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Dissolved organic carbon concentrations under conditions of different forest composition

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ABSTRACT: The study deals with the monitoring of dissolved organic carbon (DOC) concentrations in seepage water sampled from differently managed forest plots in the Drahanská vrchovina Upland. Simultaneously, the input of DOC in precipitation and throughfall is evaluated. Preliminary results show higher mobility level of carbon substances in forest soil in a pure spruce stand compared to mixed stand or a pure beech stand. DOC can be one of suitable characteristics to evaluate the conversion effectiveness of spruce monocultures.

Keywords: dissolved organic carbon; throughfall; lysimetric water; species composition; Norway spruce conversion

In the modern conception of forest ecology and forest soil science, surface humus and humus horizons are the important components of a forest ecosystem from the aspect of maintaining the element cycle in forest ecosystems and preserving their ecological stability. Under conifers, accumulation of raw humus occurs in consequence of the effect of resins and waxes, which are contained in needles and due to the anatomical structure of needles. The creation of raw humus is related to acidity, therefore, under coniferous stands, we can find humus of increased acidity. Under mixed stands, forest litter is more aerated, which affects the creation of quality humus. Dissolved forms of carbon are used for their importance in cycling forest nutrients. Dissolved organic carbon (DOC) plays a significant role in carbon flux in forest ecosystems. DOC is a primary form of carbon which is transported from forest floor to mineral soil. The forest floor plays an important role in the dynamics of carbon and nitrogen of a forest ecosystem. It is considered to be the source of carbon and nitrogen for plants and soil microorganisms as well as the reservoir of carbon and nitrogen, which enters the forest floor. DOC production in the organic horizon is thought to be determined largely by processes such as litter and humus decomposition as well as root exudation (Kalbitz et al. 2000). Accumulation of DOC in the mineral soil often represents a major carbon pool (Callesen et al. 2003). DOC is also released from the mineral soil to the soil solution (Fröberg et al. 2006). These processes are affected by soil temperature and moisture (Christ, David 1996; Gödde et al. 1996). Drying and re-wetting also influence DOC production (Tipping et al. 1999; Zhang et al. 2004). The study deals with the evaluation of the concentration of DOC in lysimetric water sampled from forest stands of various species composition in the Drahanská vrchovina Upland. At the same time, the input of DOC to soils in the form of precipitation is evaluated. Sampling soil water by means of lysimeters is probably the most suitable method to obtain information on the content of

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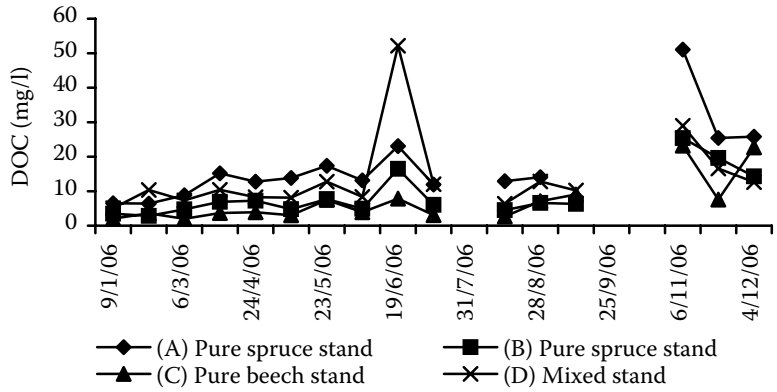

Fig. 1. The course of values of DOC among individual measurements (throughfall)

DOC in the soil solution under natural conditions of a forest site. The aim of the paper was to compare data on the content of dissolved organic carbon in forest soils on variously managed areas with different species composition.

METHODS

Research plots are located on the research area of the Institute of Forest Ecology, Mendel University of Agriculture and Forestry in Brno in the natural forest region of the Drahanská vrchovina Upland, about 3 km west of the village of Němčice (co-ordinates: 49°29'31"N and 16°43'30"E). The plots are situated on the eastern slope of a watershed at an altitude of 625 to 640 m. Mean annual air temperature is 6.5°C, mean annual precipitation is 717 mm. There is the slope soil cover including boulders of a size of about 1 m in the area of the field research station. The depth of the slope soils fluctuates and in an outcrop, rather deep weathering of granodiorite without the structure disturbance is evident. On the whole area of the research plots there is Cambisol. It refers to acid soil which is partly conditioned by the character of parent rock and partly by the character of forest litter. From the point of view of physical conditions, the profile character is not optimal for the production of forest trees. It shows rather limited physiological depth, the impermeable layer of granodiorite weathering residues which rises sporadically up to 50 cm profile depth. It means that the space of rhizosphere is limited to the layer of slope soils, which is rather gravelly. From the climatic aspects, the research station area can be ranked among the slightly warm and slightly humid zone. The research plots are ranked between the forest type group 5S – oligo-mesotrophic *Abieto-Fagetum* and forest type 5S1 – oligo-mesotrophic *Abieto-Fagetum* with *Oxalis acetosella*. *Fagus sylvatica* L. is considered to be an autochthonous species as an absolute dominating factor, the occurrence of *Abies alba* Mill. is sporadic, with admixture of *Quercus petraea* Liebl., in places with gleying also *Quercus robur* L. The description of plots selected for the purpose of research is given in Table 1.

Vacuum lysimeters of a German company UMS GmbH as well as gravitation lysimeters of our production were used. In vacuum lysimeters, water enters special draw-off vessels through vacuum (suction pressure in draw off vessels is evacuated at the beginning of each of the take-off periods – a system with decreasing vacuum – "falling tension" system). In gravitational lysimeters ("zero tension" lysimeters), water intake happens only by the gravitational

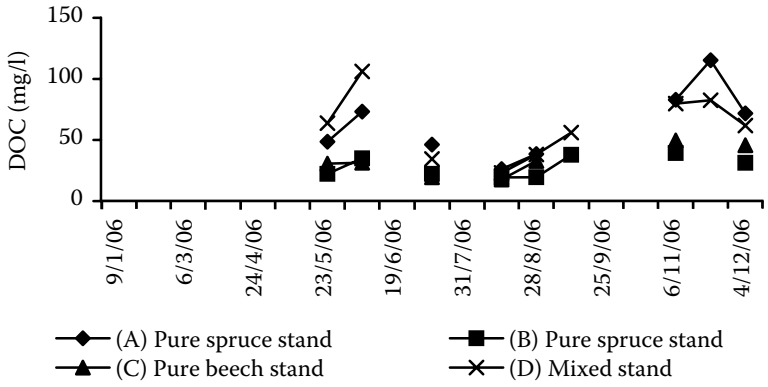

Fig. 2. The course of values of DOC among individual measurements (soil waters under the O horizon – gravitation lysimeters)

Table 1. Characteristics of research plots (Remeš et al. 2005)

	(A) Pure spruce stand	(B) Pure spruce stand	(C) Pure beech stand	(D) Mixed stand
Age (years)	103	30	40	125
Species composition (%)	spruce 100	spruce 100	beech 100	beech 55, spruce 40, fir 5, larch
Soil type	Typical Cambisol – acid variant			
Humus form	Moder	Moder	Mull-Moder	Moder
Humus reserve (t/ha)	78.8	35.9	18.8	69.6
pH (nH_2O)	3.9	4.0	5.1	4.2
C (%)	39.9	37.8	35.2	42.2
N (%)	1.3	1.3	1.2	1.6
C/N	29.9	28.7	28.5	26.0

passage of water through the soil profile. In each of the plots, three measuring places were installed and in each of the measuring places, three lysimeters were used (two vacuum and one gravitational lysimeter). In precipitation water and water intercepted in underground lysimeters, the amount and chemical composition of water was determined in every sampling – the amount of water (volumetrically), pH (using potentiometers), conductivity (using conductometers), the content of cations (through atomic absorption spectrophotometry) and the content of anions (through gradient ion chromatography). DOC was determined by means of a SHIMADZU TOC VCSH/CSN analyzer according to the ČSN EN 1484 (1998) standard. In the filtrate, we determine the content of total carbon (TC) and inorganic carbon (IC) by means of an automatic analyzer. From the obtained data the content of dissolved organic carbon is calculated (adjusted by Delprat et al. 1997; Riffaldi et al. 1998; Robertson et al. 1999; Chapman et al. 2001; Guanghui, Steinberger 2001). Samples were taken in the winter season once a month, in other seasons in 14-day intervals. In winter months, lysimetric water was not sampled. Data presented were measured in 2006. The program used for statistical analyses was STATISTICA CZ. After

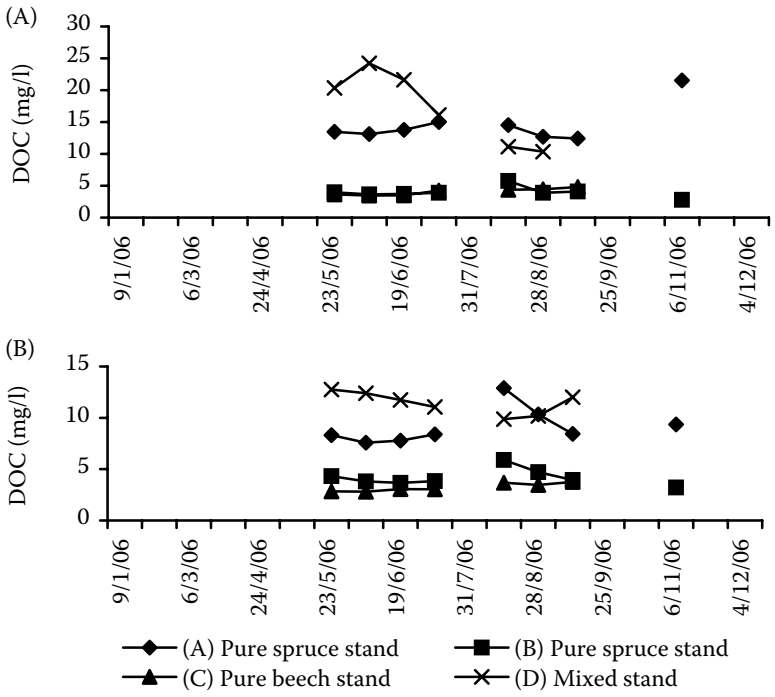

Fig. 3. The course of values of DOC among individual measurements (soil waters – vacuum lysimeters at the depth of 20 cm (A) and 40 cm (B))

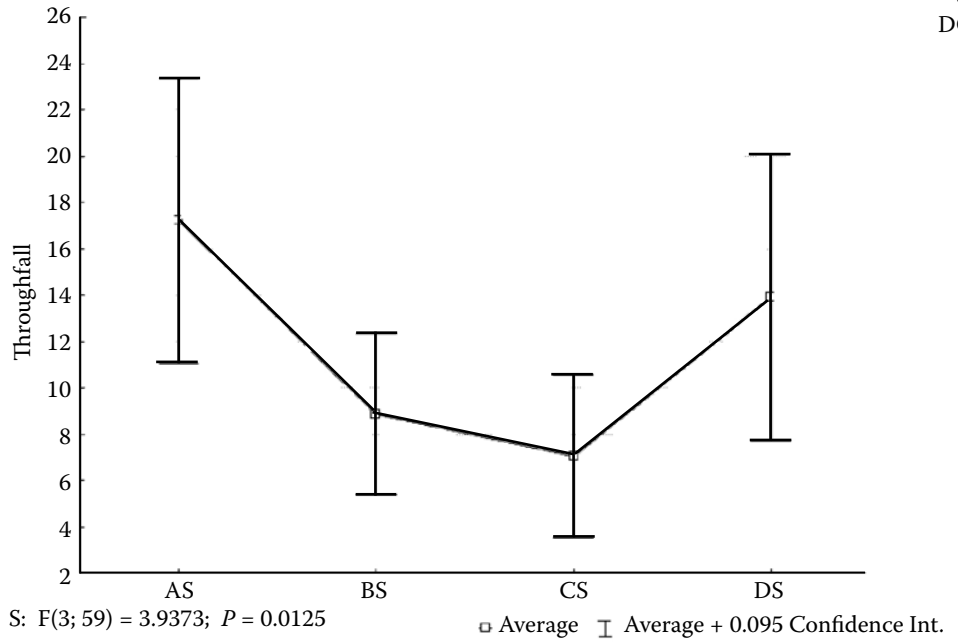

Fig. 4. Average annual values of DOC in throughfall

ANOVA, means were compared using the post-hoc test (Scheffe's test). A probability level of 0.05 was used throughout to decide on significance.

RESULTS AND DISCUSSION

Results from the statistical tests for DOC concentrations are given in Figs. 4 to 7. In throughfall, there was a significant difference in DOC concentrations between variant A and C ($P < 0.05$) (Fig. 4). In soil water from the base of the O horizon (gravitation lysimeters), there was a significant difference in DOC concentrations between variant A and B ($P < 0.05$) on the one hand and also variant B and D ($P < 0.05$) on the other (Fig. 5). Variance analysis disclosed significant differences for value V20 (soil waters – vacuum lysimeters in the depth 20 cm) and Scheffe's test displayed statistically significant difference between variant A and B ($P < 0.001$), variant A and C ($P < 0.001$), variant B and D ($P < 0.001$) and also

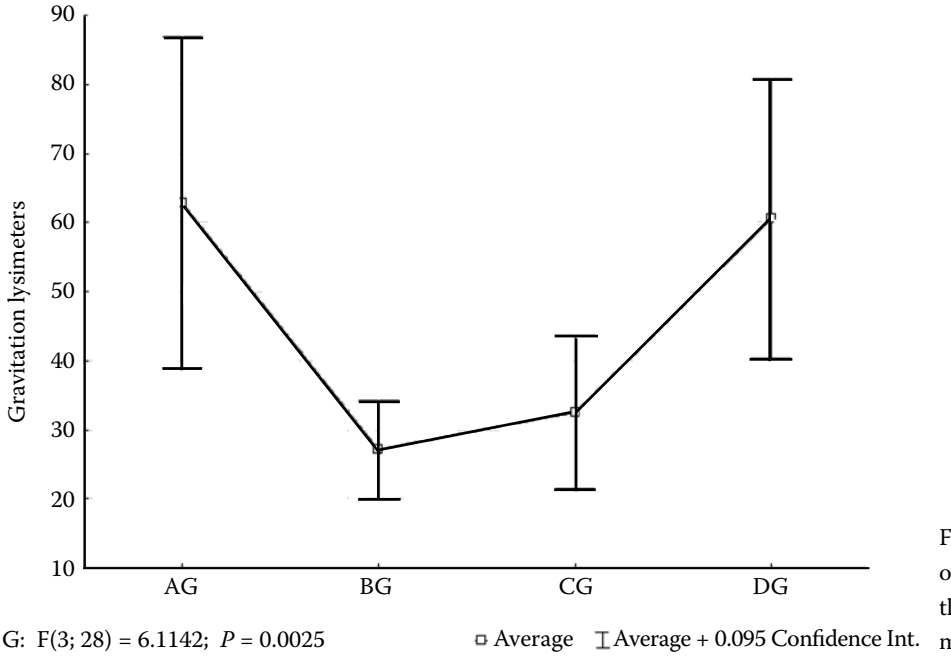

Fig. 5. Average annual values of DOC in soil waters under the O horizon (gravitation lysimeters)

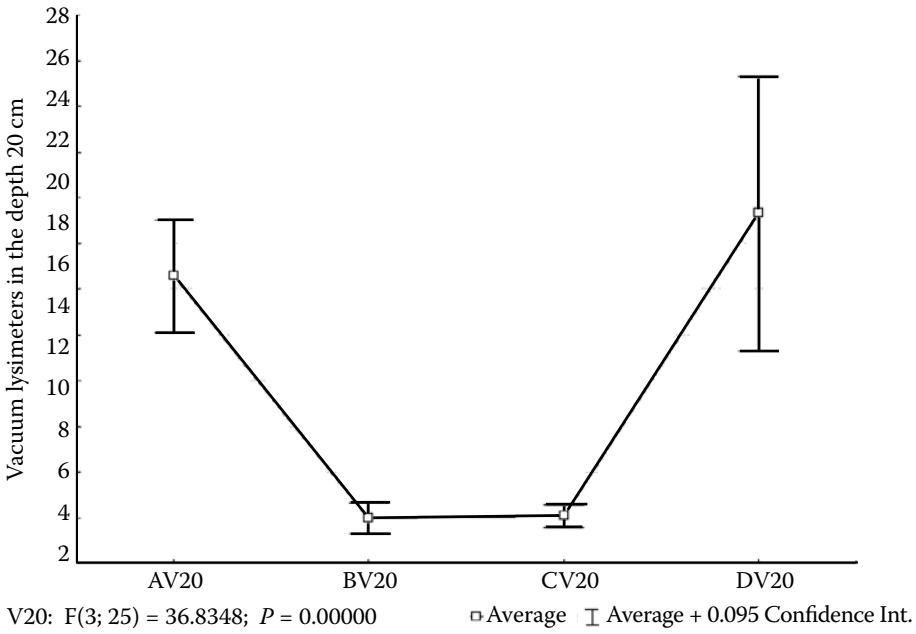

Fig. 6. Average annual values of DOC in soil waters (vacuum lysimeters at the depth of 20 cm)

variant C and D ($P < 0.001$) (Fig. 6). Variance analysis showed significant differences for value V40 (soil water – vacuum lysimeters in the depth 40 cm) and Scheffe's test displayed statistically significant difference between variant A and B ($P < 0.001$), variant A and C ($P < 0.001$), variant A and D ($P < 0.01$), variant B and D ($P < 0.001$) and also C and D ($P < 0.001$) (Fig. 7).

The course of DOC values between particular samplings and in particular sampling devices is given in Figs. 1 to 3. The highest values were obtained in throughfall in variant A, namely in a pure spruce stand, followed by a mixed stand (variant D), next a pure spruce stand (variant B) and the lowest value was noted in a pure beech stand (variant C) (Fig. 1). In gravitation lysimeters the highest values were obtained in a pure spruce stand (variant A), followed by a mixed stand (variant D), next a pure beech stand (variant C) and the lowest value was noted in a pure spruce stand (variant B) (Fig. 2). DOC concentrations in samples from vacuum lysimeters at the depth of 20 cm decreased from mixed stand (variant D), pure spruce stand (variant A), pure beech stand (variant C) to pure spruce stand (variant B) (Fig. 3A).

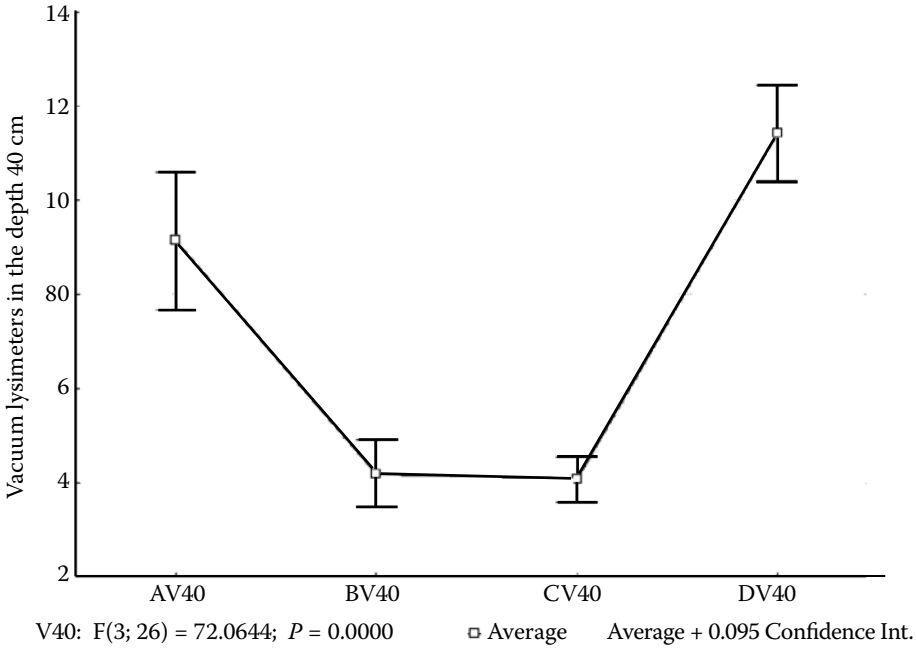

Fig. 7. Average annual values of DOC in soil waters (vacuum lysimeters at the depth of 40 cm)

DOC concentrations in samples from vacuum lysimeters at the depth of 40 cm decreased from mixed stand (variant D), pure spruce stand (variant A), pure spruce stand (variant B) to pure beech stand (variant C) (Fig. 3B). Figs. 1 to 3 present the content of dissolved organic carbon in particular variants of a stand. The highest values were found in soil solutions intercepted by gravitation lysimeters (soil water under the O horizon) whereas the lowest values in soil solutions intercepted by vacuum lysimeters at a depth of 40 cm below the soil surface. The most marked differences in the content of DOC as against other sampling devices occur in gravitation lysimeters, other values are not so marked.

DOC concentrations in throughfalls and soil water varied among stands. Variation in DOC concentrations in throughfalls is likely to be related to the canopy coverage (Kolka et al. 1999), which may explain the similarity in the patterns for throughfalls and above-ground tree litterfall. The canopy coverage will increase when a tree is young (as for the 30-year stand) but will later cease to increase and may tend to decline as the tree ages. There was a significant difference in the DOC concentrations in the soil water among individual stands (different litter composition). As litter is thought to be the most important C input to the forest floor (Kalbitz et al. 2000), DOC is largely derived from litter (Hongve 1999), and a higher litter input should lead to a higher DOC production (Gundersen et al. 1998; Park, Matzner 2003). There was significant effect of stand age on concentration of DOC in soil waters. In all cases the highest effect is between young and old stands (the highest values of DOC concentrations on these old stands). The variation in DOC concentrations in soil water may be partly explained by changes in above-ground tree litter input as a result of stand growth and aging (Clarke et al. 2007).

CONCLUSIONS

Preliminary results show that DOC can be one of suitable characteristics to evaluate the conversion effectiveness of spruce monocultures. With the increasing soil depth the content of DOC decreases. The highest values were found in soil solutions under the O horizon intercepted by gravitation lysimeters, which shows evidence of the sufficient amount of substrate available for soil microorganisms in a faster decomposition process, however, it also represents the greater risk of soil acidification. Dissolved organic carbon concentrations in lysimetric water under old stands were higher than concentrations under younger stands.

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Působení druhové skladby lesních porostů na koncentrace rozpuštěného organického uhlíku

ABSTRAKT: Studie se zabývá hodnocením koncentrací rozpuštěného organického uhlíku (DOC) v lyzimetrických vodách odebíraných z různě obhospodařovaných lesních ploch v oblasti Drahanské vrchoviny. Současně je vyhodnocován také vstup DOC do půd ve srážkách. Předběžné výsledky ukazují vyšší stupeň pohyblivosti uhlíkatých látek v půdě pod smrkovými porosty proti porostům bukovým nebo smíšeným. DOC může být jednou z vhodných charakteristik při hodnocení efektivity přeměny smrkových monokultur.

Klíčová slova: rozpustný organický uhlík; podkorunové srážky; lyzimetrické vody; druhová skladba; transformace smrkových monokultur

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