin daného druhu, ale též na intenzitu jeho kvetení, v těsné blízkosti kleče bývá též nižší okus rostlin. Takovýto efekt však nemusí být zřetelný nebo může být i opačný u některých jiných druhů bylin. Nicméně na sledovaných plochách se v těsné blízkosti keřů nebo do ca 50 cm vyskytují nejvitálnější jedinci jestřábníku, koniklece, náholníku a vřesu. Statisticky průkazné závislosti jsou pouze u jestřábníku a koniklece, u náholníku a vřesu jsou v důsledku malého počtu jedinců neprůkazné. Zjištěné poznatky jsou podmíněny skutečností, že porosty kleče jsou na sledovaných plochách řídké a sledované rostliny netrpí nedostatkem světla a naopak využívají příznivějšího mikroklimatu v závětří kleče. Lze tedy hovořit o efektu ekologického krytí.

Za příznivých podmínek se kleč poměrně rychle rozrůstá. V mladších porostech byl zjištěn plošný přírůst až 6–38 % ročně, což odpovídá ročnímu zvětšení průměru keřů o ca 3–18 %. Zápoj mladých výsadeb kleče, který se v r. 1995 pohyboval v rozmezí 5,4–11,9 % tak v r. 2000 dosáhl 16,9–32,0 %. U starších porostů bylo zjištěno průměrné roční plošné zvětšení keře o 2,84 % (plocha P4, kde není růst keře většinou limitován vzájemným dotykem). To odpovídá sice jen 1,5 % zvětšení průměru keře, je to však hodnota velmi významná vzhledem k zmenšení malých volných ploch mezi keři. Nicméně na plochách se staršími porosty kleče je dosud poměrně dostatečný podíl volné plochy (45–90 %). Velikost takto rozvolněných plošek však bývá velmi malá (většinou do 2 m v průměru) a proto i tato místa se nechovají jako volná plocha. Pro některé druhy však mohou být nedostatečně velká vzhledem k možnosti jejich přežívání.

Z výsledků vyplývá, že při managementu klečových porostů je potřebné zajistit především dostatečný odstup jednotlivých keřů tak, aby volné plochy pro zdárnou existenci sledovaných druhů (*Hieracium alpinum* agg., *Hypochoeris uniflora, Calluna vulgaris, Pulsatilla scherfelii, Arnica montana*, *Veratrum album* subsp. *lobelianum a Senecio fuchsii*) mezi nimi, měly průměr nejméně 4 m. Současně je potřebné počítat s určitou schopností kleče k rozrůstání se, která značně kolísá podle prostorové, věkové a genetické skladby porostů a imisně ekologických poměrů. Výše uvedenou minimální mez (rozestup mezi keři 4 m) není možné zcela zobecnit pro podmínky klečového lesního vegetačního stupně Krkonoš, jelikož vyplývá pouze z dílčích údajů v průběhu šesti let a na omezeném počtu ploch. Proto bude problematika optimalizace zápoje kleče u studovaných druhů předmětem dalšího výzkumu, aby bylo možno na základě exaktních poznatků přistoupit k určitým regulačním zásahům v porostech klečového lesního vegetačního stupně.

REFERENCES

Corley M. F. V., Crundwell A. C. L, Düll R., Hill M. O. et Smith A. J. E. 1981: Mosses of Europe and Azores: an annotated list of species, with synonyms from the recent literature. J. Bryol. 11: 609–689. Oxford.

Cressie N. A. C. 1991: Statistics for spatial data. John Wiley, New York etc.: 900 pp.

Hill M. O. 1979: DECORANA. A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Cornell Univ., Ithaca: 52 pp.

Jirásek J. 1996: Společenstva kosodřeviny (*Pinus mugo*) v České republice. Preslia 68: 1–12. Praha.

Kociánová M. et al. 1995: Vliv vysokohorského zalesňování na geobiocenózy arkto-alpinské tundry Krkonoš. Ms. Závěrečná zpráva grantu MŽP GA 1573/94. Správa KRNAP Vrchlabí: 36 pp.

KRAHULEC F., AGNEW A. D. Q., AGNEW S., WILLEMS H. J., eds. 1990: Spatial processes in plant communities. Proceedings of the Workshop held in Liblice,18–22 September 1989. Academia, Praha: 259 pp.

KUBÍČEK F., ŠOMŠÁK L., ŠIMONOVIČ V., MAJZLANOVÁ E., HÁBEROVÁ I., RYBÁRSKA V. 1983: Influence of tourism on dwarf pine (*Pinus mugo*) communities in the Vysoké Tatry mountains. Folia Geobot. Phytotax. 18: 363–387. Praha.

LOKVENC T. 1997: Historický přehled – zhodnocení vlivu antropogenních změn na porosty kleče horské. In: Stanovištní a porostní poměry kleče horské. (SOUČEK et al.). Ms. Dílčí zpráva. VÚLHM VS Opočno: 4–33.

MATĚJKA K. 1992: Some aspects of the theory of the ecosystem spatial structure. I. Theory. Ekológia ČSFR, 11: 369–377.

MORAVEC J. et al. 1995: Rostlinná společenstva České socialistické republiky a jejich ohrožení. Severočeskou přírodou, Litoměřice, 206 pp.

ORLÓCI L. 1978: Multivariate analysis in vegetation research. The Hague & Boston, 451 pp.

PAŠŤALKOVÁ H., VACEK S., MÁLKOVÁ J., MATĚJKA K., BASTL M. 1996: Vliv kleče horské na rostlinná společenstva v Krkonoších. In: VACEK, S. [ed.], Monitoring, výzkum a management ekosystémů na území KRNAP. Opočno, VÚLHM VS: 241–251.

PAŠŤALKOVÁ H., VACEK S., MATĚJKA K. 2001: Vegetační dynamika v ekosystémech klečového vegetačního stupně v Krkonoších. In: VIEWEGH, J. [ed.], Problematika lesnické typologie III. Kostelec nad Černými lesy, ČZU LF Praha: 53–62.

ROTHMALER W. et al. 1990: Exkursions flora. Kritischer Band. Berlin.