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The condition of forest stands on afforested agricultural land in the Orlické hory Mts

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Abstract

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The paper presents an evaluation of the growth of newly established forest stands on former agricultural land and furthermore describes the state of the upper part of the soils in these stands in comparison with neighbouring grassland in the Orlické hory Mountains. The new Norway spruce stands show an extremely high growth potential, usually significantly higher in comparison with areas forested for more generations/rotations. The formation of the surface humus layer also showed fast progress, the amount of dry mass of soil organic matter reaching values almost typical of permanently forested sites. The soils of newly afforested lands tend to resemble the status of forest soil – there was observed a process of acidification and nutrient depletion, probably connected with accumulation of the tree biomass.

Keywords: stand production; soil condition; humus accumulation; Norway spruce

Afforestation of former agricultural lands has been going on for at least two centuries, for various reasons. Human society originally used deforestation in order to gain land suitable for agricultural purposes (Williams 2000). Forest stands were cut not only for future land use in agriculture, the forest served also as a source of fuel and building materials (Kaplan et al. 2009). These changes were so extensive that some authors describe them as the biggest process of transformation of the landscape and the land surface (Olofsson, Hickler 2008).

The first documents relating to afforestation of non-forest land in the territory of the Czech Republic date back to the late 16th century, when a small wood behind the old game reserve close to the city of Prague was planted (Špulák, Kacálek 2011). Another reference dates back to 1589 and describes the new forest planting two miles from Prague close to the Hvězda Game Reserve (Špulák 2006). The last major deforestation in Europe was due to the industrial revolution in the 19th century (Kaplan et al. 2009). After that, a reverse process – afforestation – prevailed, not only in this country but also in neighbouring territories. In the early 20th century, approximately 18,000 ha of non-forest land were afforested. The most extensive afforestation of agricultural land occurred after World War II in the whole territory of the Czech Republic (Kacálek, Bartoš 2002). Changes in land use occurred mainly in the border areas of the country formerly settled mainly by the German population (Špulák, Kacálek 2011). In the 1960s, 6,000 ha of non-forest land were afforested; later, afforestation reached around 1,000 ha·yr^{-1} (Černý et al. 1995). In the post-war period, the industry faced labour shortage. A smaller portion of the non-forest land was afforested using pioneer tree species such as alder, rarely Scots pine (Špulák, Kacálek 2011)

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and considerable areas were planted with target tree species (Šindelář, Frýdl 2006). However, the most commonly used species for afforestation of non-forest land was Norway spruce which created pure monocultures (Topka 2003). These spruce forests are now reaching the age of about sixty years.

There still exists a broad potential of afforestation of agricultural lands in the Czech Republic, when Černý et al. (1995) indicated 300,000 ha, Podrázský and Štěpáník (2002) assumed a wider range of 50,000 to 500,000 ha. The aim of this study is therefore an assessment and evaluation of biomass yield for Norway spruce on former agricultural sites in comparison with the production of Norway spruce stands of identical parameters on forest sites in the same climatological conditions. A further partial goal is to evaluate the rate of recovery of the forest soil environment and its comparison with grassland sites.

MATERIAL AND METHODS

Study site. Seven permanent research plots were established in the vicinity of the Neratov village in the Orlické hory Mountains. in 2006. These stands on former agricultural land were planted shortly after World War II. They are mostly spruce monocultures; their area is more than 100 ha. The altitude of plots ranges from 620 to 710 m a.s.l. with the average rainfall from 900 to 1,100 mm·yr^{-1} and the average annual temperature about 6°C. The bedrock consists mostly of schists, phyllites and paragneisses. Prevailing soil types are Cryptopodzols, Cambisols and Fluvisols (Hatlapatková et al. 2006). The forests can be classified as spruce-beech sites. All permanent plots have a square shape of 50 × 50 m. Permanent plots 1–4 and 7 were established on afforested agricultural land, plot 6 is a forest developed by natural succession and plot 5 is an old Norway spruce forest on forest land which was chosen as a control plot. More detailed characteristics are shown in Table 1.

Mensuration. Data in all plots were collected in October 2014. DBH was measured twice perpendicularly to the nearest 1 mm. Tree height was measured with a Vertex hypsometer (Haglöf Sweden, Sweden). The resulting height was calculated as the arithmetic mean of two measurements in meters to the nearest 1 dm. The stand basal area was calculated as the sum of the tree basal areas in the stand. Stand growing stock of each plot was calculated as the sum of the volumes of individual trees using volume equations (Petráš, Pajtík 1991) for particular species. Formulas containing individual coefficients to accurately determine the volume of the tree were applied using MS Excel (Version 15.0.4805.1003, 2013). The differences between the diameters of spruce trees were separately tested by one-way ANOVA in the STATISTICA software (Version 12, 2013). Significant differences were subsequently tested by post-hoc comparisons using Tukey's HSD tests. Their significance was tested on the level α = 0.05.

Soil sampling and analysis. If possible, the forested soil samples were compared with the samples

Table 1. Description of permanent plots

Plot No.	Plot name	Main tree species	Age (yr)	Altitude (m a.s.l.)	Forest site type	Growing stock (LHP) (m^3·ha^{-1})	Rotation/regeneration length (LHP) (yr)	Soil samples
1	U Kostela	*Picea abies* (Linnaeus) H. Karsten	61	620	6S1	427	100/40	yes
2	Olše	*Alnus incana* (Linnaeus) Moench	60	680	6O1	209	120/40	yes
3	Smrky nad Olšemi	*Picea abies* (L.) Karst.	61	690	6S4	345	100/40	yes
4	Modříny	*Larix decidua* Miller	64	750	6S1	412	110/40	yes
5	Vysoký Kořen	*Picea abies* (L.) Karst.	106	760	6K5	448	110/40	no
6	U Cesty přátelství	*Betula pendula* Roth, *Fraxinus excelsior* Linnaeus	56	660	6D2	268	110/40	yes
7	U Elišky	*Picea abies* (L.) Karst.	55	710	6S4	145	100/40	no
		Betula pendula Roth	62	710	6S4	118	120/40	

LHP – data from the forest management information system of meadow soil taken in adjacent grassland (1A, 2A, 6A) (Table 2).

Soil samples were taken with a soil auger of 6.5 cm in diameter. Four composite soil samples were collected on each plot. One composite soil sample consisted of five soil cores. Each sample was divided into: organic horizon (litter, fragmented and humus), organomineral horizon (Ah) according to the actual depth and mineral horizon, designated as B, 10 cm thick. A subsequent laboratory analysis was performed by the "Tomáš" laboratory in Opočno according to standard methodologies used:

(*i*) dry matter amount in holorganic horizons ($t \cdot ha^{-1}$) at 105°C;

(*ii*) active (in water) and exchangeable pH in 1N KCl, potentiometrically, 1:10 ratio in humus and 1:5 ratio in mineral horizons;

(*iii*) characteristics of the soil adsorption complex determined by Kappen (1929) (base content – S, base saturation of adsorption complex – BS);

(*iv*) total nutrient content after mineralization of holorganic horizons using the mixture of sulphuric acid and selenium for mineralization (N, P, K, Ca, Mg) (Zbíral 2001);

(*v*) total oxidizable carbon (humus after calculation) and nitrogen content (N) by the Kjeldahl method;

(*vi*) content of plant available nutrients (P, K, Ca, Mg) by Mehlich III method.

Multifactorial analysis of variance was used at a significance level of 95% (STATISTICA 12.1, 2013) followed by Tukey's tests to recognize significant differences between areas. Comparisons were done for corresponding horizons.

RESULTS AND DISCUSSION

Growing stock of stands on sample plots

Plot 3 – an even-aged pure Norway spruce stand without admixture of other tree species – reaches the highest stand growing stock (851 $m^3 \cdot ha^{-1}$). In contrast, the growing stock of Norway spruce stand on plot 5, located on the original forest soil and in comparable climatic conditions, has reached only 586 $m^3 \cdot ha^{-1}$ of standing volume in 106 years. Plot 4 with predominant European larch has only 447 $m^3 \cdot ha^{-1}$. On the plot, larch is dominant and codominant, while the gaps are filled with other tree species, Norway spruce being in the subdominant position though with negligible production importance. The plot is not a substantially exploited production area. The growing stock on plot 6 is 313 $m^3 \cdot ha^{-1}$. It is a mixed broadleaved stand with no silvicultural interference; numerous trees are of small growth. The growing stock on plot 7 was dominated by Norway spruce as the main species, but it was gradually overgrown by birch and the growing stock is 406 $m^3 \cdot ha^{-1}$ in total.

The growing stock of stands on former agricultural land was compared with the standard volume

Table 2. Overview of analysed soil samples

Plot No.	Plot name	Land use	Dominating tree species	Altitude (m a.s.l.)
1	U Kostela	forest soil	*Picea abies* (Linnaeus) H. Karsten	620
1A	U Kostela meadow	grassland	–	620
2	Olše	forest soil	*Alnus incana* (Linnaeus) Moench	680
2A	Olše meadow	grassland	–	680
3	Smrky nad Olšemi	forest soil	*Picea abies* (L.) Karst.	690
4	Modříny	forest soil	*Larix decidua* Miller	750
6	U Cesty přátelství	forest soil	*Betula pendula* Roth, *Fraxinus excelsior* Linnaeus	660
6A	U Cesty přátelství meadow	grassland	–	660

Table 3. Data of sample plots in stand growing stock (before thinning)

Plot No.	Age (yr)	DBH (cm)	Height (m)	Stem volume (m^3)	Number of trees per ha	Basal area ($m^2 \cdot ha^{-1}$)	Stand volume ($m^3 \cdot ha^{-1}$)
1	61	42.8	29.9	1.73	392	56.3	678
2	60	27	23.5	0.554	732	41.8	405
3	61	40	28.6	1.52	560	70.5	851
4	64	35.6	26.5	0.998	448	44.6	447
5	106	43.4	28.6	1.723	340	50.4	586
6	56	17.2	12.9	0.191	1,640	38.3	313
7	55	21.8	16.7	0.29	1,400	52.1	406

defined in the official yield tables (Černý et al. 1996). The yield tables provide data for monocultures; therefore, mensurational data on the plots were recalculated for 100% one-species composition. The comparison is presented in Table 4.

The stand growing stock of all permanent plots with Norway spruce as prevailing species (plots 1 and 3) is significantly higher than in the yield tables. Higher production of spruce stands on former agricultural land was confirmed by other authors as well (Bartoš et al. 2006; Podrázský, Procházka 2009; Podrázský et al. 2011). Only plot 4 shows different results as the main species is European larch, not Norway spruce. A similar situation is on plot 7 where birch is the dominant species, and Norway spruce is, again, in the subdominant position, suffering from lack of light and slow dying. Birches manifest their pioneering character by the typical rapid initial growth (Vacek et al. 2009).

Fig. 1 shows differences in the mean diameter of Norway spruce between all plots. As mentioned above, permanent research plot 4 (27.2 ± 1.91 cm) and plot 7 (19.4 ± 0.62 cm) performed the lowest diameter and they are significantly different. The highest mean diameter was found on permanent research plot 5 (44.1 ± 1.04 cm) with 106-years-old Norway spruce stand on forest land. However, 61-years-old Norway spruce growing on former agricultural land on permanent research plots 1 (43.0 ± 1.03 cm) and 3 (40.8 ± 0.79 cm) has also high mean diameter and statistically insignificant differences from 106-years-old Norway spruce in the same climatic conditions.

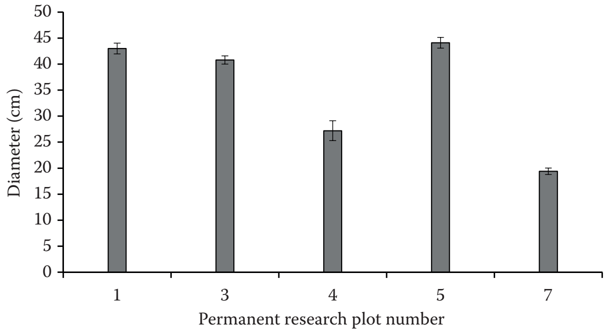

Fig. 1. Norway spruce mean diameter on permanent plots

Soil properties

An important factor that determines total restoration of the forest environment on former agricultural land is the restoration of typical forest soil, in particular the formation of typical forest floor humus (Green et al. 1993; Kacálek et al. 2007; Podrázský, Remeš 2008).

Results of analyses of surface humus top layers, total content of humus and total nitrogen in the upper horizons are presented in Table 5. In corresponding pairs, afforested areas exhibited higher accumulation of surface humus compared with non-forest soils, which was confirmed by other studies (Podrázský, Procházka 2009; Hatlapatková, Podrázský 2011). Statistically, the results are significantly different. Substantially higher accumulation of surface humus occurs mainly in coniferous forests (Podrázský, Kupka 2011), Norway spruce in our case. High accumulation of surface humus in Norway spruce stands was also confirmed by other authors (Berger, Berger 2012).

On the other hand, the litterfall of the European larch, which produces smaller quantities of litter, resulted in lower total humus accumulation, which was also confirmed by Podrázský and Štěpáník (2002). Broadleaved species showed rather large accumulation of holorganic horizons, however, the top layer is significantly mixed with mineral particles. The total content of humus in holorganic layers on plots 6 and 6A was less than half compared with the other plots; these values are close to the

Table 4. Comparison of measured and tabular (model) stand characteristics

Plot	Age (yr)	DBH (cm)	Height (m)	Increment ($m^3 \cdot ha^{-1} \cdot yr^{-1}$)	Spruce share in stand (%)	Growing stock ($m^3 \cdot ha^{-1}$)	Stocking
Official growth tables	60	27	27	9.6	100	578	1
PRP No. 1 spruce	61	44	30	11.8	81	717	1.24
PRP No. 3 spruce	61	40	30	14.0	100	851	1.47
PRP No. 4 spruce	64	27	18	6.8	15	433	0.75
Official growth tables	105	40	35	8.1	100	849	1
PRP No. 5 spruce	106	44	30	6.5	83	690	0.81
Official growth tables	55	25	25	9.7	100	534	1
PRP No. 7 spruce	55	19	15	5.3	78	294	0.41

PRP – permanent research plot, growing stock is for 100% of spruce

Table 5. Fundamental soil characteristics of top layer horizons on permanent plots

Plot No.	Plot name	Horizon	Dry matter ($t \cdot ha^{-1}$)	Total humus (%)	Total N (%)	pH (H_2O)	pH (KCl)	S ($meq \cdot 100\ g^{-1}$)	BS (%)
1	U Kostela	OF + OH	61.72^{b}	48.46^{b}	1.40^{b}	3.83^{b}	3.08^{b}	22.0^{a}	30.0^{b}
		Ah	–	8.13^{b}	0.40^{b}	3.82^{b}	3.52^{b}	4.4^{b}	20.7^{b}
		B		4.72^{b}	0.27^{b}	4.12^{b}	3.98^{b}	3.4^{b}	25.6^{b}
1A	**U Kostela meadow**	**OF + OH**	**36.86^{c}**	**56.83^{b}**	**1.30^{b}**	**4.76^{c}**	**4.05^{c}**	**17.2^{a}**	**46.0^{c}**
		Ah	**–**	**7.94^{b}**	**0.44^{b}**	**4.55^{c}**	**4.13^{c}**	**5.9^{c}**	**36.3^{c}**
		B		**4.29^{b}**	**0.30^{b}**	**4.61^{a}**	**4.29^{c}**	**5.1^{c}**	**41.5^{c}**
2	Olše	OF + OH	64.88^{b}	46.40^{b}	1.82^{c}	4.02^{b}	3.53^{b}	24.7^{a}	31.8^{b}
		Ah	–	13.34^{c}	0.66^{c}	3.57^{b}	3.45^{b}	6.4^{c}	23.1^{b}
		B		6.76^{c}	0.30^{b}	3.87^{c}	3.7^{a}	4.6^{b}	23.8^{b}
2A	**Olše meadow**	**OF + OH**	**39.10^{b}**	**24.17^{c}**	**1.23^{b}**	**4.72^{c}**	**4.36^{c}**	**23.5^{a}**	**57.5^{c}**
		Ah	**–**	**5.67^{a}**	**0.37^{b}**	**4.48^{c}**	**3.8^{a}**	**5.3^{bc}**	**35.8^{c}**
		B		**3.18^{a}**	**0.24^{c}**	**4.7^{a}**	**3.89^{b}**	**4.4^{b}**	**35.6^{c}**
3	Smrky nad Olšemi	OF + OH	74.35^{b}	45.67^{b}	1.22^{b}	3.67^{b}	3.12^{b}	12.0^{a}	18.2^{b}
		Ah	–	11.60^{c}	0.47^{b}	3.69^{b}	3.5^{b}	4.8^{bc}	21.0^{b}
		B		5.93^{c}	0.33^{bc}	3.89^{c}	3.82^{b}	3.7^{b}	23.7^{b}
4	Modříny	OF + OH	54.00^{b}	28.93^{c}	1.00^{a}	3.9^{b}	3.54^{b}	18.5^{a}	35.5^{bc}
		Ah	–	6.29^{a}	0.28^{a}	3.82^{b}	3.32^{b}	3.3^{a}	20.8^{b}
		B		3.05^{a}	0.25^{bc}	4.3^{b}	3.81^{b}	2.0^{a}	20.4^{b}
6	U Cesty přátelství	OF + OH	85.71^{a}	18.46^{c}	0.89^{a}	4.39^{a}	4.16^{a}	16.5^{a}	45.6^{c}
		Ah	–	6.51^{a}	0.39^{b}	4.36^{c}	3.65^{b}	4.3^{ba}	27.4^{a}
		B		3.06^{a}	0.22^{c}	4.59^{ca}	3.87^{b}	3.4^{b}	28.5^{b}
6A	**U Cesty přátelství meadow**	**OF + OH**	**127.46^{c}**	**16.21^{c}**	**0.84^{a}**	**4.7^{c}**	**4.26^{c}**	**19.3^{a}**	**53.8^{c}**
		Ah	**–**	**6.06^{a}**	**0.39^{b}**	**4.63^{c}**	**3.84^{a}**	**6.3^{a}**	**38.8^{c}**
		B		**4.16^{b}**	**0.27^{bc}**	**4.78^{a}**	**3.94^{b}**	**5.8^{c}**	**41.5^{c}**

OF – organic fragmented horizon, OH – organic humus horizon, Ah – organomineral horizon, B – mineral horizon, statistically significant differences between particular plots for corresponding horizons are indicated with different indexes, grassland plots in bold, S – base content, BS – base saturation of adsorption complex

limit between holorganic and organomineral horizon (Šály 1978).

The content of total humus in mineral soil horizons was significantly higher in the alder stand on plot 2 and under Norway spruce (plot 3) but, at the same time, lower under Norway spruce on plot 1, the lowest under the canopy of broadleaved species and similar on grassland plots (with one exception of plot 1A). This seems to indicate rapid decomposition of litter under broadleaved trees and in the grass with poor incorporation of organic matter into deeper soil horizons. Overall, the grassland soils tend to have the lower total humus content in comparison with forest (Kacálek et al. 2007, 2011; Hatlapatková, Podrázský 2011; Hiltbrunner et al. 2013) within mineral and organomineral horizons.

The total nitrogen content was significantly higher under the alder (plot 2), which corresponds with its ability to bind nitrogen in symbiosis with nitrogenous bacteria (Brooks, Benson 2016). On the other hand, low levels of total nitrogen under larch correspond with the poor quality of litter when compared with other tree species, which was confirmed in other studies (Podrázský 2008). The significantly lower total nitrogen content was found in broadleaved stands, which is caused by intense uptake of this nutrient by broadleaved trees; it has been documented in another study by Podrázský and Remeš (2010).

Active soil reaction (pH_{H_2O}) was significantly lower on the permanent plots on former agricultural land as compared with the grassland soil; it was confirmed by further comparisons of afforested agricultural land and grassland (Podrázský et al. 2011) for most of the soil profile (Table 5). A mixed broadleaved stand comes in-between the coniferous forests and former agricultural land. Norway spruce is the most soil-acidifying tree species, as confirmed by other authors (Podrázský, Štěpánik 2002; Ritter et al. 2003; Hagen-Thorn et al. 2004; Kanerva, Smolander 2007). Identical trends occurred in case of the potential soil reaction (pH_{KCl}); again, stronger acidity was dem-

Table 6. The content of available nutrients in horizons in the leachate (Mehlich III methods)

Plot No.	Plot name	Horizon	P (mg·kg^{-1})	K (mg·kg^{-1})	Ca (mg·kg^{-1})	Mg (mg·kg^{-1})
		OF + OH	50.0^{b}	265.5^{b}	995.5^{b}	157.5^{b}
1	U Kostela	Ah	21.3^{b}	74.0^{b}	204.3^{b}	47.8^{b}
		B	12.0^{b}	33.5^{b}	189.8^{b}	30.5^{b}
		OF + OH	**109.0^{c}**	**687.5^{c}**	**859.5^{b}**	**209.0^{b}**
1A	U Kostela meadow	Ah	**11.3^{b}**	**93.0^{b}**	**229.0^{b}**	**40.3^{b}**
		B	**8.8^{b}**	**35.5^{b}**	**206.0^{b}**	**20.0^{b}**
		OF + OH	83.5^{c}	702.0^{c}	1,458.0^{c}	318.5^{b}
2	Olše	Ah	15.3^{b}	166.3^{c}	361.5^{c}	67.5^{c}
		B	5.3^{b}	71.3^{c}	224.5^{b}	39.0^{b}
		OF+OH	**166.0^{a}**	**1,113.0^{a}**	**1,277.5^{a}**	**348.0^{b}**
2A	Olše meadow	Ah	**62.8^{c}**	**81.8^{b}**	**368.0^{c}**	**42.5^{b}**
		B	**44.8^{c}**	**41.5^{b}**	**296.8^{c}**	**30.3^{b}**
		OF + OH	465^{b}	198.5^{b}	998.5^{b}	141.5^{b}
3	Smrky nad Olšemi	Ah	22.0^{b}	68.5^{b}	239.3^{bc}	51.8^{b}
		B	14.8^{c}	28.8^{b}	171.8^{b}	34.5^{b}
		OF + OH	64.0^{c}	493.0^{c}	1,183.0^{b}	186.0^{b}
4	Modříny	Ah	28.8^{b}	63.5^{b}	260.3^{bc}	35.0^{a}
		B	18.8^{b}	41.0^{b}	212.0^{b}	23.5^{c}
		OF + OH	73.0^{c}	629.5^{c}	1,216.5^{a}	182.0^{b}
6	U Cesty přátelství	Ah	16.8^{b}	124.5^{bc}	260.0^{bc}	38.3^{bc}
		B	13.3^{b}	73.3^{c}	186.0^{b}	21.5^{c}
		OF + OH	**70.5^{c}**	**597.5^{c}**	**1,031.0^{b}**	**245.0^{b}**
6A	U Cesty přátelství meadow	Ah	**10.5^{b}**	**87.3^{b}**	**343.5^{c}**	**49.8^{b}**
		B	**3.3^{b}**	**43.5^{b}**	**333.5^{c}**	**36.5^{b}**

OF – organic fragmented horizon, OH – organic humus horizon, Ah – organomineral horizon, B – mineral horizon, statistically significant differences between particular plots for corresponding horizons are indicated with different indexes, grassland plots in bold

onstrated in case of forest stands compared with grassland (Hatlapatková, Podrázský 2011). The results in the mineral soil horizon B did not differ significantly between plots. Even in this case, the strongest acidification occurred in deeper horizons in the alder stand depending on strong nitrification and nitrate leaching.

The base content (S value) in the soil of forest stands in holorganic horizons compared with grassland did not differ significantly, the trend of lower values on permanent plots 6 and 6A was not significantly different. In the grassland and in the alder stand, there was a tendency of higher S values also in the upper mineral horizon (Ah); the differences were significant. On the other hand, the larch stand showed the lowest value of all the surveyed plots. This tendency remained unchanged in the B mineral horizon. The saturation of the sorption complex with bases (BS value) in the humus horizon has clearly and significantly lower values in forest stands in comparison with agricultural soils, which was confirmed by other studies (Podrázský et al. 2011).

The contents of plant available nutrients, which are documented in Table 6, were considerably variable, reflecting the impact of different types of vegetation, and also the influence of fertilization and other management interventions on agricultural land. Pronounced seasonal variability of these characteristics cannot be ruled out. The content of available P in holorganic horizons of grassland appeared to tend to lower values in forest stands. Different tendency was evident only in case of the last pair of plots, i.e. plots 6 and 6A, with the broadleaved species. The lower P content under the canopy of broadleaved species was reported in other studies (Podrázský et al. 2011). But overall, the content of P is higher compared with forest stands. That can be attributed to ameliorative efforts in the past (Falkengren-Grerup et al. 2006; Kacálek et al. 2011). The same applies to the content of available K and Mg; in case of these nutrients, the differences were not statistically significant. The content of available Ca appeared to have an opposite tendency.

The results were highly variable and ambiguous in the Ah horizon. On plot 1, the content of available P was insignificantly higher in the Norway spruce stands in comparison with the meadow, on plot 6 the situation was similar, but opposite to that of plots 2 and 2A. The plant available K content was different; in the first location, the content was higher under grass, but on all other plots, the forest stands showed higher levels of K content with the exception of the European larch. Meadows tend to have a higher content of available Ca, forests (with the exception of plots 6 and 6A) have a higher content of Mg.

The dynamics of plant available P in the B horizon was similar to the Ah horizon. The available K values were significantly higher under broadleaved trees. Meadows showed a significantly higher content of plant available Ca, while the forests have a higher content of Mg. This general trend was disrupted in larch stands where plot 6 was somewhat different from the other plots most probably due to the geographic distance.

CONCLUSIONS

The present study documents the development of soil environment and production of forest stands on former agricultural land in the Orlické hory Mts. All investigated permanent plots showed the high accumulation of biomass; the growing stock of approximately 61-years-old Norway spruce forests on permanent research plots number 1 (717 $m^3 \cdot ha^{-1}$) and 3 (851 $m^3 \cdot ha^{-1}$) reached significantly higher values than the reference 106-years-old stand of the forest land (690 $m^3 \cdot ha^{-1}$) and also in comparison with yield tables (578 $m^3 \cdot ha^{-1}$) established for 60-years-old Norway spruce forest. Spruce is the species with the highest production potential. Stands of broadleaved trees here show substantially lower production, as well as the European larch stand with Norway spruce in the subdominant position.

In terms of the conversion of the original agricultural soils, extensive accumulation of humus in Norway spruce stands has been documented. It reached the values typical of forest stands with similar species composition and habitat conditions, growing on "permanently" forested sites. The tendency of higher soil acidity in forest stands was also confirmed, which is the result of nutrient uptake and high accumulation in the aboveground biomass and litter which is generally more acidic compared with grassland. The phenomenon is associated with lower values of base content and saturation of the sorption complex with bases on the afforested agricultural land, thanks to the increased uptake and accumulation of bases from the soil and their storage in the aboveground biomass of stands.

The content of available nutrients on permanent plots was highly variable, which is most likely caused by fertilization and other management interventions on the former agricultural land. The full assessment of the functional effects of forests in terms of the soil-forming function is of interest for further research investigating an even longer time interval from afforestation.

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