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Original Paper

The impact of introduced and indigenous woody plants on change of selected soil chemical properties in the Arboretum Mlyňany

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In this work has been studied the impact of changed vegetation on selected soil chemical characteristics of Stagni-Haplic Luvisol in the Arboretum Mlyňany. Soil samples from A horizons were collected under growths of anthropogenically introduced (*Prunus lauroerasus* and *Pinus Jeffreyi*) and indigenous (*Picea abies*, *Taxus baccata*, *Quercus cerris* and *Carpinus betulus*) tree species. Since the original vegetation in Arboretum was *Querceto-Carpinteum* forest, the soil under rest of that forest was used as control. Obtained results suggest that anthropogenic change of vegetation highly significantly affected the soil chemizm in A horizons under both, indigenous and introduced tree species. *Prunus lauroerasus* and *Pinus Jeffreyi* (their litter, root exudates) had the most significant effect on changes of studied soil chemical properties compared to the soil under original *Querceto-Carpinteum* forest. The most affected were values of sum of base cations, base saturation, content of available phosphorus and exchangeable aluminum.

Keywords: intentional change of vegetation, soil sorption properties, pH, nutrients content

1. Introduction

Plants introduction, as intentional anthropogenic activity, means the planting of plants transported over large geographical barriers into new territory, which is situated beyond the borders of natural occurrence of particular species. Various anthropogenic activities support plants acclimation, their survival and auto-reproduction in new conditions, what leads to their naturalization. It allows plants release into the wild and penetration into natural communities (Eliáš, 2011). In recent decades, the alien species invasions have become a significant cause of species decline and degradation of natural environment (Vitousek et al., 1997). Introduced invasive species are currently considered as the second most serious threat of the world biodiversity (Eliáš, 1999).

In the Arboretum Mlyňany, the intentional anthropogenic introduction of tree species, as well as planting of indigenous trees is performed since 1892, when it was founded as a private collection of Count Ambrózy. Gradually, in the original 40 ha oak-hornbeam forest were planted introduced trees, which over time adapted to new natural conditions, and even some of them extended to the Arboretum surrounding (Tomaško, 1998). Arboretum is divided on: original Ambrozy's park founded in year 1892, area of East-Asia dendroflora in year 1964, area of North America dendroflora in year 1975, area of Korea dendroflora in year 1984 and exposition of Slovak dendroflora in year 1992 (Tábor and Pavlačka, 1992).

Soil characteristics considerably affect not only rooting and plants growth, but also their development, succession and health condition (Tokár and Kukla, 2008). On the other hand, also plants significantly affect soil properties by their root exudates, plant residues, roots penetration (Philips and Marion, 2004; Masarovičová, 2011). Therefore, the change of vegetation has significant and often major influence on soil.

The aim of the study reported here was to investigate the extent, to which selected soil chemical properties of A horizon under original oak-hornbeam growth in the Ambrozy's park were altered by long-term cultivation of introduced and indigenous tree species.

2. Material and methods

2.1 Locality description

Arboretum Mlyňany (48° 19' N, and 18° 21' E) is located in southern Slovakia, in the valley of river Žitava, at an altitude of 165–217 m above sea level, in warm, dry climate area with mean annual temperature 10.6 °C and mean annual total precipitation 541 mm (Figure 1). Undulated terrain is southern spur of Hronský Inovec and Tríbeč. Arboretum site floristically belongs to the Pannonian area, geo-botanically to the *Querceto-Carpinteum* area. Arboretum is situated on a late Tertiary geological formation, represented by clays, sands and rubble sands

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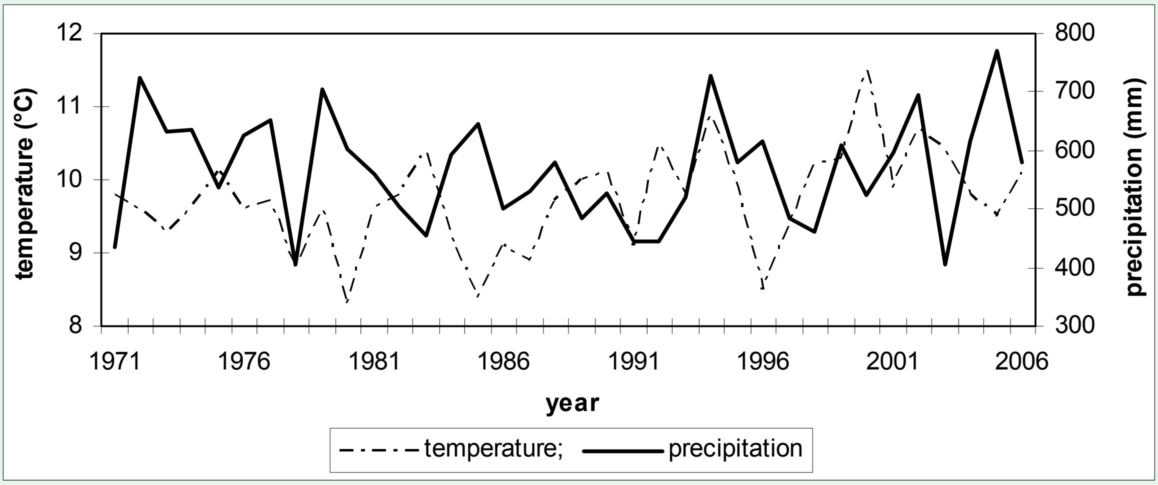

Figure 1 Mean annual temperature and mean annual total precipitation in Arboretum Mlyňany in years 1971–2006
Source: Hrubík and Hoťka, 2007

(Stenhübel, 1957; Hrubík et al., 2011). This substratum is almost all covered by wind-deposited loess, mostly without carbonates (Cifra, 1958). On majority of Arboretum area was developed Stagni-Haplic Luvisols, other subtypes are Haplic Luvisols and cultivated Stagni-Haplic Luvisols (Polláková and Konôpková, 2012).

2.2 Soil sampling and analytical methods

Soil characteristics were studied under three indigenous tree species:

1. the rest of original oak-hornbeam forest (*Quercus cerris*, L., *Carpinus betulus*, L.) – control,
2. dense growth of spruces (*Picea abies* (L.) Karsten),
3. growth of yews (*Taxus baccata*, L.)

and under two introduced tree species:

4. dense growth of cherry laurels (*Prunus lauroerasus*, L.),
5. growth of Jeffrey pines (*Pinus Jeffreyi*, Grev. et Balf.).

At each stand (1–5) was trenched soil pit (Figure 2) in which were characterized morphological properties and determined physical and chemical properties. Subsequently, the soil was classified as Stagni-Haplic Luvisols (Polláková and Konôpková, 2012).

Soil samples were collected from A horizons, which reached to the following depths: oaks-hornbeams and spruces to 0.15 m, yews and pines to 0.20 m and cherry laurels to 0.23 m. Different depths of soil sampling were related to the different thickness of A horizons. After drying, from soil samples were removed plant and root residues, samples were grinded and homogenized by sieving through sieves with mesh diameter <2 mm and <0.25 mm. In such prepared soil samples were determined: soil pH – potentiometrically in H_2O and in 1 mol dm^{-3} KCl (Hrivňáková et al., 2011); exchangeable base ions (S) and

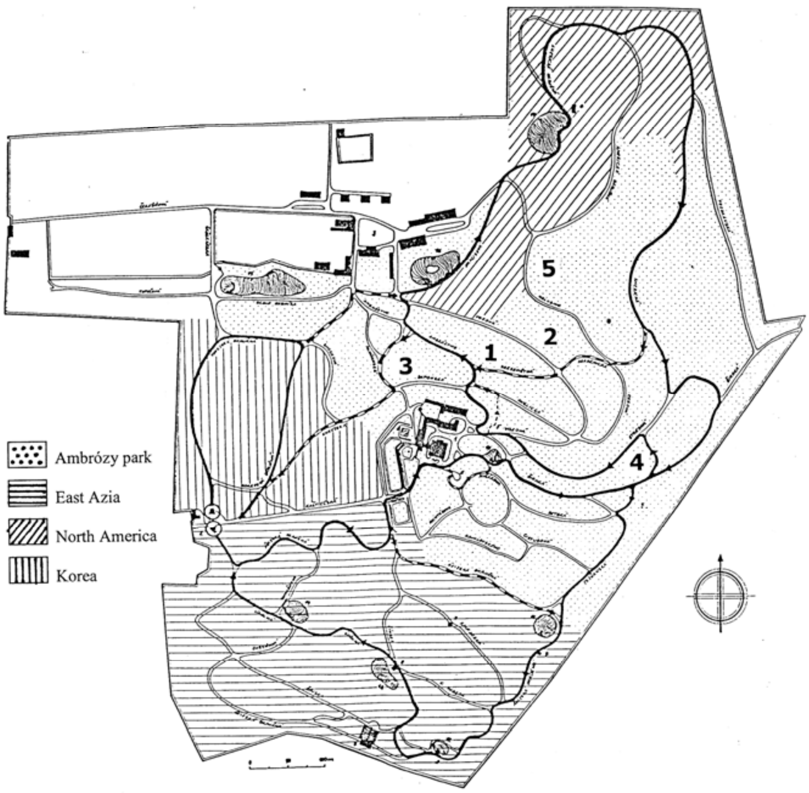

Figure 2 The map of Arboretum Mlyňany site
1 – oaks-hornbeams; 2 – spruces; 3 – yews; 4 – cherry laurels; 5 – pines

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hydrolytical acidity (H) by Kappen's method (Hrivňáková et al., 2011); exchangeable Al by method of Sokolov (Hanes, 1999), available macro-elements phosphorus (P) and potassium (K) were analysed by method Melich III (Melich, 1984), then P was detected colorimetrically on Spectrophotometer Jenway model 6400 and K on atomic absorption spectrophotometer. Total soil organic carbon (C_T) was analysed by Tyurin method (Orlov and Grischina, 1981); total nitrogen content (N_T) by Kjeldahl (Fecenko, 1991). Based on determined C_T a N_T contents were calculated their relative proportions.

Each analyse was done in 3 repeats and in paper are shown average values.

For statistical evaluation was used one-way analysis of variance, and differences between the variants (tree species) were assessed using Scheffe's test with minimum significance level of $P \leq 0.05$.

3. Results and discussion

Arboretum Mlyňany is a good site for studying the degree of different tree species influence on soil chemical properties, which were considerably changed by trees action (Polláková and Konôpková, 2012). Original growth in Ambrózy's park was oak-hornbeam forest therefore soil under the rest of this forest was chosen as a control, with which were compared soil chemical properties under growths of introduced and indigenous tree species. The differences were studied in A horizons, since these were the most influenced by trees litter and root residues and exudates.

pH is considered as the most important indicator of soil state, fertility and functioning. It provides information about soil microbial activity, potential chemical degradation, availability of elements to plants. In Arboretum Mlyňany, tree species had statistically significant influence on changes of pH values in A horizons (Table 1). In A horizons, values of pH in H_2O significantly increased under growths of cherry laurels (11%) and pines (24%) compared to the soil under the rest of original oak-hornbeam forest. Also in pH in KCl were found statistically significant differences caused by various tree species. Compared to control (oak-hornbeam forest), the litter and root exudates of yew significantly decreased pH in KCl values.

In addition to pH, indicators of soil acidity are also cationic composition of sorption complex and soil saturation by aluminum. Šebesta et al. (2011) found that the gradual acidification of anthropogenically undisturbed forest over 60 years decreased pH values by 0.1–0.3 units in A and B horizons, but base saturation

Table 1 Soil pH and characteristics of sorption complex in A horizons of Stagni-Haplic Luvisol

Locality	Horizon	Depth	pH H_2O	pH KCl	H	Al^{3+}	S	CEC	BS
		m			mmol (p$^+$) kg^{-1}				%
1 oaks-hornbeams	A	0.0–0.15	4.62^a	4.17^c	157.9^c	44.4^c	50.0^a	207.9^c	24.1^a
2 spruces	A	0.0–0.15	4.51^a	4.16^c	151.7^c	25.9^b	156.8^d	308.5^d	50.8^b
3 yews	A	0.0–0.20	4.66^a	3.55 a	79.6^b	3.5^a	97.0^c	176.6^b	54.9^c
4 cherry laurels	A	0.0–0.23	5.12^b	4.02 b	57.8^a	0.7^a	82.0^b	139.8^a	58.7^d
5 pines	A	0.0–0.20	5.71^c	4.98 d	55.2^a	0.2^a	157.0^d	212.2^c	74.0^e
± limit Scheffe 0.05	–	–	0.152	0.094	11.41	4.026	5.950	11.07	–

H – hydrolytic acidity, S – sum of exchange base cations, CEC – cation exchange capacity, BS – base saturation. Different letters between lines indicate statistically significant differences – Scheffe's test with minimum significance level at P ≤0.05

Table 2 The content of organic carbon and basic nutrients in A horizons of Stagni-Haplic Luvisol

Locality	Horizon	Depth	C_T	$C_T : N_T$	N_T	P	K
		m	g kg^{-1}		mg kg^{-1}		
1 oaks-hornbeams	A	0.0–0.15	22.6^{bc}	14.5^c	1558^{ab}	52^c	183^c
2 spruces	A	0.0–0.15	14.8^a	9.8^a	1508^a	10^a	165^{bc}
3 yews	A	0.0–0.20	20.7^b	14.9^c	1393^a	34^b	353^d
4 cherry laurels	A	0.0–0.23	26.5^d	15.2^c	1748^{bc}	14^a	98^a
5 pines	A	0.0–0.20	23.8^c	12.3^b	1939^c	10^a	148^b
± limit Scheffe 0.05	–	–	2.313	1.825	207.3	7.077	33.03

C_T – total soil organic carbon, N_T – total nitrogen content, P – available phosphorus content, K – available potassium content
Different letters between lines indicate statistically significant differences – Scheffe's test with minimum significance level at P ≤0.05

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decreased by half compared to the original state. In Arboretum Mlyňany, high production of low-molecular organic acids and fulvic acids during decomposition of poor quality humus material provided by trees, which was moreover in the form of litter deposited on the soil surface, resulted to very strong hydrolytic acidity.

From the results shown in Table 1 follows that in A horizons of examined soils, the tree species had statistically significant effect (P = 0.0000) on the changes of hydrolytic acidity (H), sum of exchange base cations (S), cation exchange capacity (CEC) as well as the degree of sorption complex saturation by base cations (BS). Under the original oak-hornbeam forest and spruces, the values of H were more than 50% higher than under growths of cherry laurels, yews and pines. The lowest values of S and the highest H in A horizons under the original oak-hornbeam forest resulted to the lowest degree of sorption complex saturation by base cations (BS = 24.1%). Stronger soil acidity was probably caused by longer period (more than 112 years) of oaks-hornbeams influence on soil (Arboretum was established in year 1892 in the original oak-hornbeam forest). Since other tree species were younger, the duration of their action on soil was shorter therefore their influence on soil chemical properties was not so distinct.

Exchange aluminum was detected in all studied A horizons. Matúš et al. (2006) stated that aluminum is present in different chemical forms, of which free Al^{3+}, $Al(OH)^{2+}$ a $Al(OH)_2^+$ are critical for the evaluation of its toxicity, and for determining the impact of protons entry into the soil and surface water. Just these are released into the soil solution due to dissolution of minerals, or ion-exchange reactions (Čurlík et al., 2003). Cronan and Grigal (1995) found that if the degree of base saturation is below 15%, aluminum will probably cause stress to plants. In all studied A horizons of Arboretum, the degree of sorption complex saturation by base cations was more than 24%, what excludes negative effect of aluminum on plants (Table 1).

Compared to the A horizon under the rest of original oak-hornbeam forest, due to changed vegetation were statistically significantly altered contents of nitrogen, phosphorus and potassium (Table 2). The content of nitrogen significantly increased under growth of pines (by 24%). Phosphorus content significantly decreased under growths of spruces (81%), yews (by 35%), cherry laurels (by 73%) and pines (by 81%). The content of potassium significantly decreased under cherry laurels (by 46%) and pines (by 19%), increased under yews (93%).

In the past, the nutrients in Arboretum soil were supplied through farmyard manure. Whereas from year 1965 in the Arboretum are not used any fertilizer it is assumed that N, P, K macronutrients originate from decomposed trees litter. Already Olson (1963) stated that litter represents the input-output system of nutrients in forests. The rate, at which litter accumulates and decomposes, regulates the flow of energy, primary productivity and nutrient cycling in forest ecosystem. According to Hättenschwiler et al. (2005), plant species affects the ecosystem through nutrient turnover, uptake and use by plants, quantity and chemical composition of litter, interaction with rhizosphere, and changes microclimate of environment.

In addition to content, also relative proportion of total carbon (C_T) and nitrogen (N_T) was evaluated. Obtained results showed that tree species had statistically significant effect on changes of $C_T : N_T$ ratios in A horizons of Stagni-Haplic Luvisol (Table 2). Compared to other trees, significantly narrowest $C_T : N_T$ ratio was under spruces. The highest statistical difference was found between growth of spruces and cherry laurels. In A horizons, $C_T : N_T$ ratio significantly decreased under pines (15%) and spruces (32%) compared to the rest of original oak-hornbeam forest.

The content of organic carbon in soil is regulated by the balance between biotic inputs and losses and abiotic conditions involving climate, topography and soil type and also various anthropogenic interventions to soil. The quality of plant residues significantly affects their decomposition and loss of carbon from soil (Vesterdal et al., 2008). The type of vegetation had statistically significant effect on changes of C_T content in A horizons ($P = 0.0000$). Compared to C_T content in A horizon under original oak-hornbeam forest, C_T significantly increased under cherry laurels (by 17%) and decreased under spruces growth (34%). Quideau et al. (2001) stated that various tree species have different effect on stock and dynamics of organic matter in soil and in addition, changes of land use cause alteration the chemical properties of organic matter. Direct relationship between tree species and soil organic matter composition was ascertained. Also in the soil of Arboretum, anthropogenically changed vegetation affected not only the quantity and quality of soil organic matter, but also the content of essential nutrients, pH values and characteristics of soil sorption complex.

4. Conclusions

Obtained results showed, that intentional, anthropogenic change of vegetation participated on highly significant change of soil chemical properties in A horizons of Arboretum Mlyňany. The impact of introduced tree species was more distinct than indigenous ones. The most influenced parameters were exchangeable aluminium, exchangeable base cations, degree of sorption complex saturation by base cations, available phosphorus content; and the least influenced parameters were pH H_2O, total carbon and nitrogen contents, and $C_T : N_T$ ratio.

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The growths of cherry laurels and pines had the greatest impact on the change of chemical properties of A horizons compared to original oak-hornbeam forest and were significantly altered 10 of 12 examined parameters. The smallest impact on chemical characteristics in A horizons had the growth of spruces, since caused significant change in 7 of 12 examined parameters.

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6. References

CIFRA, J. (1958) Short characteristic of soil in Arboretum Mlyňany. In BENČAŤ, F. (ed.). *Prírodné podmienky Arboréta Mlyňany*. Bratislava: SAV, pp. 79–96 (in Slovak).

CRONAN, C.S. and GRIGAL, D.F. (1995) Use of calcium/aluminum ratios as indicators of stress in forest ecosystems. In *J. Environm. Quality*, vol. 24, pp. 209–226.

ČURLÍK, J., BEDRNA, Z. and HANES, J. et al. (2003) *Soil pH and it´s adjustion*. Bratislava: Suma print, pp 250. (in Slovak).

ELIÁŠ, P. (1999) Global efforts to reduce biotic invasions (Global Strategy on invasive species). In *Invázie a invázne organizmy*. Nitra: SCOPE and SAV, pp. 7–13 (in Slovak).

ELIÁŠ, P. (2011) Introduction of alien species as the first step to invasion of woody plants. In *Dendrologické dni v Arboréte Mlyňany*. Nitra: SAV, 2011, pp. 66–73 (in Slovak).

FECENKO, J. (1991) *Plant nutrition and agrochemistry : Laboratory manual*. 3rd ed. Nitra: SPU, pp. 121 (in Slovak).

HANES, J. (1999) *Analyses of soil sorption properties*. Bratislava: VÚPOP, pp. 138 (in Slovak).

HÄTTENSCHWILER, S., TIUNOV, A.V. and SCHEU, S. (2005) Biodiversity and litter decomposition in terrestrial ecosystems. In *Annual Review of Ecology, Evolution, and Systematics*, vol. 36, pp. 191–218.

HRIVŇÁKOVÁ, K. et al. (2011) *The uniform methods of soil analysis*. Bratislava: VÚPOP, pp. 136 (in Slovak).

HRUBÍK, P. and HOŤKA, P. (2007). Characteristics of climatic conditions in Arboretum Mlyňany SAS for the period 1971–2006 (2007). In *Aklimatizácia a introdukcia drevín v podmienkach globálneho otepľovania*. Nitra: SAV, pp. 28–37 (in Slovak).

HRUBÍK, P. et al. (2011) Climate conditions of Arboretum Mlyňany in Vieska nad Žitavou for 1971–2011. In *Dendrologické dni v Arboréte Mlyňany*. Nitra: SAV, pp. 66–73 (in Slovak).

MASAROVIČOVÁ, E. (2011) Soil science in the view of plant physiologist. In *Phytopedon* (Bratislava), vol. 10, pp. 21–22 (in Slovak).

MATÚŠ, P. et al. (2006) Free aluminium extraction from various reference materials and acid soils with relation to plant availability. In *Talanta*, vol. 70, no. 5, pp. 996–1005. DOI: http://dx.doi.org/10.1016/j.talanta.2006.05.045

MELICH, A. (1984) Melich 3 soil test extractant – a modification of Melich 2 extractant. In *Soil Sci. and Pl. Anal.*, vol. 15, pp. 1409–1416.

OLSON, J.S. 1963. Energy storage and the balance of producers and decomposers in ecological systems. In *Ecology*, vol. 44, pp. 322–331.

ORLOV, V. and GRISHINA, I. (1981) *Guide of humus chemistry*. Moscow: Moscow University Publishing, pp. 124 (in Russian).

PHILLIPS, J.D. and MARION, D.A. (2004) Pedological memory in forest soil development. In *For. Ecol. Manag.*, vol. 188, p. 363–380. DOI: http://dx.doi.org/10.1016/j.foreco.2003.08.007

POLLÁKOVÁ, N. and KONÔPKOVÁ, J. (2012) *Soil properties under selected indigenous and introduced tree species in Arboretum Mlyňany*. Nitra: SPU, pp. 88 (in Slovak).

QUIDEAU, S.A. et al. (2001) A direct link between forest vegetation type and soil organic matter composition. In *Geoderma*, vol. 104, no. 1–2, pp. 41–60. DOI: http://dx.doi.org/10.1016/S0016-7061(01)00055-6

STEINHÜBEL, G. (1957) *Arboretum Mlyňany in the past and in present*. Bratislava: SAV, pp.145 (in Slovak).

ŠEBESTA, J. et al. (2011) Acidification of primeval forests in the Ukraine Carpathians: Vegetation and soil changes over six decades. In *For. Ecol. Manage.*, vol. 262, pp. 1265–1279. DOI: http://dx.doi.org/10.1016/j.foreco.2011.06.024

TÁBOR, I. and PAVLAČKA, R. (1992) *Arboretum Mlyňany*. VEDA: Bratislava, pp. 62 (in Slovak).

TOKÁR, F. and KUKLA, J. (2008) Development of phytocenoses and of above ground production of red oak (*Quercus rubra*, L.) and black walnut (*Juglans nigra*, L.) stands on the PRP series Ivanka pri Nitre. In *Folia Oecologica*, vol. 35, pp. 74–87.

TOMAŠKO, I. (1998) Dendrotaxons invasions of Arboretum Mlyňany. In *Invázie a invázne organizmy 2*. Nitra: SCOPE and SPU Nitra, pp. 25 (in Slovak).

VESTERDAL, L. et al. (2008) Carbon and nitrogen in forest floor and mineral soil under six common European tree species. In *For. Ecol. Manage*, vol. 255, pp. 35–48. DOI: http://dx.doi.org/10.1016/j.foreco.2007.08.015

VITOUSEK, P.M.et al. (1997) Human domination of Earth's ecosystems. In *Science*, vol. 277, pp. 494–499.

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