EFFECTS OF THE REFORESTATION OF AGRICULTURAL LANDS ON THE HUMUS FORM DEVELOPMENT IN THE MIDDLE ALTITUDES*

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The presentation documents the results of the research on accumulation of the surface humus and results of the soil chemistry in soils of forest localities compared to afforested agricultural lands 60 years ago. The research was done in the vicinity of the Šachotín village, Czech-Moravian Highland. The forest soil state is compared with the arable soil in the same site. In the stably forested part it was studied the effect of group birch admixture. The highest surface humus amount was documented in the old Norway spruce stand (62.8 t/ha), the lower was in parts with admixture of birch (52.0 t/ha) and the lowest on the afforested agricultural soil (45.9 t/ha). The arable soil did show very unfavorable soil chemistry, the forested soils of all stages nor the birch admixture show any clear differences in the soil state. Despite this, intense shifts in the soil characteristics and dynamics can be supposed after afforestation, as well as the considerable effects of the new biomass accumulation. The effects of birch in the older spruce stands can be considered as favorable.

afforestation of agricultural lands; spruce; birch; soil chemistry; humus accumulation; Czech-Moravia Highland

INTRODUCTION

The Czech-Moravian highland belongs to regions, where the changes in the land use were very often in the past as well as at present. The deforestation, agricultural use and repeated reforestation could occur several times in the past centuries. Since the end of World War II, the afforestation of large areas has been taking place and the forest area increased considerably. In large extent, the marginal agricultural lands were reforested like in the whole Czech Republic. This problem was described broadly by many authors (Hatlapatková et al., 2006; Kacálek et al., 2006, 2007; Špulák, 2006). On the other hand, there is totally missing the information on the rapidity of forest environment restoration, including the forest soil and the decisive production and stability factor and forest ecosystem compartment. The first analyses can be found (Podrázský, Štěpáník, 2002; Podrázský, 2006). The evaluation was done also of the rapidity of restoration of crucial humus layer in the Ore Mts. conditions after bulldozer site preparation (Podrázský et al., 2006). The importance of the afforestation of non-forest sites was discussed also from the viewpoint of biodiversity (Hlaváč et al., 2006).

For the consideration of rapidity of the forest ecosystem restoration, the comparison is always necessary with the state in the natural or close-to-nature forest stands in similar site conditions (Podrázský, Remeš, 2007a, b; Podrázský, Viewegh, 2003). Even so important is the comparison with the state in commercial forests representing today the most spread type of forest stands with the highest proportion in the future, too (Novák, Slodičák, 2006; Podrázský, Remeš, 2008).

The aim of the presented study is the documentation of the humus form development on the reforested agricultural lands in the territory of the Šachotín village in the Czech-Moravian Highland region, as well as the demonstration of the restoration potential for humus forms and the whole forest environment on sites typical for large areas in this region.

MATERIAL AND METHODS

The studied locality is located in the Natural Forest Area 16 – Czech-Moravian Highland. It is located approximately 1.5 km E from the Šachotín village, 11 km SE from the Havlíčkův Brod town. It is property of the Štoky forest cooperative. The studied stands extend in the altitude 520–530 m a.s.l., the terrain is very flat top plateau in middle altitudes. The average annual temperature is 6.8 °C, annual mean precipitation 700 mm (Meteorological station Přibyslav – N 6 km). Climatically is the area consiteder MT3 – mildly worm.

Bedrock is formed by schists with magmatite. The Pseudogleys are representing the main soil types with transition to the gley subtypes of Cambisols (directly research plots). The studied sites are ordinated as 5P1 – acid fir site

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Table 1. Amount of accumulated surface humus (t/ha) in particular horizons of studied stands

Stand	Spruce + birch old	Spruce old	Spruce new
	t/ha		
L+F1	10.6 a	12.1 b	7.3 c
F2	7.9 a	21.3 b	12.8 b
H	33.5	29.4	25.8
Total	52.0	62.8	45.9

Statistically significant differences are indicated by different indexes

with *Luzula pillosa*, the management type as 57 – gley sites of higher altitudes. The sampling localities in all stands were highly comparable.

Sampling was done in the stands 617D6 and 617D7 in September 2007. The following stands were studied:

- Norway spruce stand on "old" forest soil in sites with co-dominance (groups of 5–10 individuals) of birch, age 70 years – Spruce + birch old,
- Norway spruce on "old" forest soil with dominance of this species, age 70 years – Spruce old,
- Norway spruce on newly afforested agricultural soil (pasture), age 60 year (management plan 2005) – Spruce new.

The sampling is performed by iron frame 25 x 25 cm. The layers L+F1, F2, H were sampled quantitatively, the organomineral horizons A only for quality assessment. The F horizon was separated in two parts, F1 and F2. F1 layer was similar in its character to the L horizon, so it was sampled together (Green et al., 1993). The fresh and mildly changed needle was not possible to distinguish. The sampling was completed on the neighboring arable soil – layer 0–20 cm. The number of replication was 4 in all cases. The laboratory was the enterprise Tomáš, located in the building of the FGMRI Station Opočno, for the analyses were used standard methods:

- amount of the dry mass of the holorganic horizons,
- pH in water and 1N KCl solution,
- the soil adsorption complex characteristics by Kappen (S – bases content, T – cation exchange capacity, T – S = H – hydrolytical acidity, V – base saturation),
- total oxydeable carbon content,
- total nitrogen content by Kjeldahl,
- total macroelements content after mineralization by sulphuric acid and selene (N, P, K, Ca, Mg),
- plant available (exchangeable) nutrient content by citric acid method (P, K, Ca, Mg in oxide form).

The results were analyzed by one-factor analysis of variance in MS Excell on 95 % of significance.

RESULTS AND DISCUSSION

The amount of surface humus (Table 1) showed statistically significant differences among particular stands. The biggest amount was documented in the "old" spruce without birch (62.8 t/ha), lower in the case with birch co-dominance (52.0 t/ha), and the lowest in the "new" stand on newly reforested agricultural land.

The rapidity of surface humus accumulation was relatively high, the amount corresponded with relatively unfavorable site. In more favorable growth conditions on other sites, the amount of the surface horizons did reach much bigger values in spruce stands on reforested agricultural lands, even over 40 t/ha at the age of 40 years (the region of Český Rudolec, Podrázský, Štěpáník, 2002), or more than 60 t/ha at the age of 50 years (6th–7th vegetation altitudinal zone, Trčkov Natural Reserve, Podrázský, Remeš, 2007b). The amount of the surface organic matter was higher in the "old" stands in these cases too (ca 80 t/ha). Nevertheless, the reaching of "natural" level of the holorganic layers accumulation can be topical during one forest rotation (100–120 years). This represents the time scale for accumulation of the surface humus comparable with the commercial stands of non-autochthonous tree species. This amount could be even lower in the natural forest stands with close-to-nature forest species composition and natural dynamics (Podrázský, 2007; Podrázský, Remeš, 2007a), correspondingly to the different dynamics of the soil organic matter in the broad-leaved and mixed forests. The variation in the natural and close-to-nature forests can be similar to the commercial ones depending on the forestry treatments, stage of the development and species composition (Podrázský, Vieweg h, 2003). Depth of particular horizons did not differ among variants (L+F1 0.5–1 cm, F2 1–2 cm, H 2–3 cm, Ah 8–10 cm), so not differences were considered important.

Table 2 is documenting the basic characteristics of the soil adsorption complex. The active soil reaction did not show any remarkable differences among variants. Despite this, in the old stand the effects of birch on the pH values increase (L + F horizons) are visible. The values in the agricultural soil did not differ from the forest soil and even arable soil showed low values of pH active 4.4. The differences were more prominent in other cases (Podrázský, Remeš 2007b, c) and reflected the influences of long-term land use changes. This trend is documenting relatively extreme character of the studied sites.

The potential soil reaction (1 N KCl) showed statistically significant differences between "old" and "new" forest soils at least in the L+F1 a F2 horizons. The significant effect of the birch was not documented despite higher values in the stand parts with birch admixture. The birch shows clear soil improvement effects, this is documenting its importance as the soil improving species (Podrázský et al., 2005). Soil reaction of the soil from the field had similar values as the forest soils. This is not common, the status is more favorable on the arable soil (Podrázský, Remeš, 2007c) usually.

The content of exchangeable bases was the highest in the "old" spruce stand in the holorganic layers, lower in the substrates from the newly spruce afforested locality, the effect of birch was not visible. In the mineral soil, the influence of the agricultural use was reflected clearly – the values were superior in the arable soil. The maximum hydrolytic acidity (H, T-S, respectively) was registered in the

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

Stand	Horizon	pH (H_2O)	pH (KCl)	S mval/100 g	T-S mval/100 g	T mval/100 g	V %
Spruce + birch old	L+F1	5.0	4.5 a	29.4	31.4	60.8	47.3
	F2	4.3	4.0 a	28.5 ab	42.5 a	71.0 a	40.1 a
	H	3.6	3.3	21.8	61.8 a	83.6 a	26.1
	Ah	3.9	3.5	6.2 ab	25.1	31.3	19.8
Spruce old	L+F1	4.6	4.2 ab	33.8	38.9	72.7	45.5
	F2	4.0	3.7 ab	34.4 a	58.3 ab	92.8 ab	38.5 a
	H	3.6	3.1	25.0	74.2 ab	99.1 ab	26.4
	Ah	4.0	3.3	4.4 a	15.0	19.4	31.0
Spruce new	L+F1	4.4	4.1 b	22.6	37.6	60.2	37.8
	F2	3.9	3.4 b	25.1 b	68.1 b	93.2 b	26.9 b
	H	3.6	3.2	21.2	86.1 b	107.3 b	19.8
	Ah	4.0	3.5	7.7 b	16.1	23.7	32.2
Field	0–20	4.4	3.3	10.1	6.2	16.3	70.2

Statistically significant differences are indicated by different indexes

Table 3. Total nitrogen and oxideable carbon (humus) content in particular parts of studied stands

Stand	Horizon	N ($Kjelda_hl$) %	C_{ox} %	C/N	Humus %
Spruce + birch old	L+F1	1.54	35.1	22.8	60.5
	F2	1.71	35.5	20.8	61.1
	H	1.54 a	30.5	19.8	52.5
	Ah	0.56	10.6	18.9	18.2
Spruce old	L+F1	1.59	38.9	24.5	67.1
	F2	1.65	39.0	23.6	67.2
	H	1.57 a	29.2	18.6	50.3
	Ah	0.38	5.7	15.0	9.8
Spruce new	L+F1	1.52	35.0	23.0	60.3
	F2	1.63	40.3	24.7	69.5
	H	1.75 b	37.3	21.3	64.3
	Ah	0.57	6.4	11.2	11.0
Field	0–20	0.15	2.1	14.0	3.6

Statistically significant differences are indicated by different indexes

"new" spruce forest soil in the holorganic layers, the effects of the birch was not significant. In the mineral horizons, the significantly lowest values of this characteristics were documented in the soil of field, the highest ones (without significance) in the mixed stand on "old" forest site. This was probably the consequence of the correlation with the organic matter content (Table 3) in the mineral horizon of this stand part.

Cation exchange capacity showed significant difference between, "old" spruce with birch and "new" spruce stand in holorganic layers. It is considerably lower in the arable soil, as the consequence of low organic matter content again. The effect of birch was favorable in the mineral soil.

The V-characteristics – base saturation – can be considered a synthetic parameter for soil adsorption complex. Despite large variability of the analysis results it is visible dominant tendency in the holorganic layers: the maximum values of the base saturation in the mixed stands (with birch), the lower in the pure old spruce stand and the lowest in the newly afforested site. In the last case, the fast growing young spruce stand is intensively taking up the nutrients from the soil, this trend was intensified due to the relatively extreme site and really extreme marginal agricultural land. This situation is different from relatively more favorable sites, where the effects of the agricultural use were reflected by the higher bases content in the upper soil layers (Podrázský, Remeš, 2007b, c). In the mineral layer in the studied area, the effects of cultivation are highly documented by the maximum base saturation of the adsorption complex.

The total nitrogen content determined by the Kjeldahl method was statistically significantly different in the H horizon only, in other cases the N-content values did not differ considerably and did not show any visible trend. The effect of birch showed probably the favorable effect in the "old" forest stand in the mineral substrate. Low content of the nitrogen in the agricultural land is connected probably

Table 4. Total macronutrients content in particular parts of studied stands

Stand	Horizon	A	P	K	Ca	Mg
		(%)				
Spruce + birch old	L+F1	1.60	0.07	0.13 ab	1.07	0.08 ab
	F2	1.70	0.05	0.13 a	0.19	0.05
	H	1.54 a	0.08 a	0.22 a	0.03	0.04
Spruce old	L+F1	1.59 ab	0.06	0.11 a	0.76	0.06 a
	F2	1.62	0.05	0.10 b	0.19	0.04
	H	1.56 ab	0.05 b	0.15 b	0.06	0.03
Spruce new	L+F1	1.52	0.05	0.15 b	1.05	0.09 b
	F2	1.63	0.05	0.11 ab	0.11	0.05
	H	1.75 b	0.05 b	0.16 b	0.02	0.04

Statistically significant differences are indicated by different indexes

Table 5. Plant available macronutrients content in the citric acid leachate in particular parts of studied stands

Stand	Horizon	P_2O_5	K_2O	CaO	MgO	Fe_2O_3
		mg/kg				
Spruce + birch old	L+F1	768	781	6393	1027	139
	F2	490	416	5413 a	767 a	420
	H	207	285 a	1967	436 a	711
	Ah	108 ab	69	370	173 a	2174
Spruce old	L+F1	782	561	6667	880	145
	F2	383	273	3907 ab	472 b	368
	H	466	145 b	2413	388 a	534
	Ah	79 a	70	283	131 a	2084
Spruce new	L+F1	423	687	5640	1035	187
	F2	531	319	3347 b	657 a	304
	H	250	263 a	2433	621 b	703
	Ah	130 b	62	483	248 b	2418
Field	0–20	223 c	364 c	1593 c	153 c	1321

Statistically significant differences are indicated by different indexes

with extremely unfavorable site and with minimum content of the humus (Table 3). There were not significant differences in the oxidable carbon (humus) content on the forested plots, the tendency of the higher content of Cox in the mineral soil under birch was not statistically relevant. The humus content in the agricultural soil was several times lower comparing to forest soils, which indicates very poor state of these agricultural lands as well as their marginality. C/N ratio was slightly lowered by the birch admixture in the L+F1 and F2 layers, lower value was also in the mineral horizon of the new spruce stand.

Total nitrogen content determined after substrate mineralization showed similar trend as in case of the Kjeldahl method. H-horizon of the “new” forest indicated statistically significant higher content. Total phosphorus content in the L+F1 horizon was insignificantly lower from the spruce stand with birch, through “old” spruce stand in the newly afforested soil. The significantly highest P-total content in the H-horizon of the “mixed” stand reflects visibly the effect of this broad-leaved species, similarly as in the corresponding experiment in the Ore Mts. (P o d r á z s k ý et al., 2005). Also the K-total content is affected favorably by the birch, especially in the H-horizon. In the L+F1 horizon, the higher content of K can be reflected on the former agricultural land yet. In the total calcium content, there are not visible differences in the holorganic horizons, the total Mg content was higher only in the newly afforested land in the uppermost L+F1 horizon (Table 4).

Plant available P-content (Table 5) showed similar trends as the same nutrient in the total form. The highest was in the arable soil at present, reflecting the effects of fertilization without doubt. The plant available potassium content was increased due to the former agricultural use as well as due to the birch effect, its content was highly raised in the arable soil by present fertilization. The plant available calcium content reflected favorable function of the birch and effective recycling of this nutrient by the respective tree species. The same is valid for the available magnesium content – the residual magnesium is present from the former agricultural use. The content of the exchangeable iron in the citrate solution was similar among variants, it was considerably lower in the field. This corresponds to the agrotechnical measures used (Table 5).

In general, the studied locality (study series) is located in less favorable site conditions, compared to other study series from other experiments (P o d r á z s k ý , 2007b, c).

the agricultural use of neighboring localities can also have some effects and the input of ameliorative matters and other agro-chemicals is not excluded. Owing to described results, the differences can be evaluated as significant, but of relatively lower absolute values.

CONCLUSIONS

The forest stands on the agricultural lands accumulated considerable amount of the holorganic matter in the half of the rotation period and there is a real possibility to reach the amount typical for old stands, respectively for plots covered continuously by the forest, in one rotation both as for the quality and quantity of the surface organic matter. The biggest amount of the holorganic horizons was documented in the "old" Norway spruce stand without birch admixture (62.8 t/ha), lower in the same stand on localities with birch admixture (52.0 t/ha) and the lowest in the stand on the reforested agricultural land (45.9 t/ha).

The soil reaction was considerably low, in the uppermost horizons, the effects of birch were clearly visible. Higher acidity of the newly afforested soil was reflected also by higher values of the hydrolytical acidity. The complex characteristics of the soil adsorption complex quality (V – base saturation) showed more extreme values on the newly reforested agricultural soils. The current agro-use was clearly reflected by the soil adsorption complex state.

Humus as well as total carbon accumulation was very similar in particular studied variants. These characteristics were several times lower in the current agricultural soil indicating very unfavorable state of agro-soils in the studied region.

Total and plant available nutrient contents reflected insignificant effects of the birch, values were quite similar among variants, with irregular deviations. Despite poor character of the agricultural soil, the nutrient contents showed clearly the fertilization effects by macronutrients.

The accumulation process is relatively fast of the surface humus in the Norway spruce stands of the studied part of the Czech-Moravian Highland, without bigger effects on the quality of mineral soil in the first decades. The broad-leaves admixture can be considered as favorable in general.

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Vliv zalesnění zemědělských půd na humusové formy ve středních nadmořských výškách.

Scientia Agric. Bohem., *40*, 2009: 41–46.

Příspěvek dokumentuje výsledky šetření akumulace nadložního humusu a výsledky stanovení půdního chemizmu v půdách na dříve zalesněných lokalitách (považovaných za kontinuálně zalesněné) ve srovnání se zemědělskými plochami zalesněnými před 60 lety. Lokalita, na níž je prováděn výzkum, se nachází v PLO 16 – Českomoravská vrchovina. Je situována asi 1,5 km východně od obce Šachotín, zhruba 11 km jihovýchodně od Havlíčkova Brodu. Porosty jsou ve správě Lesního družstva Štoky. Zkoumané porosty se nacházejí v nadmořské výšce 520–530 m n. m. Terén je velmi mírně svažitý až rovinatý, z hlediska reliéfu okolní krajiny se jedná o vrcholovou plošinu. Průměrná roční teplota je zde asi 6,8 °C, průměrné roční srážky jsou kolem 700 mm (meteorologická stanice Přibyslav – vzdálená asi 6 km severně). Klimaticky je oblast podle Quitta zařazena jako MT 3, tj. mírně teplá.

Geologické podloží tvoří převážně dvojslídné pararuly s vložkami migmatitu. Půdním typem na nově zalesněné lokalitě je podle pedologické mapy (vlastní šetření nebylo provedeno) pseudoglej modální, u porostu na starší lesní půdě je to slabě oglejená kambizem. Porosty jsou typologicky zařazeny jako 5P1, tedy kyselá jedlina s bikou chlupatou. Vzorky byly odebrány v porostech 617D6 a 617D7 v září roku 2007. Sledovány byly porostní části: SM porost na „staré lesní půdě“ v místech (skupinách) s výskytem břízy (SM+BR starý), SM porost, čisté smrkové části (SM starý) a SM porost na zalesněné zemědělské půdě (SM nový). Stáří všech částí se podle LHP (k r. 2005) pohybovalo mezi 60–70 lety. Odběry byly doplněny kontrolním odběrem z intenzivně obhospodařovaného pole. Vzorky byly zpracovány v laboratoři Tomáš se sídlem ve VÚLHM VS Opočno a stanoveny byly následující charakteristiky podle standardně používaných metodik:
– zásoba sušiny holorganických horizontů (t/ha),
– pH aktivní a výměnné v 1 N KCl,
– vlastnosti sorpčního komplexu podle Kappena (S – obsah bází, T – kationtová výměnná acidita, H – hydrolytická acidita, V – nasycení sorpčního komplexu bázemi),
– obsah celkového oxidovatelného uhlíku (humusu) a dusíku metodou Kjeldahla,
– obsah celkových živin v holorganických horizontech po mineralizaci kyselinou sírovou a selenem (N, P, K, Ca, Mg),
– obsah přístupných živin (P, K, Ca, Mg) ve výluhu kyselinou citronovou.

Výsledky analýzy byly zpracovány jednofaktorovou analýzou rozptylu (ANOVA) v programu MS Excell. V tabulkách jsou statisticky významné rozdíly mezi hodnotami v odpovídajících si horizontech (na hladině významnosti 95 %) vyznačeny různými indexy.

Největší zásoba nadložního humusu byla determinována na původní lesní půdě v částech s čistým smrkem (62,8 t/ha), nižší v tomtéž porostu s dominancí břízy (52,0 t/ha) a nejnižší v části na zemědělské půdě (45,9 t/ha). Orná půda vykazovala velice nepříznivý stav půdního chemizmu, půda všech stadií vývoje lesa ani vliv břízy pak nevykazovaly významné a jednoznačné rozdíly v půdním chemizmu. Přesto je možné předpokládat intenzivní změny charakteristik půdy po zalesnění, značný vliv relativně rychlé akumulace biomasy na zalesněných půdách i příznivý vliv břízy ve starších porostech s trvalým lesním krytem.

zalesnění zemědělských půd; smrk; bříza; půdní chemizmus; akumulace humusu; Českomoravská vrchovina

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