Soil-forming effect of Grand fir (*Abies grandis* [Dougl. ex D. Don] Lindl.)

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ABSTRACT: The aim of the study is to evaluate the role of the Grand fir (*Abies grandis* [Dougl. ex D. Don] Lindl.) as a soil-improving species in the area of the University Training Forest in Kostelec nad Černými lesy, Jevany district. The state of humus forms in the stand part with Grand fir was compared with the mature Norway spruce (*Picea abies* [L.] Karst.) without regeneration, with young beech (*Fagus sylvatica* L.), Norway spruce (*Picea abies* [L.] Karst.) and oak (*Quercus* spp. L.) stands (all of pole stage). The site is characterized as 4P1 – acid oak-fir site with *Luzula pilosa*, the geological bedrock is formed of cretaceous sandstone with loess overlays, the soils are Luvisols, the terrain is flat at the altitude of 420–440 m a.s.l. The humus form samples (L, F, H, Ah horizons) were taken in 4 replications, quantitatively for the holorganic layers. The dry mass amount and total nutrient contents were analyzed for holorganic horizons, the basic pedochemical characteristics (pH, soil adsorption complex characteristics, exchangeable acidity and exchangeable nutrients) were determined for all horizons. The results confirmed marked and positive effects of the Grand fir litter on the surface layer characteristics. This tree species supports the litter of good composition, transforming easily and forming humus forms of higher quality compared to coniferous as well as studied broadleaved species.

Keywords: forest ecosystems; Grand fir; introduction; humus forms; humus accumulation; soil chemistry; biological amelioration

The introduction of Grand fir (*Abies grandis* [Dougl. ex D. Don] Lindl.) was more in the focus of forestry research in the Czech Republic in the past (Hofman 1963; Šika 1983). This species is among those with the highest production potential in the conditions of Central Europe. It is characterized by rapid growth, high production of technologically important wood and by the remarkable landscaping and gardening value. Production of branches for ornamental purposes is not negligible either. The decline of domestic Silver fir (*Abies alba* Mill.) partially contributed to the interest in this species in the last century. This aspect is less topical at present because of the partial revitalization of Silver fir in the last decade. The environmental obstacles also represent certain a limit for introduced tree species in general. But, as a result of past activities, the stands of Grand fir take up several hundreds of hectares in the Czech Republic (about 950 ha – Novotný, Beran 2008), this area being even more large in other European countries. Grand fir is studied as for its growth and production relatively well in the series of research plots and provenance experiments, documenting satisfactorily its production potential at younger age (Vančura 1990; Beran 2006).

There are only few publications documenting the effects of this tree species on the environment (e.g. Podrázský 2003a; Podrázský, Remeš 2007a,

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2008). The aim of the present study is to evaluate the Grand fir as a soil-improving species in the area of the University Training Forest in Kostelec nad Černými lesy. In this region, typical of larger areas of Central Bohemia, the structure and development of humus forms were studied in close-to-nature stands (Podrázský, Remeš 2007b) as well as the soil changes after conversion into spruce monocultures (Podrázský 2003b). Now, the re-conversion of the stands and effects of particular tree species on the humus forms are studied in this process and the results are presented.

MATERIAL AND METHODS

Research was conducted in the area of the University Training Forest in Kostelec nad Černými lesy, in stand 409 F. The bedrock is sandstone with loess overlays, the site is characterized by the forest type 4P1 – acid oak-fir forest on pseudogley soils (*Querceto-Abietinum variohumidum acidophilum Luzula pilosa* – Viewegh 2003). The studied parts of the stand are characterized by transition from Luvisol (dominant) to Pseudogley (Němeček et al. 2001) or Stagnosol (IUSS Working Group WRB 2006). The particular parts of the stand are as follows:

– mature Norway spruce (*Picea abies* [L.] Karst.) stand, in full density (age 120 years) (SM),
– old European beech (*Fagus sylvatica* L. – BK), Norway spruce (SM), oak (*Quercus* spp. L. – DB), and especially Grand fir (JD) areas in the pole stage (age 35–50 years).

The humus form samples were taken in all these stand parts, in 4 replications, holorganic layers quantitatively by means of an iron frame 25 × 25 cm. The analyses were performed in the accredited Laboratory Tomáš by standard analytical methods, yearly tested.

Table 1. Accumulation of surface humus and amount of fixed macronutrients in particular stands

Stand	Horizon	Dry mass (kg/ha)	N		P		K		Ca		Mg	
			(%)	(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)
SM_{old}	L + F1	11,572 b	1.47 a	170	0.08 a	9	0.10 a	12	0.83 a	96	0.06 a	7
SM_{old}	F2	14,364 bc	1.52 a	218	0.07 a	10	0.10 a	14	0.20 a	29	0.05 a	7
SM_{old}	H	39,924 a	1.57 b	628	0.07 a	26	0.14 a	56	0.07 a	28	0.03 a	13
Sum		65,860		1,016		45		82		90		27
SM	L + F1	8,516 ab	1.53 a	130	0.07 a	6	0.12 a	10	0.56 a	48	0.07 ab	6
SM	F2	11,260 abc	1.33 a	150	0.06 a	7	0.15 ab	17	0.21 a	24	0.07 a	6
SM	H	25,868 a	1.28 ab	330	0.06 a	16	0.27 b	69	0.04 a	9	0.04 a	10
Sum		45,644		610		29		96		81		22
BK	L + F1	4,844 a	1.48 a	72	0.07 a	3	0.14 a	7	1.04 ab	50	0.11 d	5
BK	F2	6,284 a	1.15 a	72	0.06 a	4	0.18 ab	11	0.42 a	26	0.09 a	6
BK	H	27,276 a	0.89 a	242	0.07 a	15	0.40 c	109	0.09 a	23	0.02 a	5
Sum		38,404		386		22		127		99		16
DB	L + F1	3,590 a	1.40 a	50	0.07 a	2	0.14 a	5	0.81 a	29	0.11 cd	4
DB	F2	7,084 bc	1.25 a	89	0.07 a	5	0.19 b	13	0.26 a	18	0.08 a	6
DB	H	29,048 a	0.94 a	274	0.05 a	14	0.36 bc	105	0.10 a	28	0.02 a	5
Sum		39,722		413		21		123		75		15
JDo	L + F1	5,568 ab	1.41 a	79	0.08 a	4	0.15 a	8	1.57 b	87	0.08 bc	5
JDo	F2	7,620 bc	1.40 a	106	0.08 a	6	0.20 b	15	0.29 a	22	0.06 a	5
JDo	H	22,320 a	1.02 a	227	0.06 a	12	0.30 bc	67	0.04 a	8	0.02 a	5
Sum		35,508		412		22		90		117		15

Various indexes indicate statistically significant differences in the framework of the same horizon

These parameters were analyzed:

- amount of surface humus (holorganic layers) at 105°C,
- content of total nutrients after mineralization with sulphuric acid and selenium, amount of nutrients within holorganic layers calculated per 1 ha,
- pH in water and 1 N KCl solutions,
- soil adsorption complex characteristics according to Kappen (S – base content, H – hydrolytical acidity, T – cation exchange capacity, V – base saturation),
- total carbon (humus) content according to Springel-Klee and total nitrogen content according to Kjeldahl,
- exchangeable nutrient content in the Mehlich III solution.

The statistical evaluation was performed using the statistical software S-PLUS by the analysis of variance. The results were evaluated by Scheffe's method by multiple comparisons at the 95% significance level. The ecologically corresponding horizons were compared. Important note: in the tables, different indexes designate statistically significant differences at the 95% significance level in the same/corresponding horizons, the same indexes or their absence mean no significant differences occur.

RESULTS AND DISCUSSION

The establishment of stand parts with different species composition led together with the small-clearcut effects to a lowering of the surface humus amount (Table 1). The young spruce stand showed a less marked decrease, all other species were very similar as for their effects. In the young stands, a non-significant decrease in the nitrogen concentration was documented, the decrease was indicated as being only insignificantly higher in the broadleaved stands. This is connected with the higher demand of

Table 2. Soil reaction and soil adsorption complex characteristics in particular stands

Stand	Horizon	pH/H_2O	pH/KCl	S	H	T	V
				(mval/100 g)			(%)
SM_{old}	L + F1	4.13 a	3.66 ab	27.35 a	21.5 a	48.85a	56.36 a
SM_{old}	F2	3.94 a	3.31 a	26.32 a	50.11 c	76.43 b	34.52 a
SM_{old}	H	3.55 a	2.78 a	18.28 a	71.39 b	89.66 c	20.44 ab
SM_{old}	Ah	3.40 a	2.76 a	3.04 a	22.07 a	25.11 a	11.45 ab
SM	L + F1	4.57 ab	3.88 abc	27.02 a	24.81 a	51.83 a	51.82 a
SM	F2	4.17 ab	3.57 ab	27.78 a	44.94 bc	72.72 ab	38.28 ab
SM	H	3.76 ab	3.03 ab	12.4 a	46.87 ab	59.27 ab	21.02 ab
SM	Ah	3.56 ab	2.98 ab	2.68 a	15.48 a	18.16 a	14.27 abc
BK	L + F1	4.38 ab	3.96 abc	47.98 ab	21.9 a	69.88 a	68.66 ab
BK	F2	4.35 ab	3.86 ab	36.78 a	25.86 a	62.64 ab	58.74 b
BK	H	4.03 b	3.42 bc	12.89 a	28.2 a	41.09 a	31.45 b
BK	Ah	3.89 c	3.18 bc	4.56 a	14.52 a	19.08 a	23.24 c
DB	L + F1	5.03 b	4.46 bc	41.18 ab	21.9 a	63.08 a	65.21 ab
DB	F2	4.34 ab	3.74 ab	31.94 a	28.63 a	60.57 a	52.65 b
DB	H	4.19 b	3.43 bc	11.33 a	29.81 a	41.14 a	27.62 ab
DB	Ah	3.86 c	3.40 c	2.71 a	10.57 a	13.28 a	20.49 bc
JDo	L + F1	5.09 b	4.59 c	56.6 b	16.82 a	73.42 a	76.46 b
JDo	F2	4.70 b	4.11 b	39.45 a	31.08 ab	70.53 ab	55.85 b
JDo	H	4.22 b	3.52 c	12.49 a	32.73 a	45.22 a	29.25 ab
JDo	Ah	3.73 bc	3.25 bc	1.64 a	13.84 a	15.48 a	10.74 ab

Various indexes indicate statistically significant differences in the framework of the same horizon

these species, documented also in other cases (Podrázský, Remeš 2008). The amount of nitrogen fixed within the holorganic layers showed the same trend as the surface humus amount. The total phosphorus content showed the same level in all stands with the exception of significantly higher values in the Grand fir one – recycling this element very effectively. In all the young stands significantly higher concentrations of total potassium were documented, the total sum was higher than in the old stand because of higher accumulation of necromass. Potassium is so recycled very intensively by the fast growing tree stands.

In the young spruce stand, the amount and content of total calcium decreased, an increase was observed in the other species. The only significant increase was documented in the Grand fir ecosystem again. All young stands showed an increase in the total magnesium content, the decrease of the amount was similar to that in the total surface humus weight.

In similar conditions, a decrease in the surface organic matter and an increase in the basic macroelement content were documented after canopy lowering (Podrázský, Remeš 2007b), changes of the base concentrations as well (Podrázský, Viewegh 2005; Podrázský, Remeš 2005a, 2007c).

Grand fir showed the highest, statistically significant, effects on the soil chemistry: increase in the soil reaction (both types), base content, base saturation (Table 2). The hydrolytical acidity decreased less compared to the broadleaved species, but in the other soil chemistry characteristics this species was superior to the other tree species. The old and young Norway spruce stands differ in the same trend, the broadleaved tree species showed the effects of medium intensity. These effects were also documented in other cases – the effects of Grand fir consisted in the higher accumulation of surface humus of high quality. The broadleaved species showed the more rapid decomposition of litter, but sometimes with less favourable soil chemistry characteristics (Podrázský 2003a,b; Podrázský et al. 2003; Podrázský, Remeš 2008). This can be

Table 3. Total humus and nitrogen contents in particular stands

Stand	Horizon	Humus Springel-Klee (%)	Nitrogen Kjeldahl (%)	C/N
SM_{old}	L + F1	71.45 a	1.39 a	30
SM_{old}	F2	81.38 c	1.39 a	34
SM_{old}	H	63.79 bc	1.46 b	25
SM_{old}	Ah	13.15 a	0.31 a	25
SM	L + F1	62.60 a	1.33 a	27
SM	F2	59.34 ab	1.42 a	24
SM	H	44.86 ab	1.15 ab	23
SM	Ah	10.31 a	0.30 a	20
BK	L + F1	60.72 a	1.42 a	25
BK	F2	47.26 a	1.14 a	24
BK	H	31.80 a	0.77 a	24
BK	Ah	10.52 a	0.36 a	17
DB	L + F1	64.84 a	1.44 a	26
DB	F2	46.55 a	1.20 a	23
DB	H	27.87 a	0.82 a	20
DB	Ah	7.49 a	0.24 a	18
JDo	L + F1	64.40 a	1.37 a	27
JDo	F2	51.87 a	1.40 a	21
JDo	H	36.63 a	1.03 ab	21
JDo	Ah	6.92 a	0.22 a	18

Various indexes indicate statistically significant differences in the framework of the same horizon

Table 4. Exchangeable nutrient content in the Mehlich III solution in particular stands (mg/kg)

Stand	Horizon	P	K	Ca	Mg
SM_{old}	L + F1	51.33 a	488.67 a	2,329.33 a	228 a
SM_{old}	F2	35 a	341 a	2,845 ab	249 a
SM_{old}	H	22 ab	257.5 a	2,047.5 b	232 b
SM_{old}	Ah	2.75 a	77.25 a	425.75 a	65 a
SM	L + F1	50.67 a	594.67 a	2,414 ab	278.67 a
SM	F2	42 a	444 ab	2,656.67 a	272.67 a
SM	H	29 ab	316.5 a	1,438.5 a	179.5 ab
SM	Ah	9.00 a	91.75 a	347.75 a	54.5 a
BK	L + F1	87 abc	963 b	4,224 bc	712 b
BK	F2	54 ab	595 b	3,731 ab	532 b
BK	H	28 ab	256.5 a	1,494.5 a	205.5 ab
BK	Ah	15.5 a	115.5 a	449.25 a	68.5 a
DB	L + F1	132 c	973 b	3,345 abc	624 b
DB	F2	74 b	549.5 b	2,920.5 ab	496 b
DB	H	34 ab	300.5 a	1,253.5 a	224.5 b
DB	Ah	10.00 a	94 a	292.25 a	58.25 a
JDo	L + F1	100 bc	681.33 ab	4,823.33 c	316.67 a
JDo	F2	62.67 ab	512.67 ab	4,130.67 b	286.67 a
JDo	H	42.5 b	352.5 a	1,718 ab	156.5 a
JDo	Ah	4.75 a	68.5 a	328.25 a	48.25 a

Various indexes indicate statistically significant differences in the framework of the same horizon

very often ascribed to the specific demands of the particular tree species and to higher demands of broadleaved trees especially for phosphorus, potassium and bivalent bases.

The total humus content (total carbon content × 1.724 coefficient – rough estimation only) was lowered in the young spruce stand due to more intensive surface humus transformation – mineralization and humification – in the period of stand regeneration. This can occur due to the process of natural regeneration (Podrázský, Remeš 2007b), thinning (e.g. Šarman 1982, 1985) or clear-cutting (Podrázský, Remeš 2005b). The broadleaved species with their litter of higher quality caused an even more marked lowering of the total humus contents compared to coniferous monocultures (Fabiánek et al. 2009). Grand fir was fully comparable with the broadleaves in the studied case. The total nitrogen content according to Kjeldahl showed similar trends, but the Grand fir exhibited even lower nitrogen losses. The regeneration phases together with high demands of fast growing young stages of the forest tree species are leading to nitrogen extraction from the soil (Table 3). The C/N ratio was decreased in the young spruce stand, even more in the other stands. The Grand fir showed a similar or lower ratio compared to the broadleaved tree species.

Table 4 documents the contents of plant available (exchangeable) nutrients in individual horizons of particular stands. The content of plant available phosphorus increased especially in the oak and Grand fir stands, showing upward tendencies in all parts of the young stand. Potassium concentrations grew especially in the broadleaved stands, partly in correspondence with the total form of macronutrients. The bivalent cations showed downward tendencies in lower (H, Ah) horizons of young spruce, Grand fir and broadleaved stands, the increase in upper horizons (L, F) was documented for Grand fir and broadleaves. This probably indicates the increased uptake of these elements and transport in litter and slightly transformed humus matter.

The humus forms underwent considerable quantitative and qualitative changes and indicate visible changes after the forestry treatments studied. The Grand fir effects are also visible and the results provide an important evidence of its environmental functions.

CONCLUSIONS

All the results, obtained in the present study, document the increased humus mineralization and transformation after the forestry treatments and during the regeneration processes. The reduction or removal of the canopy results in the lowering of the surface humus amount and changes in its qualitative characteristics.

In spite of the Grand fir, the quantitative effects were comparable to the most important broadleaved tree species studied: beech and oak. European beech is considered to be one of the most important site improving and stabilizing tree species. The Grand fir is similarly effective as for quantitative aspects.

The characteristics of the soil chemistry, i.e. soil reaction, soil adsorption complex characteristics, humus and nutrient contents, also improved visibly, often significantly, after the regeneration and tree species change. The young Norway spruce showed less marked changes.

From the qualitative aspect, the Grand fir was fully comparable with the studied broadleaved tree species and its characteristics as site-improving species were confirmed without doubt. The high production potential – in contrast to beech and oak as co-dominants in coniferous monocultures – supports its cultivation to a larger extent. The introduction of Grand fir as production increasing and site improving species has to be recommended to a reasonable extent and at convenient sites.

References

BERAN F., 2006. Některé poznatky z hodnocení mezinárodního provenienčního pokusu s jedlí obrovskou – *Abies grandis* (Douglas) Lindl. In: Douglaska a jedle obrovská – opomíjení giganti. Sborník referátů z konference v Kostelci nad Černými lesy 12.–13. 10. 2006. Praha, ČZU: 17–27.

FABIÁNEK T., MENŠÍK L., TOMÁŠKOVÁ I., KULHAVÝ J., 2009. Effect of spruce, beech and mixed commercial stand on humus conditions of forest soils. Journal of Forest Science, *55*: 119–126.

HOFMAN J., 1963. Pěstování jedle obrovské. Praha, SZN: 116.

IUSS Working Group WRB, 2006. World reference base for soil resources 2006. World Soil Resources Reports No. 103. Rome, FAO.

NĚMEČEK J. et al., 2001. Taxonomický klasifikační systém půd České republiky. Praha, ČZU: 78.

NOVOTNÝ P., BERAN F., 2008. Introdukované dřeviny v lesním hospodářství ČR. Lesnická práce, *33*: 394–395.

PODRÁZSKÝ V., 2003a. Effects of Giant fir cultivation on the humus form. Scientia agriculturae bohemica, *34*: 63–66.

PODRÁZSKÝ V., 2003b. Effects of Norway spruce introduction on humus form changes in the Voděradské bučiny Nature Reserve Area. Phytopedon, *2*: 23–26.

PODRÁZSKÝ V., REMEŠ J., 2005a. Effect of tree species on the humus form state at lower altitudes. Journal of Forest Science, *51*: 60–66.

PODRÁZSKÝ V., REMEŠ J., 2005b. Retenční schopnost svrchní vrstvy půd lesních porostů s různým druhovým složením. Zprávy lesnického výzkumu, *50*: 46–48.

PODRÁZSKÝ V., REMEŠ J., 2007a. Fertilization effect on the Grand fir plantations. Scientia agriculturae bohemica, *38*: 198–201.

PODRÁZSKÝ V., REMEŠ J., 2007b. Změny kvality a množství nadložního humusu při přirozeném zmlazení bukových porostů na území Školního lesního podniku Kostelec nad Černými lesy. Zprávy lesnického výzkumu, *52*: 39–43.

PODRÁZSKÝ V., REMEŠ J., 2007c. Humus form status in close-to-nature forest parts comparing to afforested agricultural lands. Lesnícky časopis – Forestry Journal, *53*: 99–106.

PODRÁZSKÝ V., REMEŠ J., 2008. Půdotvorná role významných introdukovaných jehličnanů – douglasky tisolisté, jedle obrovské a borovice vejmutovky. Zprávy lesnického výzkumu, *53*: 27–33.

PODRÁZSKÝ V., VIEWEGH J., 2005. Comparison of humus form state in beech and spruce parts of the Žákova hora National Nature Reserve. Journal of Forest Science, *51*, Special Issue: 29–37.

PODRÁZSKÝ V., VIEWEGH J., REMEŠ J., 2003. Srovnání stavu humusových forem v mladých porostech smrku a buku na území NPR Žákova hora. Zprávy lesnického výzkumu, *48*: 61–63.

ŠARMAN J., 1982. Vliv probírky na povrchový humus ve smrkovém porostu. Lesnictví, *28*: 31–42.

ŠARMAN J., 1985. Vliv probírky na humusový profil v bukovém porostu. Lesnictví, *28*: 31–42.

ŠIKA A., 1983. Introdukce jedle obrovské v ČSR. Zprávy lesnického výzkumu, *28*: 1–3.

VANČURA K., 1990. Provenienční pokus s jedlí obrovskou série IUFRO ve věku 13 let. Práce VÚLHM, *75*: 47–66.

VIEWEGH J., 2003. Klasifikace lesních rostlinných společenstev (se zaměřením na Typologický systém ÚHÚL). Praha, ČZU: 216.

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Půdotvorná funkce jedle obrovské (*Abies grandis* [Dougl. ex D. Don] Lindl.)

ABSTRAKT: Cílem studie bylo zhodnocení funkce jedle obrovské (*Abies grandis* [Dougl. ex D. Don] Lindl.) jako meliorační dřeviny na území ŠLP Kostelec nad Černými lesy, polesí Jevany. Byl srovnáván stav humusových forem v porostní části (kotlíku) s jedlí obrovskou ve stadiu tyčoviny se stavem v částech s dominancí smrku (*Picea abies* [L.] Karst.), dubu (*Quercus* spp. L.) a buku (*Fagus sylvatica* L.) a v původním dospělém porostu smrku. Stanoviště je charakterizováno jako 4P1 – kyselá dubová jedlina biková, geologický podklad tvoří křídový pískovec se sprašovými překryvy, převažujícím půdním typem jsou luvizemě. Terén je plochý v nadmořské výšce 420–440 m. Byly odebírány vzorky horizontů humusových forem (L, F, H, Ah) v počtu opakování 4, holorganické horizonty kvantitativně. U všech vzorků byly stanoveny základní pedochemické charakteristiky: pH aktivní i potenciální, charakteristiky půdního sorpčního komplexu a výměnné acidity a přístupné živiny, u holorganických navíc ještě zásoba sušiny a obsah celkových živin. Výsledky potvrdily značný a pozitivní vliv jedle obrovské na stav svrchních půdních horizontů. Tato dřevina tvoří opad s dobrou skladbou, který se dobře a rychle transformuje a vytváří kvalitní humusovou formu jak ve srovnání se smrkem, tak i se studovanými listnáči.

Klíčová slova: lesní ekosystémy; jedle obrovská; introdukce; humusové formy; akumulace humusu; půdní chemismus; biologická meliorace

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