Soil conditions of black walnut (*Juglans nigra* L.) stands in the alluvium of the Svratka and Jihlava rivers

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ABSTRACT: Physical, chemical and microbiological properties of soils were studied in black walnut (*Juglans nigra* L.) stands and compared with those in stands of natural species composition, in mixed stands of black walnut with linden and in pure oak stands. The objectives were to consider a possibility of black walnut planting at floodplain sites in the alluvial area of Southern Moravia. The first results did not show any worsening of soil properties and soil production potential. A positive amelioration effect of soil-improving species was proved in black walnut stands.

Keywords: black walnut; soil condition; alluvium of the Svratka and Jihlava rivers; Czech Republic

Black walnut (*Juglans nigra* L.) is an introduced North-American tree species that has been cultivated in Europe for more than 300 years. The relatively extensive original range of black walnut covers Eastern and Central parts of North America. Forest management of black walnut can be traced first in Ruhrland, Germany and in the area around Strasbourg, France. Within the territory of the Slovak Republic, black walnut stands were cultivated in warmer areas of Southern and Western Slovakia, predominantly in lowlands and along the Váh, Hron and Nitra rivers. The largest areas of man-made black walnut plantations are encountered in the lower reaches of the Hron river, about 43 ha in the vicinity of Želiezovce (Májovský, Krejča 1965).

In the Czech Republic, black walnut is cultivated only in Southern Moravia, in Židlochovice management-plan area, Strážnice management-plan area and in Znojmo forest district. In these areas black walnut replaced the original *Ulmeto-Fraxineta* communities. The tradition of black walnut cultivation in South Moravian forests boasts 200-years-old history. The stands are either cultivated as monocultures or as mixed stands with the understorey of small-leaved linden (*Tilia cordata* L.). According to the Forest Management Plan data the total area of black walnut stands in Židlochovice Forest Enterprise takes up 258 ha of timber land (reduced area). Almost three fifths (154 ha) of the total area of black walnut stands are encountered on the alluvia of the Svratka and Jihlava rivers. The peak of black walnut cultivation can be traced back to the 1940s and 1950s. The total area of black walnut stands managed by the Forests of the Czech Republic, State Enterprise, in the territory of the Czech Republic takes up 526 ha of reduced area.

More than 80% of black walnut stands were planted at sites that can be classified as 1L forest type – elm floodplain forest (Hrib 2001). Within this group of forest types we can encounter the following forest types most frequently: *Ulmeto-Fraxineta carpinea* on drift brown soil (1L2), on light-textured drift soil (1L4), on heavy-textured drift soil (1L1), even on heavy-textured gley soil (1L9). Almost one half (47.1%) of the present stand area falls into the category of special purpose forests – pheasantries. The majority of stands were sown and agroforestry was implemented simultaneously. Taking into account the generally low proportion of black walnut stands in the forests in the Czech Republic and considering the possibility of alternative use of black walnut in place of imported exotic species, we expect the extension of its stands in localities with favourable site conditions.

The aim of this project was to evaluate soil conditions in black walnut stands. We also tried to answer a question whether the long-term cultivation of black walnut at sites

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Table 1. Characteristics of test sites for soil sampling (sampling on July 21, 2001)

Site	Group	Bore-hole	Alluvium	Stand	Tree species	Age	Percentage of tree species (%)	Diameter at breast height (cm)/ height (m)	Stock 1 ha (m^3 o.b.)	Stand density – stocking	Forest type
1	1	+	Svratka	126 F 11	DB	104	75	56/29	257	7	1L2
					JS		20	49/30	55		
					TP		5	60/31	17		
2		+	Svratka	126 F 6	ORC	53	95	32/26	346	10	1L2
					LP		5	23/22	14		
3		–	Svratka	126 F 6	ORC	53	100	32/26	346	10	1L2
4	2	+	Svratka	125 B 6b	ORC	55	100	30/27	381	10	1L2
5		+	Svratka	125 B 6c	ORC	55	95	30/27	362	10	1L2
					LP		5	20/20	12		
6		–	Svratka	125 B 6a	DB	55	100	29/25	339	10	1L2
7	3	+	Jihlava	224 C 10	DB	100	98	53/32	486	9	1L4
					JS		2	56/32	8		
8		+	Jihlava	224 D 10	ORC	100	100	49/31	516	10	1L2
9	4	+	Jihlava	224 F 3b	DB	26	100	13/15	102	10	1L4
10		+	Jihlava	224 C 2	ORC	20	100	11/13	104	10	1L2

Note: DB – oak; JS – ash; TP – poplar; ORC – black walnut; LP – linden

belonging to the group of 1L forest type does not result in the deterioration of soil quality and whether it does not cause the deterioration of soil production potentials.

MATERIAL AND METHODS

SITE CHARACTERISTICS

Forest stands that were chosen for comparative tests belong to Židlochovice Forest Enterprise. They are situated on the alluvia surrounding the confluence of the Svratka and Jihlava rivers. The matrix in these localities consists of alluvial sediments that provided the base for Fluvisol formation.

With the objective of carrying out our tests, we determined 10 sites differing in age (young, middle-age and mature stands) and in species composition (pure black walnut stands, mixed stands of black walnut and linden, pedunculate oak monocultures, to provide a double check, we included stands of natural species composition with dominant oak and ash). Table 1 gives a full list of test sites.

Sites 1–6

Židlochovice Forest District, Forest Range: Uherčický les pheasantry

The Svratka river alluvium

- altitude: 175–180 (200) m above sea level
- area percentage of the main tree species cultivated in the forest district: oak 33%, ash 11%, black walnut 10%, poplar 10%
- main commercial, most frequently represented species: oak, ash, black walnut, poplar
- dominant group of forest types in the forest range: 1L (about 5% of 1G)
- mean annual air temperature: 8.4°C
- mean temperature in the vegetation period (April–September): 14.8°C
- mean annual precipitation: 551 mm
- mean precipitation in the vegetation period (April–September): 350 mm.

Sites 7–10

Velký Dvůr Forest District, Dlouhá leč Forest Range

The Jihlava river alluvium

- altitude: 169–177 (198 m) m above sea level
- area percentage of the main tree species cultivated in the forest district: oak 25%, poplar 19%, robinia 17%, ash 12%, black walnut 5%
- main commercial, most frequently represented species: oak, ash, black walnut, poplar
- dominant group of forest types in the forest range: 1L (about 4% of 1G)
- mean annual air temperature: 9°C
- mean temperature in the vegetation period (April–September): 15.6°C
- mean annual precipitation: 499 mm
- mean precipitation in the vegetation period (April–September): 319 mm.

SAMPLING

At two sites in each group, soil pits were dug out, their description was carried out and physical samples were

Table 2. Extent of analyses and numbers of samples

Parameters	Number of individually analysed samples
Digging and description of boreholes	8
Soil texture characteristics	8
Physical properties (undisturbed samples)	16
pH	40
Available nutrients (P, K, Mg, Ca, Mehlich III)	40
Total nutrients	40
C_{ox}	40
C, N	40
Respiration activity	10
Nitrification activity	10
Aerobic bacteria – nutritive agar	10
Aerobic bacteria – starch agar	10
Aerobic bacteria – Thornton's agar	10
Actinomycetes – starch agar	10
Actinomycetes – Thornton's agar	10
Micromycetes – Jensen's agar	10

taken from diagnostic horizons. The groups represent stands of comparable age situated at comparable sites.

For analytic purposes 3–5 composite samples were taken from each site, each weighing about 2 kg. A composite sample consisted of five individual samplings in the area of about 100 m^2. Individual samples were taken from the humus horizon (horizon A) in such a way that the entire thickness of the horizon was represented. At chosen sites samples for chemical analyses were taken from the subsurface horizons of the pit.

For microbiological and biochemical analyses a composite sample was taken at each site from 5 different sampling places. Table 2 gives a list of analysed samples and the extent of individual analyses.

Disintegrated samples were dried up and screened into fine earth < 2 mm. Nondisintegrated physical samples were taken from the A1n and M1 horizons and analysed immediately upon sampling. Samples for microbiological and biochemical analyses were put in plastic bags and stored in a portable refrigerator and transported into the laboratory. Analyses of these samples were launched within 24 hours at the latest.

LABORATORY ANALYSES

Activity of hydrogen ions (pH) was measured in a soil suspension by a glass ion selective electrode.

Content of available nutrients was determined by Mehlich III method (ZBÍRAL 1995): soil was extracted with a solution containing ammonium fluoride and ammonium nitrate, the acidity of the solution was adjusted by acetic and nitric acid. The extraction solution simulates well the availability of nutrients in the soil to plants. After eliminating undesired impacts by adding lanthanum, the concentration of magnesium and calcium in the extract was determined by the method of atomic absorption spectrophotometry. The concentration of potassium was determined by flame photometry. The concentration of phosphorus was determined by spectrophotometry from molybdenum blue, following a reaction with molybdenum in an acid medium.

Content of total nutrients (P, K, Ca, Mg and others) was determined after the soil had been extracted with boiling aqua regia by the method of optical emission spectroscopy, by flame atomic absorption spectrophotometry or by spectrophotometry (in the case of phosphorus).

Content of carbon and nitrogen was determined by an automatic analyser LECO CNS-2000. After incinerating an exact charge of sample in 1,000°C in a blast of oxygen, the released elementary carbon and nitrogen convert into CO_2, NO_2 and NO_x and can be detected on infrared (CO_2) and heat-conductive (nitrogen oxides) cells.

Cation exchange capacity and exchange acidity

Cations bound in the sorption complex of soil are displaced during soil extraction with a dilute solution of barium bichloride. The contents of calcium, magnesium, potassium, sodium, aluminium, iron and manganese in the extract were determined by the ICP–AES method or the AAS method. The resulting cation exchange capacity was determined by adding the content of potassium, calcium, magnesium and sodium into the sorption complex of soil. The quotient of hydrogen ion saturation was determined by titration of the extract up to pH = 7.8 or from the aluminium, iron and manganese content.

Determination of biochemical parameters – basal microbial respiration

A sample of fresh soil (20 g) was incubated at 25°C for 48 hours in 300 ml NTS bottle over 20 ml H_2O and consequently for 24 hours over 20 ml of NaOH (c = 0.05 mol/l). The released CO_2 was determined by regressive (back) titration of HCl (c = 0.1 mol/l) to phe-

Table 3. Amount of nutrients and nutrient reserve in surface humus (sampling in February 2002)

	Site									
(kg/ha)	1	2	3	4	5	6	7	8	9	10
Amount	2,797	2,857	1,472	2,262	3,458	2,947	2,956	2,406	3,473	2,211
C	1,278	1,257	684	1,028	1,456	1,423	1,425	1,117	1,618	1,028
N	47.41	41.28	16.42	23.75	41.15	44.35	40.06	30.79	52.79	23.10
S	6.489	4.985	1.870	2.556	5.101	5.407	4.922	3.320	6.512	2.675
P	5.398	3.657	1.914	3.235	4.945	4.361	4.080	2.718	5.314	3.493
Ca	69.93	86.28	57.57	90.71	107.55	46.56	41.98	78.90	58.35	73.83
K	10.04	10.48	3.548	6.515	13.83	10.11	9.756	6.158	9.377	4.421
Mg	9.594	11.48	6.714	10.95	15.22	7.161	9.993	12.63	11.29	11.76
Fe	5.583	7.093	0.848	1.846	10.39	2.917	4.050	2.495	5.453	1.505
Mn	0.453	0.349	0.069	0.120	0.463	0.881	1.052	0.198	1.542	0.118
Zn	0.178	0.099	0.052	0.085	0.139	0.102	0.092	0.079	0.133	0.084
Cu	0.027	0.028	0.013	0.022	0.037	0.018	0.020	0.018	0.026	0.023

Note: (1) oak + ash + poplar, (2) black walnut + linden, (3) black walnut, (4) black walnut, (5) black walnut + linden, (6) oak, (7) oak, (8) black walnut, (9) oak, (10) black walnut

nolphthalein after the precipitation of barium carbonate with 2 ml of $BaCl_2$ (c = 0.5 mol/l). The result is in mg of carbon dioxide released from 100 g of soil per day.

Determination of biochemical parameters – nitrification test

A quantity of nitrates in the original fresh sample is determined. It helps assess oxidation processes in soil – the conversion of ammonium in nitrates.

Determination of nitrates was carried out in soil sample (eluted with 1% solution of aluminium-potassium sulphate) on an ion selective electrode by employing the method of direct potentiometry, using a calibration curve. The amount of nitrates is given in mg $N–NO_3^-$ in 100 g of dry matter.

Nitrification activity

A fresh sample (10 g) moistened with 3 ml of water was incubated at 25°C for two weeks. At the beginning and at the end of incubation the amount of nitrogen in ammonium and nitrates was determined. The rate of nitrification is expressed as an increase in nitrate nitrogen in the course of 8 days. Nitrification activity is expressed in mg NO_3 per 100 g of dry matter within one day.

Determination of microbiological parameters

The amount and qualitative composition of soil microflora was determined by indirect cultivation methods in nutrient media suitable for the most important physiological groups of the main soil microbe communities, specifically:

– aerobic bacteria on nutritive agar (NA)
– aerobic bacteria on Thornton's agar (TA)
– aerobic bacteria on starch agar (SA)
– micromycetes on Jensen's agar (JA)
– azotobacter on Ashby's agar (AA)
– actinomycetes on starch and Thornton's agar (SA, TA).

The detected counts for monitored groups of soil microorganisms were given per 1 mg of sample dry matter.

Microbiological analyses of soil samples were performed by the Agency of Nature and Landscape Protection in the CR, Brno Laboratory.

RESULTS AND DISCUSSION

Soils of the monitored area on the alluvia of the Svratka and Jihlava rivers, which house the largest area of black walnut stands in the Czech Republic, can be characterised as typical Fluvisol. Surface humus is in the form of mull. The total annual leaf fall in black walnut stands was determined in relation to the age of the respective stands from 1.47 to 2.41 t per ha per year, in mixed black walnut and linden stands it was 2.86 and 3.46 t per ha per year and in oak stands from 2.80 to 3.47 t per ha per year (Table 3). The amount of leaf fall is determined by the age of the stand rather than by its species composition (Fig. 1). According to KLIMO (1985), in a floodplain forest (Lednice

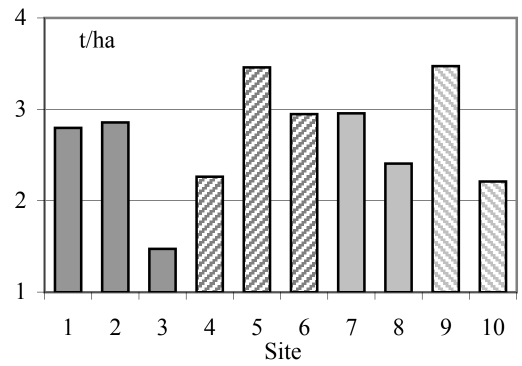

Fig. 1. The amount of leaf fall per year in individual sites
Note: 1 – oak + ash + poplar, 2 – black walnut + linden, 3 – black walnut, 4 – black walnut, 5 – black walnut + linden, 6 – oak, 7 – oak, 8 – black walnut, 9 – oak, 10 – black walnut

Table 4. Physical properties of soils at chosen sites (sampling on July 21, 2001)

Analyses	Unit	Site									
		1	2	3	4	5	6	7	8	9	10
Soil texture											
< 0.01 mm	(%)	28.60	18.80	32.50	27.80	32.70	38.50	16.80	25.40	28.30	23.90
0.01–0.05 mm	(%)	46.20	35.00	41.90	31.60	44.60	44.90	17.40	21.80	40.40	26.30
0.05–0.1 mm	(%)	22.60	23.80	18.20	12.50	18.10	14.80	9.90	14.50	19.30	11.80
0.1–2.0 mm	(%)	2.60	22.40	7.40	28.10	4.60	1.80	55.90	38.30	12.00	38.00
Soil density	g/cm^3	2.57	2.48	–	2.56	2.62	–	2.36	2.58	2.83	2.51
Reduced volume weight	g/cm^3	1.11	1.04	–	0.99	1.08	–	1.10	1.09	1.28	1.30
Porosity	% vol.	56.81	58.18	–	61.43	55.19	–	53.36	57.86	54.15	48.31
Max. capillary capacity	% vol.	41.03	39.35	–	39.21	41.48	–	37.65	42.83	42.66	45.45
Min. air capacity	% vol.	15.78	18.83	–	22.22	13.71	–	15.71	15.03	11.50	2.86
Actual moisture content	% vol.	26.84	31.84	–	30.76	35.64	–	30.38	37.51	35.95	40.31
Actual air content	% vol.	30.97	26.33	–	30.67	19.55	–	22.98	20.36	18.20	8.01
Relative moisture content	% vol.	65.45	80.98	–	78.08	85.94	–	80.48	87.57	84.21	87.96

(1) oak + ash + poplar, (2) black walnut + linden, (3) black walnut, (4) black walnut, (5) black walnut + linden, (6) oak, (7) oak, (8) black walnut, (9) oak, (10) black walnut

na Moravě) where oak (*Quercus* L.) at the age of 85–104 years was a dominant species and linden (*Tilia cordata*) at the age of 51–56 years and ash (*Fraxinus* ssp.) at the age of 85–88 years were associated species the leaf fall was 5.65 t per ha/year.

The leaf decomposition is fast, virtually all the leaves decompose fully within a year. GRUNDA (1985) found out that 75% of leaf mass in a floodplain forest decompose within a year while the remaining 25% come in the form of cellulose which decomposes gradually. Leaves decompose in relation to the given tree species characteristics, climatic conditions and the quantity and quality of the respective phytoedaphon. Under black walnut stands (sites 3, 4, 8, 10), provided that all the leavesfully decompose, the following amount of nutrients gets into the soil: 16.4–30.8 kg/ha N, 57.6–90.7 kg/ha Ca, 3.5–6.5 kg/ha K, 6.7–12.6 kg/ha Mg and 1.9–3.5 kg/ha P. Under black walnut and linden stands (sites 2, 5) it amounts to 41.3 and 41.2 kg/ha N, 86.3 and 107.6 kg/ha Ca, 10.5 and 13.8 kg/ha K, 11.5 and 15.2 kg/ha Mg, 3.6 and 4.9 kg/ha P. Oak monocultures (sites 6, 7, 9) show the following data: 40.1–52.8 kg/ha N, 42.0–58.4 kg/ha Ca, 9.4–10.1 kg/ha K, 7.2–11.3 kg/ha Mg and 4.1–5.3 kg/ha P. In stands of natural species composition (site 1) the quantity amounts to 47.4 kg/ha N, 69.9 kg/ha Ca, 10.0 kg/ha K, 9.6 kg/ha Mg and 5.4 kg/ha P (Table 3).

The upper layers of soil to a depth of 10 cm have predominantly loamy texture, crumb structure and the remaining physical properties are balanced (Table 4). The relatively heavy soil at sites 3 and 5 and lighter soils at site 7 are an exception to the rule. The balanced physical soil properties are conditioned by soil preparation for forest regeneration: mostly whole-area soil preparation (subsoil ploughing) with initial stumping. Central parts of soil profiles have a predominantly loamy texture as well, but they are more compacted and their structure is rather polyhedral or prismatic. Lower parts of soil profiles have a predominantly clay-loam texture and show gleying. In several cases (sites 1, 2) the so-called buried soil horizons with higher content of humic agents were detected. The thickness of alluvial silts is more than 2 m and the groundwater level fluctuated between 148 and 267 cm in 2000, and between 129 and 221 cm in 2001.

Soil reaction in the Svratka river alluvium (sites 1–6) is neutral, with the exception of the pure oak stand at site 6, pH/H_2O values being slightly over 7. In the alluvium of the Jihlava river (sites 7–10) the soil reaction is almost neutral, pH values fall slightly under 7, with the exception of site 10 (Table 5). Black walnut cultivation for the period of 20–60 years did not result in the deterioration of soil reaction. On the contrary, statistically lower pH values were detected under oak monocultures (Fig. 2). C/N values (11.4–12.6) and C/P values (33.5–56.5) correspond to the L-Mull form of surface humus (MEIWES et al. 1986). The adsorption complex of the analysed soils (Table 5) is highly saturated (BS 78.6–91.6%) and the available nutrients are sufficiently abundant (Fig. 2). The total nutrient reserve in the upper soil layer to a depth of 10 cm, which is directly influenced by leaf fall and decomposition processes, is presented in Table 6. This table shows that within the first group of forest stands the highest content of total and available nutrients was detected under natural mixed stands (oak, ash, poplar), it was lower under black walnut and linden stands and the lowest values were detected under pure black walnut stands. In the second group of stands the nutrient conditions were more favourable in black walnut and linden stands (site 5) when compared with pure oak and black walnut stands. Similarly, in groups 3 and 4 soils under black walnut stands (sites 8, 10) were better supplied with

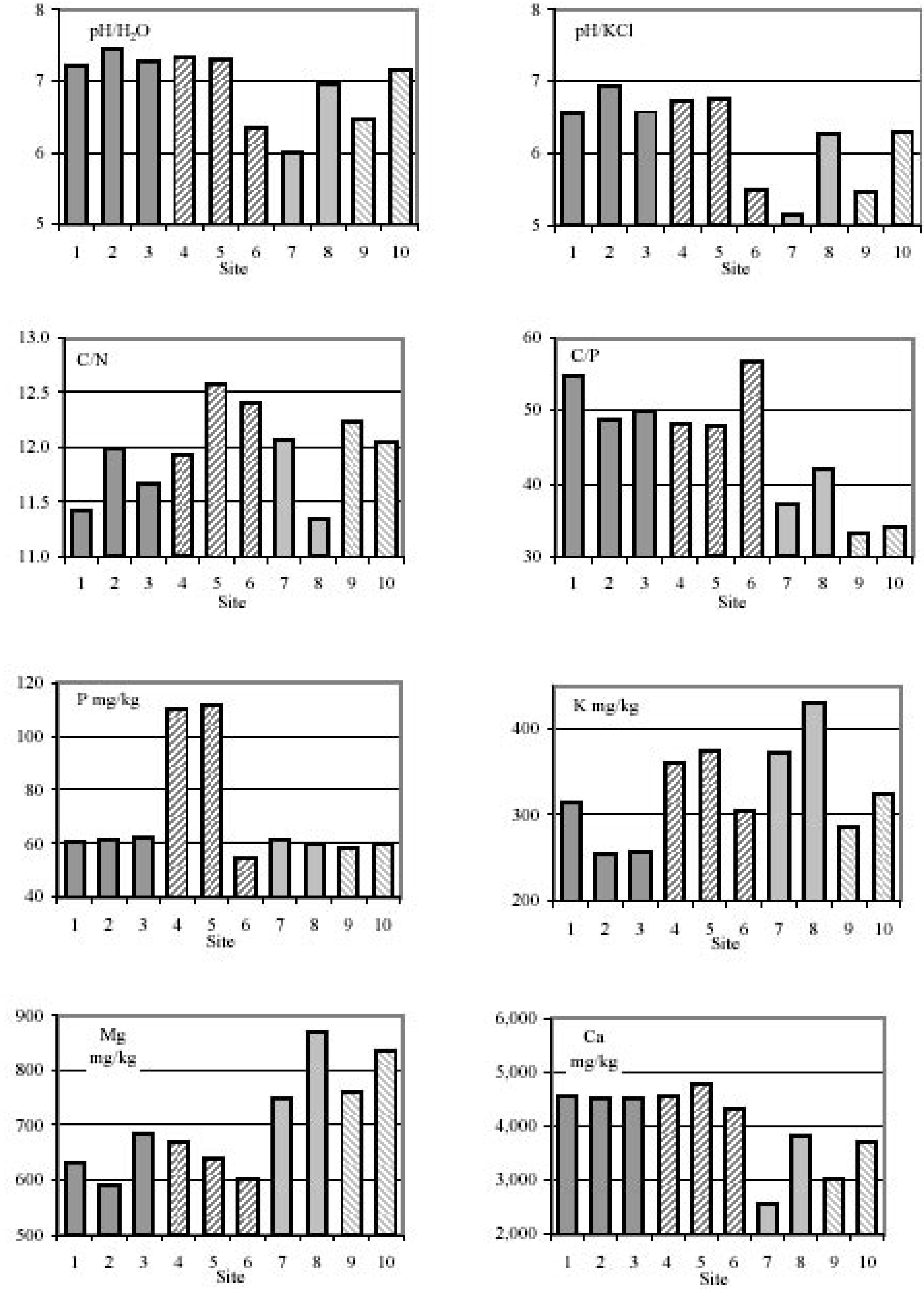

Fig. 2. pH, C/A, C/P ratios and available nutrients in 0–10 cm soil layer
Note: 1 – oak + ash + poplar, 2 – black walnut + linden, 3 – black walnut, 4 – black walnut, 5 – black walnut + linden, 6 – oak, 7 – oak, 8 – black walnut, 9 – oak, 10 – black walnut

Table 5. Chemical properties of soil samples, depth 0–10 cm (sampling on July 21, 2001)

Analyses	Unit	Site									
		1	2	3	4	5	6	7	8	9	10
pH/H_2O		7.21	7.45	7.26	7.33	7.31	6.35	6.01	6.96	6.47	7.15
pH/KCl		6.56	6.93	6.58	6.73	6.77	5.51	5.15	6.28	5.47	6.30
Total nutrients											
C	(% DM)	3.61	3.09	3.20	3.59	3.57	4.01	2.89	3.45	2.75	2.77
N	(% DM)	0.316	0.258	0.274	0.301	0.283	0.323	0.240	0.304	0.224	0.230
C/N		11.42	11.98	11.68	11.93	12.61	12.41	12.04	11.35	12.28	12.04
P	(g/kg)	0.66	0.63	0.64	0.74	0.74	0.71	0.78	0.82	0.82	0.81
C/P		54.7	49.0	50.0	48.5	48.2	56.5	37.1	42.1	33.5	34.2
Mg	(g/kg)	7.22	6.44	7.31	7.45	7.51	7.73	9.69	11.57	11.13	11.70
Ca	(g/kg)	7.40	7.64	7.37	7.72	7.83	6.16	4.53	6.38	5.57	6.43
K	(g/kg)	3.78	3.49	3.86	3.85	3.82	3.94	4.43	5.58	5.10	5.33
Fe	(g/kg)	26.6	22.7	27.5	26.7	26.4	29.2	27.2	31.0	26.6	29.5
Mn	(mg/kg)	672	655	709	749	809	780	771	847	816	850
Zn	(mg/kg)	106	93.9	108	115	129	118	104	117	109	112
Cu	(mg/kg)	38.2	32.5	35.6	30.3	33.6	29.1	22.6	27.2	24.4	26.4
Available nutr. – Mehlich III											
P	(mg/kg)	61	61	62	110	112	55	61	60	59	60
K	(mg/kg)	313	253	256	359	374	305	373	431	285	324
Mg	(mg/kg)	631	590	686	669	640	600	751	869	760	836
Ca	(mg/kg)	4,567	4,524	4,511	4,549	4,782	4,332	2,561	3,809	3,024	3,715
Available nutr. – Oxalate											
Fe	(g/kg)	4.24	3.74	4.24	4.09	4.63	4.68	4.30	4.64	4.21	4.68
Al	(g/kg)	1.27	1.16	1.29	1.14	1.28	1.40	1.23	1.18	1.19	1.26
Sorp. complex – Mehlich II											
H^+	(mmol eq/kg)	33	24	29	30	33	54	51	41	59	30
Ca	(mmol eq/kg)	224.9	214.2	223.3	219.2	232.8	208.9	128.4	185.9	147.2	183.1
Mg	(mmol eq/kg)	47.5	45.9	56.3	53.6	51.2	47.1	59.8	71.3	61.8	68.3
K	(mmol eq/kg)	7.03	5.85	6.47	8.50	8.69	7.06	8.59	10.7	6.60	7.70
KVK	(mmol eq/kg)	312.1	290.2	314.9	311.3	325.7	317.4	248.1	309.0	274.4	289.1
BS	(%)	89.53	91.64	90.84	90.36	89.86	82.88	79.32	86.70	78.57	89.62

(1) oak + ash + poplar, (2) black walnut + linden, (3) black walnut, (4) black walnut, (5) black walnut + linden, (6) oak, (7) oak, (8) black walnut, (9) oak, (10) black walnut

nutrients than those under oak monocultures. The order of tree species in relation to a decreasing nutrient reserve in soil is as follows: (oak + ash + poplar) > (black walnut + linden) > black walnut > oak. In most cases this order corresponds with the content of elements in leaf fall.

Potential respiration activity (Table 7) that measures the speed of decomposition of organic matter in soil does not show a definite trend in relation to the stand species composition.

The nitrification activity of soil micro-organisms in pure black walnut stands was always lower when compared with the other stands (Fig. 3). The counts of aerobic bacteria, which are dependent on the decomposition of nitrogen-containing organic matter, were higher under pure oak and black walnut stands than those under mixed stands. The counts of starch-eating and mineral nitrogen-eating bacteria fluctuated regardless of the respective tree species. The counts of aerobic bacteria exploiting nitrogen from NO_3 and carbon from amino acids and high alcohols fluctuated at individual sites as well, this group of micro-organisms being significantly abundant in pure oak and black walnut stands. The counts of actinomycetes were relatively low and did not show any significant dependence on the given tree species (Fig. 4). Azotobacter (as a free binder of atmospheric nitrogen) was not detected. The counts of micromycetes slightly increased in relation to soil acidity. The generally more favourable values of the monitored parameters in mixed stands of black walnut and linden evidence the significant soil improving function of linden. Experience from abroad verifies the favourable influence of interplanting black walnut with other species.

Table 6. The reserve of total and available nutrients in soil, depth 0–10 cm (sampling on July 21, 2001)

	Site							
(t/ha)	1	2	4	5	7	8	9	10
Total nutrients								
C	40.070	31.980	35.360	38.560	31.790	37.430	35.200	35.870
N	3.508	2.670	2.965	3.056	2.640	3.298	2.867	2.979
P	0.733	0.652	0.729	0.799	0.858	0.890	1.050	1.049
Mg	8.014	6.665	7.338	8.111	10.660	12.550	14.250	15.150
Ca	8.214	7.907	7.604	8.456	4.983	6.922	7.130	8.327
K	4.196	3.612	3.792	4.126	4.873	6.054	6.528	6.902
Fe	29.490	23.460	26.280	28.490	29.880	33.620	34.060	38.160
Mn	0.739	0.678	0.738	0.874	0.848	0.919	1.044	1.101
Zn	0.118	0.097	0.113	0.139	0.114	0.127	0.140	0.145
Cu	0.042	0.034	0.030	0.036	0.025	0.030	0.031	0.034
Available nutrients								
P	0.068	0.063	0.108	0.121	0.067	0.065	0.076	0.078
Mg	0.700	0.611	0.659	0.691	0.826	0.943	0.973	1.083
Ca	5.069	4.682	4.481	5.165	2.817	4.133	3.871	4.811
K	0.347	0.262	0.354	0.404	0.410	0.468	0.365	0.420

Note: (1) oak + ash + poplar, (2) black walnut + linden, (3) black walnut, (4) black walnut, (5) black walnut + linden, (6) oak, (7) oak, (8) black walnut, (9) oak, (10) black walnut

Interplanting black walnut with nitrogen-fixing woody species is expected to improve soil nitrogen fertility and thereafter to improve the growth of black walnut trees. Many trials with interplanting were made in America: DAWSON and VAN SAMBEEK (1993) interplanted black walnut (*Juglans nigra* L.) with four different nitrogen fixing woody nurse crops (*Alnus glutinosa, Elaeagnus umbellata, E. angustifolia* or *Caragana arborescens*). Interplanting increased walnut's annual height and stem diameter (dbh) growth by as much as 50% and doubled or tripled its crown volume compared with check plots. Walnut interplanted with non-nitrogen fixing, woody nurse crops (*Lonicera maackii*, *Acer ginnala* or *Pinus sylvestris*) did not grow significantly more than walnut in check plots. The results indicate that nitrogen fixing nurse crops can be superior to non-nitrogen fixing nurse crops in promoting walnut growth. Moreover, CAMPBELL and DAWSON (1988) evaluated interplanting black walnut with European black alder (*Alnus glutinosa*) or autumn olive (*Elaeagnus umbellata*) and their effects on the growth, yield and economic value of black walnut (*Juglans nigra*) plantations. Interplanting with nitrogen-fixing species increased the projected growth and yield of walnut in comparison with the check plot (pure walnut). Associated present values of black walnut were higher with autumn olive than those with black alder.

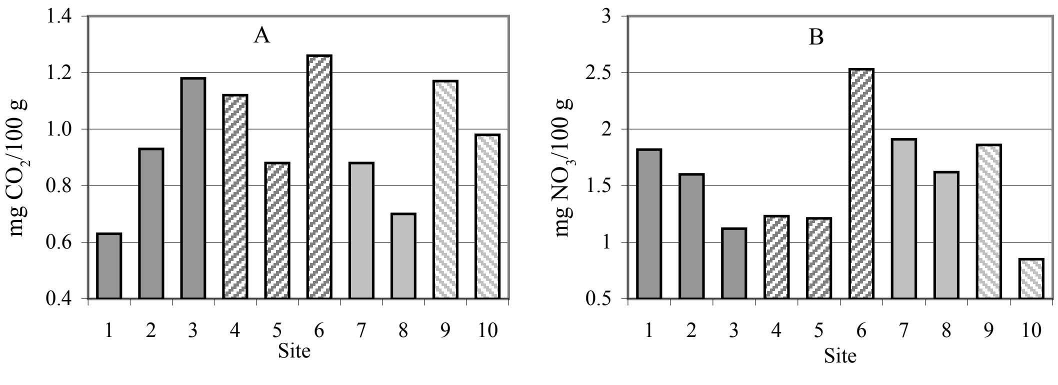

Fig. 3. Biological activity of soil microorganisms. A – respiration activity, B – nitrification test
Note: 1 – oak + ash + poplar, 2 – black walnut + linden, 3 – black walnut, 4 – black walnut, 5 – black walnut + linden, 6 – oak, 7 – oak, 8 – black walnut, 9 – oak, 10 – black walnut

Table 7. Microbiological analyses of soil samples (sampling on July 21, 2001)

Analyses	Unit	Site									
		1	2	3	4	5	6	7	8	9	10
Respiration activity	(mg CO_2/ 100 g/day)	0.63	0.93	1.18	1.12	0.88	1.26	0.88	0.70	1.17	0.98
Actual NO_3 content	(mg NO_3/ 100 g)	0.34	0.16	0.15	0.15	0.25	0.43	0.36	0.3	0.20	0.09
Nitrification activity	(mg NO_3/ 100 g/day)	0.23	0.20	0.14	0.15	0.15	0.32	0.24	0.20	0.23	0.11
Aerobic bacteria (NA)	(10^{-3}/g DM)	767	114	2,540	959	456	13,600	886	379	274	241
Aerobic bacteria (SA)	(10^{-3}/g DM)	1,520	343	1,930	1,030	1,310	1,320	2,930	3,220	1,690	300
Actinomycetes (SA)	(10^{-3}/g DM)	157	0.31	232	17.2	106	179	93.3	94.8	132	13.6
Aerobic bacteria (TA)	(10^{-3}/g DM)	313	1.56	654	103	88.5	187	373	895	1,610	911
Actinomycetes (TA)	(10^{-3}/g DM)	1.57	2.08	8.44	3.13	42.4	14.3	5.18	6.32	3.16	31.4
Micromycetes (JA)	(10^{-3}/g DM)	7.83	11.4	45.4	43.8	28.6	36.9	5.18	54.8	46.3	66.0

(1) oak + ash + poplar, (2) black walnut + linden, (3) black walnut, (4) black walnut, (5) black walnut + linden, (6) oak, (7) oak, (8) black walnut, (9) oak, (10) black walnut
NA – nutritive agar, SA – starch agar, TA – Thornton's agar, JA – Jensen's agar, DM – dry matter

From five interplanted tree species (*Acer saccharinum*, *Eleagnus umbellata*, *Robinia pseudoacacia*, *Pinus strobus* and *Fraxinus americana*) ALTHEN et al. (1989) consider silver maple to be best for interplanting with *Juglans nigra*. Best competition control and height growth of black walnut was noted in mixtures with silver maple at spacing of 2 m between rows and 1.5 m within rows, while foliar N in walnut was lower in mixtures with silver maple than

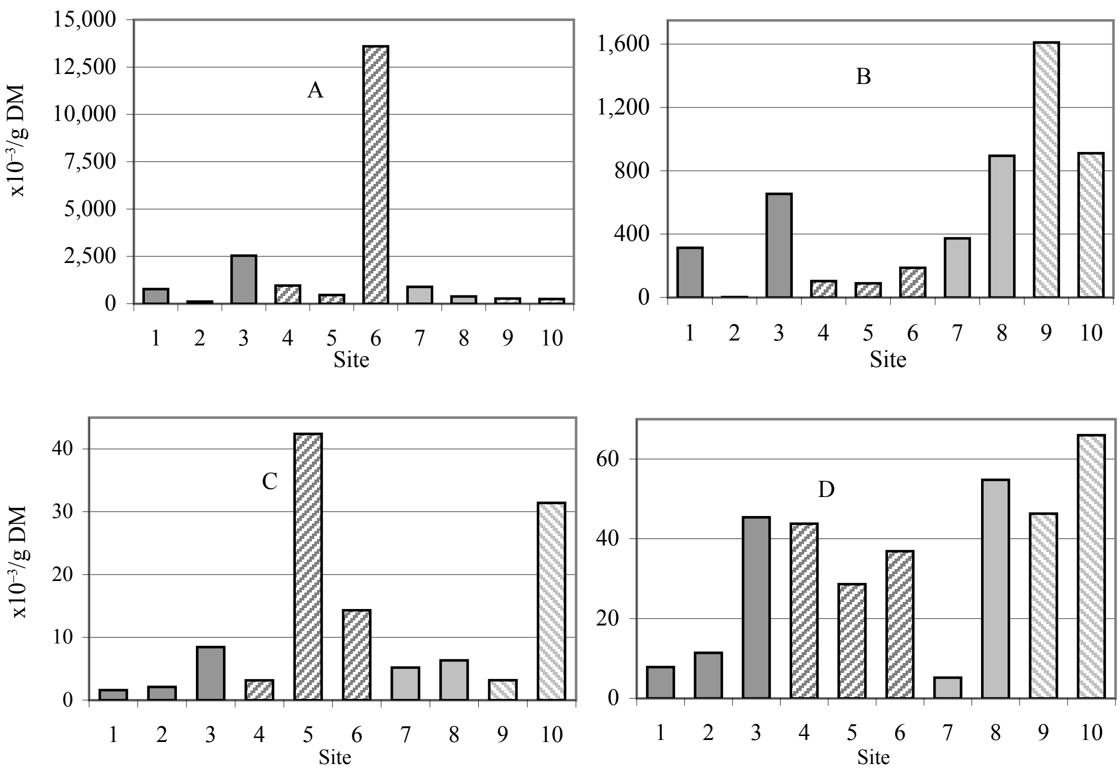

Fig. 4. The amount of microorganisms in nutrient media
A – nutritive agar, aerobic bacteria, B – Thornton's agar, micromycetes, C – Thornton's agar, actinomycetes, D – Jensen's agar, micromycetes
Note: 1 – oak + ash + poplar, 2 – black walnut + linden, 3 – black walnut, 4 – black walnut, 5 – black walnut + linden, 6 – oak, 7 – oak, 8 – black walnut, 9 – oak, 10 – black walnut

in those with autumn olive. Black walnut naturally grows in many mixed mesophytic forests of North America, but is seldom abundant. Usually it is found scattered among other trees; pure stands are rare, small, and usually located on forest edges. Main associated species include yellow poplar (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), black cherry (*Prunus serotina*), basswood (*Tilia americana*), beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), oaks (*Quercus* spp.), and hickories (*Carya* spp.). Near the western edge of its range, black walnut may be confined to floodplains where it grows either with American elm (*Ulmus americana*), hackberry (*Celtis occidentalis*), green ash (*Fraxinus pennsylvanica*), and boxelder (*Acer negundo*), or with basswood and red oak (*Quercus rubra*) on lower slopes and at other favourable sites (WILLIAMS 1990).

Beside the trials in America, many trials with growing black walnut trees were made in Europe, inspired by the prospects of its valuable wood. Trials in Slovakia described by KOHÁN (1999) were situated in uninundated alluvia of the rivers Latorica, Tisa, Hron and Dunaj, in terms of forest typology in floodplain hornbeam-ash stands (hardwood floodplains). The intensively managed stands were established at 4 × 2 and 2.5 × 2.5 m, in contrast to the spacing of 2 × 1.5 and 2.5 × 1.5 m used under traditional management. Silvicultural treatments (cleaning and selective thinning) were also very important under the intensive management system, which resulted in improved stand structure, standing volume and basal area.

Most authors are consistent on the question of the best soil conditions for black walnut. It is considered that deep, well-drained neutral soils that are moist, rich and fertile are the best for black walnut trees (CAMPBELL et al. 1989; DUKE 1983; POKORNÝ 1953; WILLIAMS 1990; www.bluehen.ags.udel.edu; www.fs.fed.us; www.museum.state.il.us, and others). These soils are in the orders Alfisols and Entisols. Walnut grows best on sandy loam, loam, or silt loam textured soils but it also grows well on silty clay loam soils. Soils with these textures hold large amounts of water that is available to the trees during dry periods of the growing season (WILLIAMS 1990). This is in agreement with KOHÁN's (1999) trials in Slovakia which show that the best soil types for growing black walnut trees are sandy, medium-heavy loamy and heavy-textured clay-loamy to clayey soils with slightly acid, neutral or weakly alkaline reactions. Internal drainage and depth to gravel are highly important site characteristics for black walnut. On well-drained soils trees are larger in dbh than trees growing on imperfectly drained soils (WILLIAMS 1990). Walnut is common on limestone soils and grows especially well on deep loams, loess soils, and fertile alluvial deposits along streams and bottomlands (but not on wet or saturated bottomlands or extremely dry, sandy soils of ridges). It can also grow on coves, lower slopes and agricultural soils (www.museum.state.il.us; www.fs.fed.us; www.exnet.iastate.edu; WILLIAMS 1990). According to WILLIAMS (1990) and POKORNÝ (1953) walnut grows slowly or poorly on wet bottomland and on sandy or dry ridges and slopes, and especially on excessively wet, cold soils without drainage. In the Czech Republic, black walnut (*Juglans nigra* L.) has been planted on a restricted area of 320 ha. Black walnut is recommended as an alternative to oak at some floodplain sites and some *Carpineto-Quercetum* sites. KULYGIN (1990) presented data on the growth of *Juglans nigra* up to the age of 20 and 30 years in plantations in the Don region in Ukraine. The plantations were established at steppe sites, and were either pure or in mixture with other broadleaves (oak, ash, walnut, robinia, maple [*Quercus robur*, *Fraxinus* sp., *Juglans regia*, *Robinia pseudoacacia*, *Acer* spp.]). The best method of establishing plantations was spring planting of seedlings 1 or 2 years old, at spacings of 3 × 1.5, 3 × 2 and 2.5 × 2 m. The best associate species are *Acer* spp. and *Tilia cordata*; *Quercus robur* is also possible. *Robinia pseudoacacia* and *Fraxinus excelsior* suppress *Juglans nigra*, and *J. regia* grows very poorly with *Juglans nigra*.

CONCLUSIONS

When compared with pure oak or black walnut stands, mixed stands with natural species composition and mixed stands of black walnut and linden showed higher sum of leaf fall, more favourable soil chemistry and certain microbial characteristics. The annual sum of leaf fall in the analysed stands ranged between 2.2 and 3.5 t per ha. Upper layers of soil to a depth of 10 cm had a predominantly loamy texture, crumb structure and balanced physical properties. Soil reaction was neutral, an evident shift of pH values towards acid reaction was detected in the alluvium of the Jihlava river and generally under oak monocultures. The adsorption complex of the analysed soils was markedly saturated and the available nutrients were sufficiently abundant. Long-term black walnut cultivation in comparable stands did not result in a dramatic deterioration of the respective soil production potentials. Generally more favourable parameters were detected in mixed stands with additional soil-improving species.

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Půdní poměry v porostech ořešáku černého (*Juglans nigra* L.) v aluviu řek Svratky a Jihlavy

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ABSTRAKT: Byly hodnoceny fyzikální, chemické a mikrobiologické vlastnosti půd v porostech ořešáku černého (*Juglans nigra* L.) v porovnání s porosty reprezentujícími přirozenou skladbu dřevin, směsi ořešáku s lípou a čistých porostů dubu s cílem posoudit možnosti jeho pěstování na lužních stanovištích jižní Moravy. Výsledky neprokázaly výrazné zhoršení půdních vlastností a produkčního potenciálu půd. Nejlepší výsledky byly zjištěny v porostech ořešáku černého s meliorační dřevinou.

Klíčová slova: ořešák černý; půda; aluvium řeky Svratky a Jihlavy; Česká republika

V České republice je ořešák černý (*Juglans nigra* L.) pěstován v lesních porostech pouze na jižní Moravě – na Lesním hospodářském celku Židlochovice, Lesním hospodářském celku Strážnice a na Lesní správě Znojmo. V těchto lokalitách byla tímto druhem introdukované dřeviny nahrazena původní společenstva *Ulmeto-Fraxinetum*. Celková výměra ořešákových porostů v rámci České republiky, na nichž hospodaří podnik státních lesů – Lesy České republiky, dosáhla 526 ha redukované plochy. Porosty byly zakládány pomocí síjí a pěstují se buď jako monokultury, nebo jako smíšené, se spodní etáží lípy srdčité (*Tilia cordata* L.). Podle údajů lesního hospodářského plánu činí celková výměra porostů ořešáku na Lesním hospodářském celku (LHC) Židlochovice 258 ha porostní půdy (redukovaná plocha). Téměř tři pětiny (154 ha) z rozlohy porostů ořešáku se nacházejí v aluviu řek Svratky a Jihlavy. Zájem o pěstování této dřeviny vyvrcholil ve čtyřicátých a padesátých letech minulého století. Nejstarší výsadby do lesních porostů na jižní Moravě proběhly na počátku 19. století, v aluviu Svratky a Jihlavy potom koncem 19. století.

Ořešákové porosty byly zakládány více než z 80 % na stanovištích odpovídajících zařazení do souboru lesních typů 1L – jilmový luh. V rámci tohoto souboru lesních typů jsou nejvíce zastoupeny lesní typy *Ulmeto-Fraxineta* *carpinea*: jilmový luh bršlicový na naplavené hnědozemní půdě (1L2), jilmový luh válečkový na lehkých naplavených půdách (1L4) a jilmový luh s ostružiníkem ježiníkem na těžkých naplavených půdách (1L1) i dubová jasenina s ostružiníkem ježiníkem na těžkých oglejených půdách (1L9).

Cílem řešení bylo hodnocení půdních poměrů v porostech ořešáku černého a posouzení, zda jeho dlouhodobým pěstováním na stanovištích patřících do souboru lesních typů 1L nedochází ke zhoršování půdních vlastností a snižování produkčního potenciálu půd.

Porosty, které byly vybrány k provedení srovnávacích šetření, patří LHC Židlochovice. Jsou situovány do aluviálních poloh kolem soutoku řek Svratky a Jihlavy. Půdotvorným substrátem jsou nivní sedimenty, na nichž se vytvořily půdy typu fluvizemí.

K vlastnímu šetření bylo určeno 10 lokalit, které se lišily věkem (porosty mladé, středního věku a dospělé) a druhovou skladbou (porosty čistého ořešáku černého, porosty ořešáku ve směsi s lípou, porosty dubu letního v monokultuře a pro kontrolu porosty s přirozenou druhovou skladbou s převahou dubu a jasanu). Lokality 1–6 se nacházejí na polesí Židlochovice, lesnický úsek bažantnice Uherčický les v aluviu řeky Svratky v nadmořské výšce 175–180 m n. m. Hlavní hospodářské a nejvíce zastoupené dřeviny v revíru: DB, JS, ORC, TP, převažující soubor lesních typů na lesním úseku: 1L (zastoupení 1G asi 5 %). K dalším charakteristikám patří: průměrná roční teplota 8,4 °C, průměrná teplota ve vegetačním období (IV.–IX.) 14,8 °C, průměrný roční úhrn srážek 551 mm, průměrný úhrn srážek ve vegetačním období (IV.–IX.) 350 mm.

Lokality 7–10 jsou situovány na polesí Velký Dvůr, lesnický úsek Dlouhá leč v aluviu řeky Jihlavy v nadmořské výšce 169–177 m n. m. Zastoupení hlavních dřevin polesí VD podle plochy: DB 25 %, TP 19 %, AK 17 %, JS 12 %, ORC 5 %, hlavní hospodářské a nejvíce zastoupené dřeviny v revíru: DB, JS, ORC, TP, převažující soubor lesních typů na lesnickém úseku 1L (zastoupen i 1G asi 4 %). Průměrná roční teplota 9 °C, průměrná teplota ve vegetačním období (IV.–IX.) 15,6 °C, průměrný roční úhrn srážek 499 mm, průměrný úhrn srážek ve vegetačním období (IV.–IX.) 319 mm.

Vždy na dvou lokalitách v každé skupině byly vykopány pedologické sondy, byl proveden jejich popis a z diagnostických horizontů byly odebrány fyzikální válečky. Skupiny představují v podstatě věkově přibližně srovnatelné porosty nacházející se na srovnatelných stanovištích.

K provedení analýz bylo odebráno z každé lokality 3–5 směsných vzorků, každý o hmotnosti asi 2 kg. Směsný vzorek byl tvořen z pěti individuálních odběrů na ploše 100 m^2. Individuální vzorky byly odebírány z humusového horizontu (horizont A) tak, aby byla reprezentativně zastoupena celá mocnost horizontu. Na vybraných lokalitách byly také odebrány z pedologické sondy z podpovrchových horizontů vzorky k analýzám chemických vlastností.

K provedení mikrobiologických a biochemických analýz byl vytvořen vždy pro každou lokalitu jeden směsný vzorek z pěti odběrových míst.

Standardními metodami bylo zjišťováno: pH, přístupné živiny (Mehlich III), celkové živiny (P, K, Ca, Mg a další), obsah uhlíku a dusíku, kationtová výměnná kapacita, biochemické a mikrobiologické parametry.

Půdy zájmového území v aluviu řek Svratky a Jihlavy, kde je největší rozloha porostů ořešáku černého v ČR, mají charakter typických fluvizemí. Formou povrchového humusu je mull. Roční suma opadu byla zjištěna v závislosti na věku pod porosty ořešáku od 1,47 do 2,41 t/ha za rok, pod porosty ořešáku s lípou od 2,86 do 3,46 t/ha za rok a pod porosty s dubem od 2,80 do 3,47 t/ha za rok. Množství opadu závisí více na stáří porostu než na druhovém složení. Dekompozice opadu probíhá v závislosti na charakteru dřeviny, klimatických podmínkách a množství a kvalitě půdní mikroflóry. Prakticky veškerý opad (75 % listové hmoty) je v průběhu jednoho roku zcela rozložen; 25 % představují zbytky celulózového charakteru s pozvolným průběhem rozkladu. Pod porosty ořešáku (lokality 3, 4, 8, 10) přichází za předpokladu úplného rozložení opadu každoročně do půdy 16,4–30,8 kg/ha N, 57,6–90,7 kg/ha Ca, 3,5–6,5 kg/ha K, 6,7–12,6 kg/ha Mg a 1,9–3,5 kg/ha P, pod porosty ořešáku s lípou (lokality 2, 5) 1,3 a 41,2 kg/ha N, 86,3 a 107,6 kg/ha Ca, 10,5 a 13,8 kg/ha K, 11,5 a 15,2 kg/ha Mg, 3,6 a 4,9 kg/ha P. Pod porosty dubu v monokultuře (lokality 6, 7, 9) je to 40,1–52,8 kg/ha N, 42,0–58,4 kg/ha Ca, 9,4–10,1 kg/ha K, 7,2–11,3 kg/ha Mg a 4,1–5,3 kg/ha P. V porostech s přirozenou druhovou skladbou (lokalita 1) je to 47,4 kg/ha N, 69,9 kg/ha Ca, 10,0 kg/ha K, 9,6 kg/ha Mg a 5,4 kg/ha P.

Půdy ve svrchní vrstvě do hloubky 10 cm mají převážně hlinitou texturu, drobtovitou strukturu a ostatní fyzikální vlastnosti vyrovnané díky celoplošné přípravě půdy (hluboké orby) s předchozím klučením pařezů. Výjimkou jsou pouze poněkud těžší půdy na lokalitách 3 a 5 a naopak lehčí půdy na lokalitě 7. Střední části půdních profilů mají rovněž převážně hlinitou texturu, ale jsou slehlejší a struktura je spíše polyedrická nebo prizmatická. Hlubší části půdního profilu mají převážně jílovitohlinitý charakter a patrné jsou známky oglejení. V některých případech (lokalita 1 a 2) je zřejmý výskyt tzv. pohřbených horizontů s vyšším obsahem humusových látek. Mocnost povodňových hlín je více než 2 m a hladina podzemní vody kolísá v průběhu roku mezi 148–267 cm (r. 2000), resp. mezi 129–221 cm (r. 2001).

Půdní reakce v aluviu řeky Svratky (lokality 1–6) je až na lokalitu 6 s čistým dubovým porostem neutrální a v aluviu řeky Jihlavy (lokality 7–10) téměř neutrální. Pěstování porostů ořešáku po dobu 20 až 60 let neznamenalo zhoršení půdní reakce. Naopak, nižší hodnoty pH byly nalezeny pod monokulturami dubu. Hodnoty C/N (11,4–12,6) a C/P (33,5–56,5) odpovídají formě povrchového humusu L-Mull. Sorpční komplex hodnocených půd je výrazně nasycený (BS 78,6–91,6 %) a přístupné živiny jsou zastoupeny dostatečně. V rámci první skupiny porostů byl nejvyšší obsah celkových a přístupných živin ve svrchní vrstvě půdy do 10 cm pod přirozenými smíšenými porosty (DB + JS + TP), nižší pod porosty ořešáku a lípy a nejnižší v čistých porostech ořešáku. Ve druhé skupině porostů byly příznivější nutriční poměry v porostech ořešáku a lípy (lokalita 5) ve srovnání s čistými porosty dubu. Podobně ve třetí a čtvrté skupině porostů byly půdy lépe zásobené živinami pod porosty ořešáku (lokality 8, 10) než pod porosty s monokulturou dubu. Pořadí dřevin s klesající zásobou živin v půdě je tedy následující: (DB + JS + TP) > (ORC + LP) > ORC > DB.

Potenciální respirační aktivita, která je měřítkem rychlosti rozkladu ústrojných látek v půdě, nevykazuje jednoznačný trend s ohledem na druhové složení porostu. Nitrifikační aktivita půdních mikroorganismů byla v čistých porostech ořešáku ve srovnání s ostatními porosty vždy nižší. Počet aerobních bakterií vázaných na rozklad organických dusíkatých látek byl vyšší pod čistými porosty dubu a ořešáku než pod porosty pěstovanými ve směsích. Počet bakterií využívajících škrob a minerální dusík byl rozkolísaný a bez zřejmého vlivu dřeviny. Počet aerobních bakterií využívající dusík z NO_3 a C z aminokyselin a vyšších alkoholů rovněž na jednotlivých lokalitách kolísal a nejvíce byla tato skupina půdní mikroflóry zastoupena v čistých porostech dubu a ořešáku. Počet aktinomycet byl relativně nízký a nevykazoval žádnou významnější závislost na druhu dřeviny. Azotobacter (jako volný poutač vzdušného N) nebyl zjištěn. Počet mikromycet mírně stoupal v závislosti na aciditě půdy. Vesměs příznivější hodnoty sledovaných parametrů ve smíšených porostech ořešáku s lípou svědčí o významné meliorační funkci lípy. Příznivé účinky pěstování ořešáku ve směsích jsou uváděny i ze zahraničí.

Výsledky ukázaly, že smíšené porosty s přirozenou druhovou skladbou dřevin a smíšené porosty ořešáku s lípou vykazovaly ve srovnání s čistými porosty dubu nebo ořešáku vyšší sumu opadu, příznivější chemismus půd a některé mikrobiální charakteristiky. Dlouhodobé pěstování ořešáku v první generaci na srovnatelných stanovištích však neznamenalo dramatické zhoršení produkčního potenciálu půd.

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