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SOIL CHARACTERISTICS OF SUBMONTANE BEECH FORESTS AND SPRUCE MONOCULTURES IN TURČIANSKA KOTLINA BASIN

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Abstract

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This paper deals with soil conditions in spruce monoculture of *Oxalido-culti-Picetum* association and in natural submontane beech forest of *Dentario bulbiferae-Fagetum*, which are spread in forest park Bôr (Turčianska kotlina basin). A comparison of macromorphologic, stratigraphic and chemical characteristics of two parallel soil probes shows data on spruce monoculture influence on thickness of litter horizon, consistence, oxidative-reductive processes, soil reaction and content of Ca, Mg, K, Na, Mn, Fe, Zn and P cations.
In spruce monoculture the organogenic horizon (Oo) has 4-times lower thickness, diminished soil already in ochric (Aoq) horizon, gleyic cambic horizon (Bv), its soil reaction is more acid by 11.11–33.15% and has lower content of calcium by 48-67.9%, potassium by 55.33 and 70%, zinc by 26.91–78.25% and phosphorus by 10.36–96%. Spruce forests accumulate in cambic, transitional and substrate (Bvg, Blc and Cg) horizons more magnesium by 22–52.93%, sodium in ochric (Ao) and cambic (Bv, Bvg) horizon by 2.94–10%, manganese by 16.19% and iron by 58.89%. Phosphorus translocation is more intensive in spruce monocultures by 8.96%.

Key words: soils, cultural spruce stands, natural submontane beech forests

Introduction

Floristics composition of forests in Turčianska kotlina basin was shaped by long-term process in postglacial period. It was changed in dependence on natural characteristics and in historic period under the influence of anthropic factors, particularly. Intensive cultivation of the area is documentated in writing 600 years ago, when Mossons barons then (Révay and Prónay) started to use Turiec land. According to Forest Management Plan from 1925, the spruce was usually planted. Nowadays are spruce monocultures spread on approximately two thirds of forest land resources and one third represents pine monocultures. Natural forests communities are only in Diviacky háj grove in Veľký les forest and in forest park Bôr.

Scientific literature contains information on structure, floristics composition, etc. of coniferous tree species monocultures. There are continuous information on their influence on soil environment of natural Slovak forests and they came predominantly from 1960s–1980s (example Šály, 1965; Šály, Obr, 1965; Ambroz, 1968, 1973; Bublinec, 1974; Klimo, 1981; Prudič, 1971; Fajmonová, 1987, etc.). Recently papers include Bublinec, 1994; Kukla, 1994, 1995, 1996, 1997; Kontriš et al., 2008a, b; Benčaťová et al., 2008. This contribution is a follow-up to a research of mentioned authors and its aim is a comparison of soil characteristics of the natural beech forests (*Dentario bulbiferae-Fagetum*) and spruce monocultures (*Oxalido-culti-Piceetum excelsae*).

Material and methods

Site description

According to geomorphologic point of view (Mazúr, Lukniš, 1986) Turčianska kotlina basin belongs to Fatransko-Tatranská region. It has character of high basin between mountains from the Vnútorné Západné Karpaty (Inner Western Carpathians) subprovince. It is created from rock mostly from Neogene, Dacian-Romanian, Pannonian, Late Badenian-Sarmatian and Eggenburgerian.

Rocks of Late Cretaceous and Paleogene of the inter Carpathians are only in the northeast part (Biely et al., 2002). The basin has longwise shape and it is sloping from the north to the south. The highest point of the basin is Vtáčí vŕšok Mt. (666.8 m a.s.l.), the lowest one (382 m a.s.l.) is Vrútky. Cambisols are original in the south and north part of basin. Illimerizated and gleyic soils are spread only in central part of basin. On the alluvial plain of Turiec are most common Fluvisols and Mollic Fluvisols, Planosols and Stagnosols and Albic Luvisols are rarer (Šály, Šurina, 2002). Central part of Turčianska kotlina basin has moderately warm, humid, valley-basin climate with cool to cold winter. Total precipitation is 600–700 mm per year (Faško, Šťastný, 2000). Natural forest communities were represent mostly by oak-hombeam-woods with lime-tree, oak woods with *Potentilla alba*, elm floodplain forests (hardwood alluvial forests) and alder floodplain forests. Oak woods with *Quercus cerris* and beech forests were only rare (Maglocký, 2002).

Methodology of pedological and phytocoenological research

Pedological and phytocoenological research was done on 24th October 2007 in the forest park Bôr. Relevés were done on 21st July 2007 according to Zűrich-Montpellier School (Braun-Blanquet, 1964 in Moravec 1994). The forest park is situated eastwards from village Dolná Štubňa at the foot of the Hriadky hill. Soil probes were dug in the natural beech stand and in the spruce monoculture. The distance between soil probes was approximately 100 m. Stratigraphic and morphologic characteristics were described according to visual contact from fresh soil. Soil reaction (in H_2O and KCl) was measured by potenciometry. A rate between solutions and soil was 1:2.5. Chemical analyses were done according to obligatory methods Mehlich II (Kobza et al., 1999), soil nomenclature is according to Morphogenetic Soil Classification System of Slovakia (Šály et al., 2000) Syntaxonomic nomenclature is in the sense of Mucina, Maglocký (1985) and nomenclature of plant species according to Marhold, Hindák (1998).

Results and discussion

Soils of both phytocoenoses arose on pyroxene and hornblende pyroxene or basaltic and pyroxene andesites. Soil probe in beech stand is deeper by 7 cm. Differences in depth are caused mainly by various thickness of B/C horizons. Marked variation is in the thickness of litter horizon that is 4-times bigger in beech forest. Similar situation is in thickness variation of subhorizon of litter horizon. These differences are not most likely caused only by humification processes and various necromass quality but also by the length of litter accumulation period as well as a buffer ability of natural beech forest soil with the first generation of spruce. There is also variation in consistence and oxidation-reduction processes. Soil is slightly compacted in ochric (Aoq) horizon in monoculture of spruce. In contrast, the same consistence is in the cambic (Bv) horizon in natural beech forests. In the soil profile of spruce monoculture, oxidation-reduction process starts in a form of rust spots or rust colour of cambic (Bvq) horizon. Only soil in substrate horizon (Cg) is rust in natural submontane beech forest. Gleying process is not caused only by spruce influence but most likely by hydro-pedologic processes, physical characteristics, etc.

Stratigraphic and macromorphologic characteristics of soil probe No. 1

Locality: Dolná Štubňa, V – Hriadky (wetlands), alt. 700 m, exp. NW, slope 10°, regular shape of relief, iluvial, Cambisol Modal, ass. *Dentario bulbiferae-Fagetum*. Coverage E_3 85%, E_2 5%, E_1 75%.

E_3: *Fagus sylvatica* 3, *Tilia cordata* 2, *Picea abies* 1, *Quercus dalechampii* 1

E_2: *Acer pseudoplatanus* 1, *Tilia cordata* 1, *Fagus sylvatica* +, *Ligustrum vulgare* +, *Fraxinus excelsior* +

E_1: *Oxalis acetosella* 2, *Melica nutans* 2, *Carex digitata* 2, *Viola reichenbachiana* 2, *Ajuga reptans* 1, *Brachypodium sylvaticum* 1, *Dryopteris filix-mas* 1, *Galim schultesii* 1, *G. odoratum* 1, *Acer pseudoplatanus* 1, *Luzula luzuloides* 1, *L. pilosa* +, *Fraxinus excelsior* +, *Primula elatior* +, *Tithymalus amygdaloides* +, *Pulmonaria officinalis* +

Ool horizon: 4 + 11 cm;	non-decomposed leaves, herbs and twigs
Oof horizon: 1 + 4 cm;	partially decomposed biomass
Ooh horizon: 0 + 1 cm;	dark grey decomposed biomass
Ao horizon: 0–11 cm;	dark greyish brown, mellow, freshly moist soil, contin. passing into an other horizon, on the surface rarely skelet, 2–3 up to 40 cm
Bv horizon: 11–22 cm;	greyish brown, slightly compacted, moist soil, skelet average 2 cm up to 10%
B/C horizon: 22–44 cm;	greyish brown, granular, moist soil, skelet 60%.
Cg horizon: 44 cm and more;	compact layer of skelet, space filled with rust soil.

Stratigraphic and macromorphologic characteristics of soil probe No. 2

Locality: Dolná Štubňa, V – Hriadky (wetlands), approx. 100 m eastward from soil probe no. 1, alt. 700 m, exp. NW, slope 10°, regular shape of relief, illuvial, Cambisol Pseudogley, ass: *Oxalido-culti-Picetum*. Coverage E_3 90%, E_2 20%, E_1 90%.

E_3: *Picea abies* 5, *Pinus sylvestris* 1, *Quercus dalechampii* 1, *Tilia cordata* 1, *Ulmus glabra* +
E_2: *Tilia cordata* 2, *Acer pseudoplatanus* 1
E_1: *Oxalis acetosella* 5, *Viola sylvatica* 2, *Galium odoratum* 2, *Carex digitata* 1, *Tithymalus amygdaloides* 1, *Melica nutans* 1, *Geranium robertianum* 1, *Lysimachia nummularia* 1, *Carex digitata* 1, *Brachypodium sylvaticum* 1, *Majanthemum bifolium* 1, *Carex sylvatica* 1, *Acer pseudoplatanus* 1, *Mycelis muralis* +, *Ajuga reptans* +, *Sanicula europaea* +, *Primula elatior* +, *Rubus hirtus* +, *Hieracium sylvaticum* +, *Impatiens parviflora* +, *Fragaria vesca* +, *Luzula pilosa* +, *Athyrium filix-femina* +, *Dryopteris filix-mas* +, *Hieracium racemosum* +, *Sorbus aucuparia* +, *Quercus dalechampii*+, *Picea abies* +, *Abies alba* +

Ool horizon: 1 + 3 cm;	needles, twigs, rarely leaves
Oof horizon: 0.0 + 1 cm;	partially decomposed biomass
Ooh horizon: 0 + 0.5 cm;	greyish brown, decomposed biomass
Aoq horizon: 0–10 cm;	greyish brown, slightly moist and compacted, sandy – loam, progressively passing into another horizon
Bvg horizon: 10–22 cm;	brown, granulated with rarely rusty spots
B/Cg horizon: 22–37 cm;	brown, granulated with ochre and rusty spots, 15% of skelet up to 5 cm.
Cg horizon: 37 and more;	rusty-brown, compacted soil within the skelet with dimension 50 cm.

T a b l e 1. Chemical characteristics of soil probe in submontane beech stand (Ooh – the lowest litter subhorizon, Ao – ochric, Bv – cambic, B/C – cambic-substrate horizon, Cg – substrate marbled horizon).

Horizon	Thickness (cm)	pH (H_2O)	pH (KCl)	Ca	Mg	K	Na	Mn	Fe	Zn	P
				(mg.1000g^{-1})							
Ooh	1	5.40	4.70	3933.67	441.70	591.25	39.95	184.94	6.63	8.14	34.6
Ao	11	5.18	4.52	3182.65	311.78	371.47	22.96	136.87	8.00	6.07	28.2
Bv	11	5.20	4.16	2355.98	221.53	342.23	21.34	142.24	17.05	1.99	20.8
B/C	22	5.40	4.30	2542.78	407.02	87.46	28.28	77.04	23.27	–	18.2
Cg	10<	–	–	–	–	–	–	–	–	–	–

T a b l e 2. Chemical characteristics of soil probe in secondary spruce stand (Ooh – the lowest litter subhorizon, Aoq – ochric silicate, Bvg – cambic marbled horizon, B/Cg – cambic-substrate and marbled horizon, Cg – substrate marbled horizon).

Horizon	Thickness (cm)	pH (H_2O)	pH (KCl)	Ca	Mg	K	Na	Mn	Fe	Zn	P
				(mg.1000g^{-1})							
Ooh	0.5	6.39	5.69	2045.06	324.21	242.57	29.01	333.75	28.78	7.51	36.8
Aoq	10	4.77	3.75	841.42	218.33	80.58	22.63	141.85	25.45	1.32	12.7
Bvg	12	4.91	3.86	754.37	252.28	59.02	23.7	119.73	30.07	0.04	14.5
B/Cg	15	5.27	4.26	1269.41	445.97	72.83	31.41	126.42	34.60	–	16.8
Cg	10<	5.53	4.40	1015.39	427.80	62.15	31.16	84.83	47.77	–	12.5

T a b l e 3. An average sample of Ao horizon in submontane beech stand (Ao – ochric horizon).

Horizon	Thickness (cm)	pH (H_2O)	pH (KCl)	Ca	Mg	K	Na	Mn	Fe	Zn	P
				(mg.1000g^{-1})							
Ao	10	5.14	4.23	3168.66	291.25	268.89	20.35	124.81	15.87	6.13	20.3

T a b l e 4. An average sample of Aoq horizon in secondary spruce stand (Aoq – orchic silicate horizon).

Horizon	Thickness (cm)	pH (H_2O)	pH (KCl)	Ca	Mg	K	Na	Mn	Fe	Zn	P
				(mg.1000g^{-1})							
Aoq	10	6.47	3.76	1259.26	137.08	120.09	19.75	188.30	12.97	4.48	18.2

T a b l e 5. Differences in chemical elements contain between submontane beech stands and spruce monocultures (mg.1000g^{-1} and %), + = a value in favour of submontane beech stands; – = a value in favour of spruce monocultures. (Ooh – the lowest litter subhorizon, Ao – ochric, Bv – cambic horizon, B/C – cambic-substrate horizon).

Soil horizon		pH (H_2O)	pH (KCl)	Ca	Mg	K	Na	Mn	Fe	Zn	P
Ooh	mg	-0.99	-0.99	+1888.60	+117.5	+348.7	+10.94	-148.8	-22.15	+0.63	-2.2
	%	15.50	16.20	48.00	26.59	58.97	27.38	44.58	76.96	7.73	5.97
Ao	mg	+0.41	+0.77	+2341.20	+93.50	+290.9	+0.33	-4.98	-17.45	+4.75	+15.5
	%	7.90	17.00	73.56	29.97	78.3	1.43	3.51	68.56	78.25	96.45
Bv	mg	+0.29	+0.30	+1601.60	-30.70	+283.2	-2.36	22.51	-13.02	+1.95	+6.3
	%	5.60	7.20	67.98	12.18	82.75	9.95	15.82	43.29	54.96	30.28
B/C	mg	+0.13	-0.10	+1527.40	-38.90	+14.6	-3.13	-49.3	-11.33	–	+1.4
	%	2.40	2.33	60.06	8.73	16.72	9.96	39.06	32.74	–	7.96
Average sample											
Ao	mg	-1.33	+0.47	+1909.40	+154.2	+148.8	+0.6	-63.5	+2.9	+1.65	+2.1
	%	20.55	11.10	60.25	52.93	55.33	2.94	33.71	18.27	26.91	1.34

Morphologic characteristics of soil probes show that natural submontane beech stands are spread on Cambisols Modal and secondary spruce stands on Cambisols Pseudogley. Spruce stands planted on submontane beech stands biotopes markedly influence both kinds of soil reaction. Soil reaction is the highest in Ooh horizon (pH 5.4 and 6.34 respectively) in both communities. In comparison to beech forests, spruce ones have more alkali exchange acidity by 16.2% and actual soil acidity by 15.5%. Spruce forests have decisive influence in markedly acidification (by 1.62 pH(H_2O)), particularly in Aoq and Bvg horizons. Similar character has also pH (KCl) which is in mentioned horizons more acid by 33.15% in comparison with Ooh horizon. pH value in H_2O of an average Ao horizon sample shows negative influence of spruce on soil reaction because its pH (H_2O) is more acid by 20.55% and pH (KCl) by 11.11%.

Analyses of elements (Tables 1–5) show negative influence of secondary spruce forests on Ca^{2+} cations in all soil horizons. The biggest differences (2341.23 mg.1000g^{-1}) are in Aoq horizon (73.56%). In other horizons is his rate lower by 1888.6–1909.4 mg.1000g^{-1} (from 48 to 67.9%) in spruce forests. Similar as in the case of soil reaction, also Ca content is lower in Aoq and Bvq horizon 1290.7 mg.1000g^{-1} (by 63%) in comparison to covering humified subhorizon. In the average sample from Ao horizon is Ca rate lower by 1909 mg.1000g^{-1} (60.25%).

Spruce monocultures have positive effect on Mg content in bottom Bvq, B/C and Cg horizons. As Table 5 shows, also in A horizon of spruce forest is its content higher by 52.93% in compare to beech stands. Because of higher Mg content in Ooh subhorizon (by 22–36%) in compare to Boq and Bvq as well as higher magnesium content in transition and substrate horizon than in litter subhorizon (by 27.3%) is possible to suppose that a translocation process is connected with soil reaction and hydro-pedological regime.

Content of univalent cations in each horizon and their translocation in soil profile is parallel to bivalent Ca and Mg cations. The content of K as well as Ca is lower in spruce forests by 70%. It is also lower (by 55.33%) in the average sample of Ao horizon. Litter Ooh and humus Aoq horizon contents lower amount of Na by 27.38%. In other horizons has higher content approximately by 10% and in average sample of Ao horizons only by 2.94%.

Zinc and phosphorus are accumulated in ochric Aoq horizon in natural beech forest. In contrast to secondary spruce forests, there is more zinc by 78.25% and phosphorus by 96%. In cambic Bv horizon is higher Zn content by 1.95 mg.1000g^{-1} (54.96%) and P content by 6.3 mg.1000g^{-1}. The average Ao horizon sample contents more Zn by 26.91% and more P by 10.34%.

Soils in spruce forest have higher content of Mn by 26.04 mg.1000g^{-1} (16.19%) and Fe by 19.60 mg.1000g^{-1} (58.8%) than beech forests. Transmiting of P is more intensive by 8.96% in secondary spruce forests.

Bublinec (1994) who compared nutrients cycle in submontane beech forest and spruce monocultures in Malé Karpaty Mts notes that humus-accumulated horizon of spruce forests is higher Fe content by 57% as well as Mn by 31%. In contrast to Turčianska kotlina basin spruce monocultures from Malé Karpaty Mts have more K (by 23.5%) in soils. Reversely, there is more P (50%) in covering humus layer than in Turčianska kotlina basin as well as higher content of K (29%), Mg (48.9%), Fe (65 %) and Na (53%). Only Ca content is higher (8.2%) in beech forest in Malé Karpaty Mts than in spruce forests. Klimo (1981) studied elements cycle in spruce monoculture in Rajec nad Sázavou and states that spruce exhausts great amount of calcium what confirms results from Turčianska kotlina basin, too. Authors Kontriš et al. (2008a, b) state that it is no related to Fluvisols and humic carbonated soils. Results of Bublinec (1994), Fajmonová (1987) and Kontriš et al. (2008a, b) and ours, unambiguously show that spruce monocultures influence particularly soil reaction and in connection to acidification also sorption saturation and translocation or accumulation of nutrients in soil horizons. Fajmonová (1987) notes that mentioned negative influence of coniferous on soil is general.

Conclusion

This paper is focused on soil environmental evaluation by comparison of the macromorphological, stratigraphical and chemical parameters of two parallel soil probes localized in *Oxalido-culti-Picetum* association monocultures and *Dentario bulbiferae-Fagetum* association (natural submontane beech forest). Analyses of chemical elements (Ca, Mg, K, Na, Mn, Fe, Zn and P), consistence, oxidative-reductive processes, soil reaction and stratighraphical data show that the thickness of spruce monoculture B/Cg horizon is higher by 7 cm than in beech forest. The thickness of humus layer is 4-times smaller in spruce monoculture. Symptoms of slightly compacting are in Aoq horizon in monoculture and oxidative-reductive processes in Bvg horizon. These processes are presented in lower horizons in beech forests. Soil reaction has higher value only in Ooh horizon in spruce monocultures. In other horizons are pH (H_2O) values lower by 0.13–1.62 and pH (KCl) by 0.04–0.77. Content of Ca cations is lower in spruce monoculture by 1 880.6–2341.23 $mg.1000g^{-1}$. Mg content in spruce stands is lower in Ooh horizon by 117.49 $mg.1000g^{-1}$and in Aoq horizon by 93.45 $mg.1000g^{-1}$. But in Bvg horizon has higher content by 39.75 $mg.1000g^{-1}$ and in B/Cg by 38.95 $mg.1000g^{-1}$. In spruce monocultures is lower K content by 14.63– 348.68 $mg.1000g^{-1}$ and zinc by 0.63–4.75 $mg.1000g^{-1}$. In Ooh horizon is also higher amount of P by 2.2 $mg.1000g^{-1}$. In others horizons is P content lower (by 1.4–15.5 $mg.1000g^{-1}$) in comparison to beech forests. Spruce monoculture has in Ooh horizon less of Na (by 10.94 $mg.1000g^{-1}$), in the Aoq horizon is its content lesser only by 0.33 $mg.1000g^{-1}$. In others soil horizons is its content higher by 2.3–3.13 $mg.1000g^{-1}$. Soil of spruce monoculture has more Mn (by 4.96–49.38 $mg.1000g^{-1}$). An only exception is Bvg horizon with lesser amount in comparison to beech forest (by 22.51 $mg.1000g^{-1}$). The Fe content in soils of spruce forests is higher by 11.33–22.15 $mg.1000g^{-1}$.

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References

Ambroz, Z., 1968: Influence of tree species composition on chosen soil characteristics and wood production (in Slovak). Lesnícky Časopis, 14: 973–984.

Ambroz, Z., 1973: Contribution to issue on influence of coniferous in forests on soil fertility (in Slovak). VPVULH, Zvolen, 17: 219–234.

Benčaťová, B., Kontriš, J., Gregor, J., Kontrišová, O., 2008: Research of soil characteristisc in secondary limestone pine and beech forests in Pieniny National Park (in Slovak). In Pálka, B. (ed.), Piate pedologické dni. Zborník, Sielnica, p. 175–182.

Biely, A., Bezák, V., Elečko, M., Gross, P., Kaličiak, M., Konečný, V., Lexa, J., Mello, J., Nemčok, J., Polák, M., Potfaj, M., Rakús, M., Vass, D., Vozár, J., Vozárová, A., 2002: Geological structure (in Slovak). In Atlas krajiny Slovenskej republiky. MŽP SR Bratislava, SAŽP Banská Bystrica, p. 74–75.
Bublinec, E., 1994: Concentration, accumulation and nutrient cycles in beech and spruce ecosystem (in Slovak). Acta Dendrobiologica, Suppl., 85 pp.
Fajmonová, E., 1987: Several results of spruce influence on soil sorption complex studying (in Slovak). Biológia, Bratislava, 32: 759–767.
Faško, P., Šťastný, P., 2002: Mean annual precipitation totals (in Slovak). In Atlas krajiny Slovenskej republiky. MŽP SR Bratislava, SAŽP Banská Bystrica, p. 99.
Klimo, E., 1981: Concentration and bioelements reserves in artificial spruce forest ecosystem (in Czech). Acta Ecologica, 23: 55–117.
Kobza, J, 1999: Partial monitoring system – soil. Obligatory methods (in Slovak). Výskumný ústav pôdoznalectva a ochrany pôdy, Bratislava, 138 pp.
Kontriš, J., Kontrišová, O., Gregor, J., 2008a: Influence of spruce monocultures on soil characteristics of mezotrophic fir-beech forests in Spišská Magura (in Slovak). In Pálka, B. (ed.), Piate pedologické dni. Zborník, Sielnica, p. 175–182.
Kontriš, J., Kontrišová, O., Gregor, J., Malajterová, N., 2008b: Influence of spruce monocultures on soil characteristics of Carpathian oak forests (in Slovak). In Pálka, B. (ed.), Piate pedologické dni. Zborník, Sielnica, p. 183–188.
Kukla, J., 1994: Contribution to pedological – chemical processes dynamic in spruce geobiocoenoses of Biely Váh (in Slovak). Lesnícky Časopis, 6: 295–408.
Kukla, J., 1995: Dynamics of pedochemical processes in the climax spruce forest of Zadná Poľana. Ekológia (Bratislava), 14: 97–110.
Kukla, J., 1996: The influence of spruce edificator on soil development. Folia Dendrologica, 21–22: 23–30.
Kukla, J., 1997: Trends of soil acidification and their relation to change of forest geobiocenoses adaphic-trophic character. Ekológia (Bratislava), 16, 4: 421–431.
Maglocký, Š., 2002: Potential natural vegetation (in Slovak). In Atlas krajiny SR. MŽP SR Bratislava, SAŽP Banská Bystrica, p. 114–115.
Marhold, K., Hindák, F. (eds), 1998: The checklist of non-vascular and vascular plants of Slovakia (in Slovak). Veda, Bratislava, 687 pp.
Mucina, L., Maglocký, Š. (eds), 1985: A list of vegetation units of Slovakia. Documents Phytosociologiques, Camerino, 9: 176–220.
Moravec, J. (ed.), 1994: Phytocoenology (in Czech). Academia, Praha, 403 pp.
Rudič, Z., 1971: The influence of spruce on soil conditions *Querceto-Fageta* Hostýnských vrchů (in Czech). Lesníctví, 17: 391–398.
Šály, R., 1965: Notes on spruce forests influence on soil (in Slovak). Les, 21: 7–14.
Šály, R., Obr, F., 1965: Notes to low forests transformation and to spruce monoculture issue in ČSSR (in Slovak). Lesnícky Časopis, 11: 1–16.
Šály, R., Bedrna, Z., Bublinec, E., Čurlík, J., Fulajtár, E., Gregor, J., Hanes, J., Juráni, B., Kukla, J., Račko, J., Sobocká, J., Šurina, B., 2000: Morphogenetic soil classification system of Slovakia – base reference taxonomy. VÚPOP, Bratislava, 76 pp.
Šály, R., Šurina, B., 2002: Soils (in Slovak). In Atlas krajiny Slovenskej republiky. MŽP SR, Bratislava, SAŽP Banská Bystrica, p. 106.