REGULATION OF *Pteridium aquilinum* (L.) K u h n WITH TRICLOPYR

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Abstract

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A three-year experiment was established on the pasture grassland with the high occurrence of poisonous species *Pteridium aquilinum* (L.) K u h n in forest and agricultural area of Strážovské vrchy Mts (altitude of 600 m). The vegetation cover of original, non-degraded pasture grassland was represented by species from the association *Festuco-Cynosuretum cristati typicum* R. T x. in B ü k k e r 1942. It consisted of 12 grass species (5 highly valuable ones), 5 species of leguminoses (2 highly valuable ones), and 25 other herbs (5 valuable species). The occurrence of mosses and empty places was 8%. 42 plant species were monitored (13 drug plants and 7 toxic species). The total grassland quality E_{GQ} was 69.61 which indicates that the grassland was valuable. The occurrence of dominant species *P. aquilinum*, which penetrated into the research abandoned pasture from the nearby forest, ranged from 14 to 19 plants per m^2. It represented the cover of 51–64% (mean 58%). Evaluation of species quality (E_{SQ}) was –29 (toxic species). It strongly influenced the total grassland quality E_{GQ} that reached the values from –4.39 to –23.76 (mean –16.31). The effective substance triclopyr (dose 40 ml per 1 liter of water) was used in the phase of *P. aquilinum's* fan development. In the first year, after the decline of *P. aquilinum*, the occurrence of mosses and empty places was high, from 15 to 26% (mean 19.26%); it raised during the second year but in the third year it nearly reached the first year level (from 14–28%, mean 23.13%). The quality of grassland was improved because of three cuttings in the course of three years. The total value E_{GQ} increased from –16.31 to 44.81 from 100-point scale.

Key words: semi-natural grassland, *Pteridium aquilinum*, invasive species, triclopyr, E_{SQ}, E_{GQ}

Introduction

In many parts of the world, especially in marginal areas, the share of the species *Pteridium aquilinum* is rising because of the influence of extensification. It covers vast areas in the UK (Moore, 1962; Williams, 1977; Taylor, 1986; Pakeman et al., 2000 and others). In 1984–1990 it encroached 600 km^2 at the altitude of 200–300 m. In 1990–1998 it covered 1.068 km^2 and its share is continuously rising (Haines-Young, 2000). Petrov (1988) and Petrov, Marrs

(2001) assert its relatively quick spreading in Bulgaria. Oikawa et al. (2004) record its occurrence in Japan. However, *P. aquilinum* also occurs in tropical areas (Taylor, 1986; Pakeman et al., 2000). In the last decade, after the reduction of cattle and sheep stock, we recorded the occurrence of invasive species *P. aquilinum* also in montain and submontain areas of Slovakia (Novák, 1994). It is spreading on uncultivated and unutilized pastures near to forest communities, mainly on the edge of forests. However, there has not been any mention of this species in feed literature published in the area of Slovakia. We have not recorded any increase of this species yet, but it is necessary to monitor it carefully because the upcoming extensification and abandonment of previously exploited grasslands may cause its invasion into many areas because it is spreading quickly by branched creeping rhizomes. The occurrence of the species causes a sharp reduction of the share of valuable grass species and leguminoses because of the influence of competitively strong species shade.

According to Deyl, Hisek (1973) and Martinovský et al. (1987), the above mentioned species belongs to the family *Polypodiaceae*. According to Futák (1966), Dostál and Červenka (1991) and Adler et al. (1994), it belongs to the family *Dennstaedtiaceae* and according to Marhold and Hindák (1998) to the family *Hypolepidaceae*. It has strong branched creeping rhizomes branching deeply under the ground; therefore it belongs to the tenacious species. A leaf grows out of the rhizome on the leaf stem. The plant is 2 m high and prefers poor and acid soils. Plant species purity is verified by beveled cutting of the stalk on the basis. A vascular bundle arrangement resembling a two-head eagle is found in the cross-section. *Pteridium aquilinum* is a very aggressive and invasive species because it spreads and propagates vegetatively by rhizomes and, because of its strong competitive ability, it occupies mainly extensive pasture areas. Klapp (1956) names this species "a migrating weed", which is able to suppress other species. It is a carcinogenic and toxic part of the grassland for cattle and sheep. It causes anaemia, leukaemia, and cancer, but it also influences allelopatically other plant species. According to Nösberger, Opitz von Boberfeld (1986), Galler (1989), it belongs to total weeds (poisonous) that have a harmful influence on the animal organism. Regal, Krajčovič (1963) does not mention this species in the list for quality evaluation. According to Klapp et al. (1953), its toxicity is -1 from 10-point scale. According to Novák (2004), its toxicity is -4 from 13-point scale. Because animals on the pasture do not graze this species up, it causes toxicosis only when it is mixed in the fresh or conservation fodder while feeding the animals in the stable. *P. aquilinum* contains enzyme thiaminase, which causes bitter taste in milk, butter and cheese, toxicosis and symptoms of poison in animals.

By now, most of the theses have dealt with the regulation of *P. aquilinum* by chemical way with asulam, e.g. Williams (1977), Jackson (1981), Petrov (1988), Pakeman et al.(1997), Le Duc et al. (2000), Petrov, Marrs (2001) and others. Some authors have used an effective substance glyphosate for the regulation, e.g. Martin (1976), Al-Jaff et al. (1982), Nösberger, Opitz von Boberfeld (1986), Voigtländer, Jacob (1987), Burril et al. (1989) and others. Other effective substances have also been used: amitrole-T, dicamba, dalapon, karbutilate, picloram, 4-CPA, chlorthiamid, dichlorbenil and others (Chavasse, Davenhill, 1973; Miller, Kidd, 1983; Nösberger, Opitz von Boberfeld, 1986; Voigtländer, Jacob, 1987) and others.

Some theses have dealt with the mechanic regulation by cutting, e.g. Lowday et al. (1983), Fenwick (1989), Pakeman et al. (2002). Other authors have dealt with the regulation by fire, e.g. Conard, Radosevich (1982) or biologically with insects (Lawton, 1986).

Material and methods

The three-year experiment was established on the pasture grassland with the occurrence of *Pteridium aquilinum* (L.) K u h n in the forest and agricultural area of Strážovské vrchy Mts (altitude of 600 m, inclination 8°). The average annual temperature was 7.5 °C, in vegetation period 11.2 °C; the total annual precipitation was 848 mm and during the vegetation 481 mm. The soil type was represented by extremely acid Cambisol with good or high store of potassium and very low store of nitrogen, phosphorus and leaf mold (Table 1.)

T a b l e 1. Chemical analyses of soil samples.

Depth (mm)	pH/KCl	P ($mg.kg^{-1}$)	K ($mg.kg^{-1}$)	$N\text{-}NO_3$ ($mg.kg^{-1}$)	$N\text{-}NH_4$ ($mg.kg^{-1}$)	C_{ox} (%)	Humus (%)
0–100	4.50	2.20	225	4.90	6.40	2.10	3.62
101–200	4.50	2.40	175	5.60	5.80	2.37	4.09

The vegetation cover of the original non-degraded pasture grassland on the site was represented by the species from the association *Festuco-Cynosuretum cristati typicum* R. T x. in B ü k k e r 1942 (Table 2). By gradual succession, the original grassland turned into the degraded one with the dominance of *Pteridium aquilinum* as the result of the abandonment of exploitation by grazing and deteriorating. *P. aquilinum* penetrated into the grassland from the nearby forest. The diagnosis and signaling preceded the regulation of weed species *P. aquilinum* on the horizontal transects of the grassland. Firstly, the regulation of weed species was realized chemically with triclopyr in doses of 40 and 80 ml per liter of water in four repetitions during the phase of leaf fan formation. It was evaluated according to the evaluation scale of European Weed Research Control – EWRC (Líška et al., 2002).

Floristic analyses were carried out by the method of real dominance in four repetitions on the transect 2x5 m in spring, summer and autumn. According to the floristic composition in % and forage values for every species, we calculated values of qualitative representation of particular species. There is a subsistence forage value from the 13 point scale (from - 4 to 8) for every plant species. 8 is given to the highly valuable species and values from -1 to -4 are given to the toxic ones. For the computation of the species and total quality of the ground cover the following equation is used

$$E_{SQ} = \frac{D.FV}{8}, \quad E_{GQ} = \frac{\sum (D.FV)}{8},$$

where E_{SQ} is evaluation of species quality and E_{GQ} is evaluation of grassland quality, D [%] is predominance of species in %, FV is forage value of species. Considering the floristic composition and forage values we calculated the Evaluation of Species Quality (E_{SQ}) and by their addition the total Evaluation of Grassland Quality (E_{GQ}). We used our own methodics for it (Novák, 2004).

Results

In Slovakia, *Pteridium aquilinum* (bracken) occurs mainly on uncultivated semi-natural pastures, which were previously regularly exploited. The occurrence of this species on ex-

tensive pasture grassland area in the forest and agricultural country causes its high weediness and therefore it becomes inaccessible for farming animals. When the grasslands are kept ungrazed, *P. aquilinum* penetrates into the disturbed and thinned turf and this continuously leads to the sharp reduction of the grassed areas of the pasture, which was not exploited by animals, and to the reduction of its share for agricultural exploitation.

The original association *Festuco-Cynosuretum cristati typicum* R. T x. in B ü k k er 1942 consisted of 12 grass species (5 highly valuable ones; FV = 7-8), 5 species of leguminoses (2 highly valuable ones), and 25 other herbs (5 valuable species; FV = 5-6). The occurrence of mosses and empty places was 8%. 42 plant species were monitored (13 drug plants and 7 toxic species). The total grassland quality E_{GQ} was 69.61 which indicates that the grassland was valuable (Table 2). The occurrence of dominant species *Pteridium aquilinum* on the research abandoned pasture together with shrub species (*Rosa canina, Crataegus* spp., *Prunus spinosa, Coryllus avellana, Rubus* spp.) and young trees (Betula spp., Picea abies, Pinus silvestris, Populus spp.) disturbed the original face of the landscape. The share of Pteridium aquilinum in the grassland (51–64%) and its forage value (–4) formed the toxic fodder for animals with E_{GQ} from –4.39 to –23.76 (Table 4). Although it reached high production of aboveground biomass, its productive ability was reduced and this kind of fodder was not of any agricultural importance for the animal nutrition. While grazing, the enclaves with the occurrence of *P. aquilinum* on the adjacent pasture sites remained unutilized during the vegetation. The plants shaded the lower layers of the original grassland by the formation of huge leaf fan. The occurrence of species was reduced by the secondary succession, empty places were formed and the grassland continuously degraded.

The results verify that both the revitalization of unwanted vegetation with the dominance of *P. aquilinum* and accompanying self-seeding wood plants on the abandoned pasture, and the application of effective substance triclopyr for the regulation of the species *P. aquilinum* have their reasons. There has not been any reference to the application of triclopyr for the regulation of *P. aquilinum* in the literature. To carry out the regulation, we set the point of harmfulness 1 plant per m^2 as Nösberger and Opitz von Boberfeld (1986), but also Voigtländer and Jacob (1987) assert. Its occurrence culminated way above this point, from 14 to 19 plants per m^2, in the transects of the experiment (Table 3). After the application, the effective substance triclopyr was translocated from the leaves into the roots of plants and caused typical auxin symptoms, which culminated after 3 weeks with browning and perishing of the whole plants. We compared the state of treated transects and we used 2 doses for that: 40 $ml.l^{-1}$ of water 80 $ml.l^{-1}$ of water in 4 repetitions. The effect of herbicide was evaluated according to the EWCR scale (Table 3). The living weeds did not appear until the end of vegetation when the dose of 40 $ml.l^{-1}$ of water was applied. When the fytotoxicity was evaluated, *Trifolium repens* was damaged in some cases, mainly when the dose of 80 $ml.l^{-1}$ of water was applied. The damage was caused by high dose of water (80 $ml.l^{-1}$). Effective substance did not damage the grasses. We assert that *Pteridium aquilinum* was successfully eliminated from the monitored transects during the chemical regulation. The grassland was exploited by cutting only after the chemical regulation, the elimination of browned rests from the grassland and after the 28 days protective period.

T a b l e 2. Floristic and qualitative evaluation of the original association *Festuco-Cynosuretum cristati typicum* R. T x. in B ü k k e r 1942.

Floristic groups	Species	FV	%D	E_{SQ}
Grasses	*Agrostis capillaris* L.	5	3	1.87
	Anthoxanthum odoratum L.	3	+	–
	Cynosurus cristatus L.	6/5	8	6.00
	Dactylis glomerata L.	7	4	3.50
	Deschampsia caespitosa (L.) P. B e a u v.	3/1	+	–
	Festuca pratensis H u d s.	8	4	4.00
	Festuca rubra L. *ssp. rubra*	5/3	5	3.12
	Lolium perenne L.	8	7	7.00
	Phleum pratense L.	8	2	2.00
	Poa pratensis L.	8	5	5.00
	Poa trivialis L.	6/4	3	2.25
	Trisetum flavescens (L.) P. B e a u v.	6/4	6	4.50
Leguminoses	*Lotus corniculatus* L.	7/5	1	0.87
	Trifolium campestre S c h r e b.	4	+	–
	Trifolium pratense L. *	7	2	1.75
	Trifolium repens L.	8	13	13.00
	Vicia sepium L.	6/5	1	0.75
Other herbs	*Achillea millefolium* L. *	5/3	3	2.25
	Alchemilla vulgaris L.	5	2	1.25
	Anthriscus sylvestris L. H o f f m.	4	1	0.50
	Bellis perennis L. *	2	+	–
	Campanula patula L.	3	+	–
	Carum carvi L. *	5/3	2	1.25
	Cirsium arvense L.	0	+	–
	Colchicum autumnale L. *	-4	+	–
	Crepis biennis L.	4	+	–
	Galium mollugo L.	3/2	+	–
	Euphrasia roskoviana H a y n e *	-2	1	–0.25
	Glechoma hederacea L. *	-2	+	–
	Hypericum maculatum G r a n t z	-1	1	–0.12
	Jacea pratensis L a m.	3/2	+	–
	Leucanthemum vulgare L a m.	2	1	1.00
	Luzula sylvatica (H u d s.) G a u d i n	2/1	1	1.00
	Plantago lanceolata L. *	6/4	1	0.75
	Plantago major L.	2	1	1.00
	Potentilla erecta (L.) R a e u s c h. *	1!	1	0.12
	Prunella vulgaris L. *	2	1	1.00
	Ranunculus acris L. *	-3	1	–0.37
	Ranunculus repens L.	-1	2	–0.25
	Taraxacum officinale W e b e r *	5/3	7	4.37
	Tithymalus cyparissias (L.) S c o p.	-3	+	–
	Veronica chamaedrys L.	2	2	0.50
Pteridophyte ferns	–	–	–	–
Mosses and empty places			8	
E_{GQ} in total				69.61

Notes: * – drug plants; + – traces in the grassland (low rate); value behind the slash at the occurrence above 10 %; ! – occurrence above 3 % deteriorates forage value (FV)

We recommend grazing on pastures during the process of production.

The species with under- and aboveground protuberances predominated on all research sites (in 4 repetitions) in the second and third year. They occupied empty places after the subsided species *P. aquilinum* (Figs 1–6). Predominated grasses were *Agrostis capillaris, Festuca rubra* and *Poa trivialis*. Considering the share of leguminoses, *Trifolium repens* predominated. Other herbs, e.g. *Glechoma hederacea, Potentilla erecta* a *Ranunculus repens* also contributed to the covering of empty places in the sward. The above mentioned herbs did not contribute to the improving of grassland quality because of their low forage value and toxicosis. In the first year, the occurrence of mosses and empty places ranged from 15 to 26% (mean 19.26%); it increased in the second year after the reduction of *Pteridium aqulinum*, but in the third year it nearly reached the first year level; which is still a high rate (from 14% to 28%, mean 23.13%).

T a b l e 3. Evaluation of triclopyr effect according to EWRC scale.

Pteridium aqulinum before treatment		Treatment of the grassland				Evaluation					
						of effective substance applied on *Pteridium aqulinum* after treatment			of phytotoxicity effect on the grassland		
Transect	Cover (pc.m^{-2})	Growing phase	Name of effective substance	Dose: effective substance (ml)	Dose: water (l)	(%)	Points	Effect in words	(%)	Points	In words
1	18	Full plant's fan development	triclopyr	40	1	100	1	excellent*	0	1	without damage
2	14	Full plant's fan development	triclopyr	40	1	100	1	excellent*	0	1	without damage
3	17	Full plant's fan development	triclopyr	40	1	100	1	excellent*	2.50	2	insignificant damage**
4	15	Full plant's fan development	triclopyr	40	1	100	1	excellent*	0	1	without damage
5	16	Full plant's fan development	triclopyr	80	1	100	1	excellent*	2.50	2	insignificant damage**
6	15	Full plant's fan development	triclopyr	80	1	100	1	excellent*	10	4	majority damaged**
7	17	Full plant's fan development	triclopyr	80	1	100	1	excellent*	2.50	2	insignificant damage**
8	19	Full plant's fan development	triclopyr	80	1	100	1	excellent*	5	3	rare damage**

Notes: * – without living plant *Pteridium aquilinum*, ** – damage of leaves *Trifolium repens*

T a b l e 4. Total evaluation of grassland in the floristic groups in the course of three years.

Floristic groups	% share/ E_{GQ}	Year		
		1	2	3
Grasses	%	13.12	35.50	39.75
	E_{GQ}	8.14	23.17	23.29
Leguminoses	%	2.50	13.12	16.00
	E_{GQ}	1.81	12.47	15.12
Other herbs	%	7.12	17.75	21.12
	E_{GQ}	2.74	5.34	6.40
Pteridophyte ferns – *Pteridium aquilinum*	%	58.00	0.12	–
	E_{SQ}	–29.00	-0.48	–
Grassland in total:	%	80.74	66.49	76.87
	E_{GQ} :	–16.31	40.50	44.81
Mosses and empty places:	%	19.26	33.51	23.13

Notes: E_{GQ} – evaluation of grassland quality, E_{SQ} – evaluation of species quality

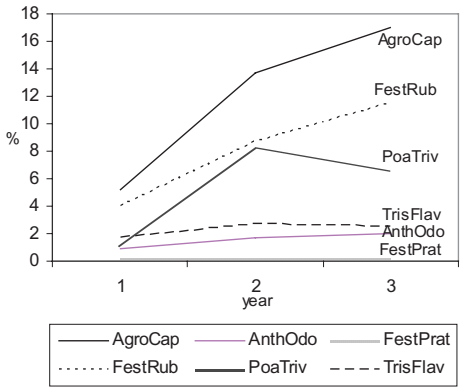

Fig. 1. Floristic representation of individual grasses in years.

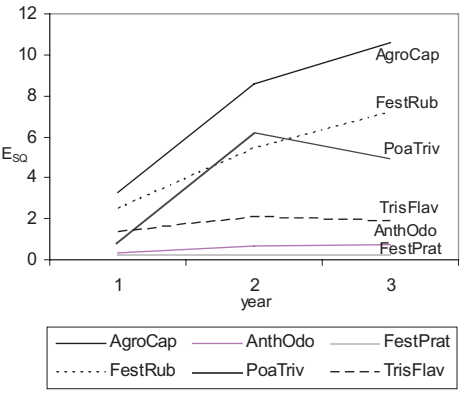

Fig. 2. Evaluation of individual grass species (E_{SQ}) in years.

AgroCap – *Agrostis capillaris*, AnthOdo – *Anthoxanthum odoratum*, FestPrat – *Festuca pratensis*, FestRub – *Festuca rubra*, PoaTriv – *Poa trivialis*, TrisFlav – *Trisetum flavescens* E_{SQ} – evaluation of species quality

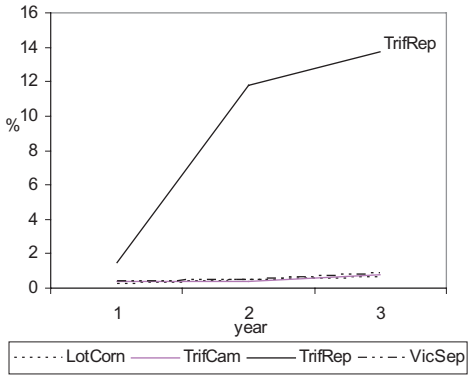

Fig. 3. Floristic representation of individual leguminoses in years.

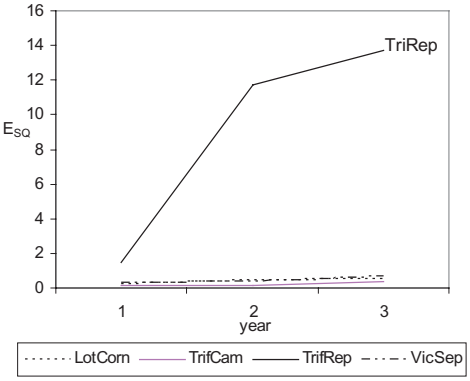

Fig. 4. Evaluation of individual leguminous species (E_{SQ}) in years.

LotCorn – *Lotus corniculatus*, TrifCam – *Trifolium campestre*, TrifRep – *Trifolium repens,* VicSep – *Vicia sepium*
E_{SQ} – evaluation of species quality

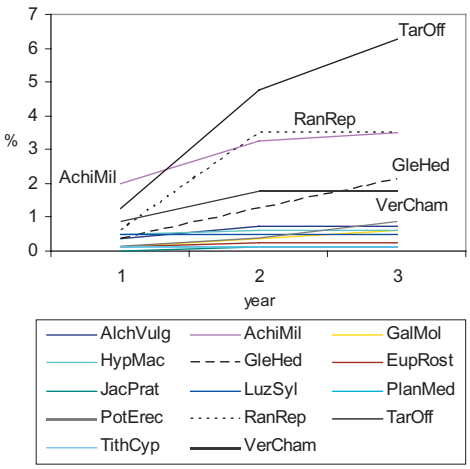

Fig. 5. Floristic representation of individual other herbs in years.

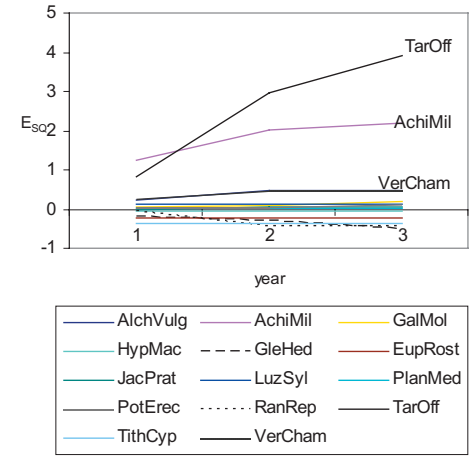

Fig. 6. Evaluation of individual other herbs species (E_{SQ}) in years.

AlchVulg – *Alchemilla vulgaris*, AchiMil – *Achillea millefolium*, GalMol – *Galium mollugo*, HypMac – *Hypericum maculatum*, GleHed – *Glechoma hederacea*, EupRost – *Euphrasia rostkoviana*, JacPrat – *Jacea pratensis*, LuzSyl – *Luzula sylvatica*, PlanMed – *Plantago media*, PotErec – *Potentilla erecta*, RanRep – *Ranunculus repens*, TarOff – *Taraxacum officinale*, TithCyp – *Tithymalus cyparissias*, VerCham – *Veronica chamaedrys*
E_{SQ} – evaluation of species quality

Discussion

The spreading of *Pteridium aqulinum* on the semi-natural grassland through the rhizome and spore propagation coincides with the results of the research carried out by Marrs et al. (2000). Moore (1962), Williams (1977), Taylor (1986), Marrs (1987), Pakeman et al. (2000) and others in the UK state that *P. aqulinum* did not occur on the sites together with *Calluna spp*. We obtained similar results as the authors mentioned above. Mitschell et al. (1997) declare the occurrence of *Pteridium aquilinum* on the sites together with *Betula spp.,* Petrov and Marrs (2001) assert that *Pteridium aquilinum* occurred together with *Achillea millefolium*, and together with *Agrostis capillaris* and *Festuca rubra* (Birch, 2002) which is similar to the situation in Slovakia. According to Oikawa et al. (2004), *Anthoxanthum odoratum* was the only accompanying species in Japan, which was identical to the occurrence in Slovakia. The results show that the point of harmfulness 1 plant per m^2 corresponds to the results obtained by Nösberger and Opitz von Boberfeld (1986) but also by Voigtländer and Jacob (1987). We recorded the occurrence from 14 to 19 plants per m^2 but Petrov and Marrs (2001) state 25 plants per m^2 at the altitude of 550 m.

The spreading of *Pteridium aquilinum* in Slovakia coincides with the results of the research carried out by Marrs et al. (2000). As the authors assert, *P. aquilinum* influences succession both through invasion into early-successional communities (1) and through controlling the invasion of later-successional species (2). In the first case, *P. aquilinum* colonizes semi-natural habitats either through the spore – prothallus pathway or by rhizome invasion from adjoining land. The colonization through spore – prothallus pathway is less common than the one that comes from rhizome invasion. In the second case, it is known that a tree canopy can suppress *P. aquilinum*. Therefore it is reasonable to expect a grassland – bracken – woodland succession.

Six species were presented in the floristic group of grasses. Considering the floristic composition, we evaluated the percentage share and quality of individual species E_{SQ}. Except of highly valuable species *Festuca pratensis* and less valuable species *Anthoxanthum odoratum*, both, the percentage and qualitative increase in other valuable species, were observed. The cover and quality of *Poa trivialis* and *Trisetum flavescens* increased only in the first two years and in the case of *Agrostis capillaris* (up to 17%) and *Festuca rubra* (up to 11.50%) in the course of three years. *Poa trivialis* together with its aboveground protuberances belonged to the unstable species but with its higher occurrence it contributed to the formation of sward. In the third year its share declined (Figs 1, 2). The total evaluation shows that the grasses contributed to the increase of cover from 13.12 to 39.75% and of E_{GQ} from 8.14 to 23.29 from 100-point scale (Table 4).

Floristic group of leguminoses consisted of four species. The highly valuable species *Trifolium repens* (Figs 3, 4) significantly contributed to the increase of percentage share (13.75%) and quality. A low share of the valuable species *Lotus corniculatus* particularly contributed to the improving of grassland. Other valuable species were presented only in minimum amount. In comparison with the first year, the share of leguminoses increased in the third year from 2.50 to 16% because of the influence of stand thinning after three cuttings. The evaluation of grassland quality increased as well (the increase of E_{GQ} from 1.81 to 15.12).

Fourteen species were presented in the floristic group of other herbs. Three valuable species particularly enriched the grassland: *Alchemilla vulgaris, Achillea millefolium* and *Taraxacum officinale*. A growing tendency of percentage share in the course of three years was observed especially in the species *Taraxacum officinale* (up to 6.25%) and *Achillea millefolium* (up to 3.50%). Apart from highly poisonous species *Pteridium aquilinum* which was removed from the grassland in the first year, another less poisonous species, e.g. *Hypericum maculatum, Glechoma hederacea, Ranunculus repens,* highly poisonous species *Tithymalus cyparissias* and a semi-parasitic plant *Euphrasia rostkoviana* were presented in this group. *Ranunculus repens* occurred up to 3.50%, other herbs up to 2% and their minus value decreased the quality of the grassland (Figs 5, 6). Other herbs, which belonged to the worthless and less valuable species contributed especially to the increase of species diversity of the grassland.

The value E_{GQ} increased significantly from -16.31 to 44.81 from 100-point scale in the course of years. However, the grassland ranked among the less valuable ones because highly valuable grasses and leguminoses were not presented in the floristic composition. After the regulation of *Pteridium aquilinum*, a high share of mosses and empty places was observed even in the third year. The low forage value or toxicity of some species contributed to the deteriorating of fodder. It is suggested to renovate degraded grassland by non-tillage additional sowing after the application of triclopyr. Highly valuable grasses and leguminoses will be added into the mixture. Therefore the empty places will be filled in and the production ability of pasture will be improved as well.

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