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THE CHANGES OF SELECTED SOIL CHEMICAL PARAMETERS IN THE LONG-TERM CULTIVATION OF *ARUNDO DONAX* L. AND *ELYMUS ELONGATUS* GAERTNER

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SUMMARY

The changes of selected soil chemical parameters were observed in Gleyic Fluvisols. The field experiment was established with two energy crops (*Arundo donax* L., *Elymus elongatus* Gaertner). The energy crops were fertilized with phosphorus in rate 40 kg ha^{-1} and potassium in rate 60 kg ha^{-1} each year in spring. The nitrogen fertilization was not carried out. Soil samples were taken from depth from 0 to 0.3 m at the beginning of the experiment in the autumn 2012 and at the end of reference period in the autumn 2018. The development of selected soil parameters in the time series was evaluated by trend analysis. Land management conversion, from market crops to perennial energy crops cultivation, has influenced changes of selected soil chemical parameters. Since the establishment of the experiments, an increase in soil organic carbon in the monitored energy crops was found. The annual increase in carbon in the soil was 0.61 t ha^{-1} year^{-1} C for the *Arundo* and 0.98 t ha^{-1} year^{-1} C for the *Elymus*. At the same time, the same impact of the crops on content of total nitrogen, content of available phosphorus and potassium and soil reaction was found. Since the establishment of the experiments was found an increase in total nitrogen in the soil, too. The annual increase in total nitrogen in the soil was 115 kg ha^{-1} year^{-1} N for the *Arundo* and 102 kg ha^{-1} year^{-1} N for the *Elymus*. It was recorded that both cultivated crops decreased the soil reaction. The content of available phosphorus did not change significantly and the content of available potassium increased during the cultivation of *Arundo* and conversely, slightly decreased during the cultivation

of *Elymus*. The exchange soil reaction decreased significantly during long-term cultivation of Arundo and Elymus by 0.28, resp. 0.17. The linear trends found in both energy crop indicate the carbon sequestration after conversion from conventional crop to energy crop cultivation. From the trend analysis of data in cultivated energy crop was found the significant increase of the total nitrogen in the soil and the significant decrease of the exchange soil reaction. The development trends of the content of selected soil parameters in energy crops, which was determined using a regression model expressed by the linear equation pointed out the assumed development of the given soil parameter.
Keywords: *Arundo donax* L., *Elymus elongatus* Gaertner, Gleyic Fluvisols, soil organic carbon, total nitrogen, available phosphorus and potassium, soil reaction, trend analysis

INTRODUCTION

Climatic change is one of the major challenges which humanity has to deal with. Climatic change is not just about the future, but it is also a serious problem today. Global temperature of the oceans and the earth's surface has risen by 0.6 ± 0.2 ºC degrees in more than one hundred years (Sixth national Report of the Slovak Republic on Climate Change 2013).

The consequences of climate change in agriculture will be: changes in the spectrum of harmful organisms (diseases, pests, weeds), but especially the increase in the number of economically significant pathogens; changes in the temperature security of agricultural plants; extension of a main vegetation period (T above 10 °C) by 43 days in southern Slovakia and 84 days in the north of Slovakia until 2075; changes in phenological conditions; changes in precipitation distribution and humidity security and also changes of soil physical and chemical properties; accelerated decomposition of organic matter, accelerated growth of the root system; increased wind erosion; new plant species (Ministry of the Environment of the Slovak Republic 2014).

Climate change results in soil organic matter degradation and soil degradation. In Slovakia degradation threatens up to 70 % of the soil (*Kobza,* 2014). Soil degradation has a gradual and cumulative character. The threat to the soil is also the decline in available nutrients related with their negative balance, as well as the deterioration of other chemical and physical parameters of the soil.

There are a lot of strategies to increase the soil carbon stock and two of them are energy crops cultivation and no-till soil management (*Lal*, 2004). Perennial energy crops cultivation combines both of mentioned strategies, because there is no soil cultivation during productive years, besides cultivation before planting. Growing energy crops has the potential to mitigate carbon dioxide emissions by the replacement of fossil fuels and also by storing carbon in the soil due to land use change (*Don et al.*, 2012, *Zimmermann et al.*, 2012).

Biomass, as one of the renewable energy sources, has suitable soil-climatic conditions in the conditions of the regions of Slovakia and a wide range of uses. Targeted grown biomass of fast-growing crops used for energy purposes is one of the possibilities for diversification of agricultural production. The advantage is that energy crops can be located on temporarily or permanently unusable areas, which cannot be used for the primary production of commodities intended for food purposes (*Mandalová et al.*, 2017).

Carbon accumulation under energy crops is similar like under perennial grasses (*Anderson-Teixeira et al.*, 2009) or under native pasture (*Dondini et al.*, 2009). Carbon sequestration or carbon loss from soil in the conversion of used agricultural land or natural stands to energy crops depends on plant species (*Schneckenberger and Kuzyakov*, 2007, *Hillier et al.*, 2009). The different soil utilization affects not only the changes in soil parameters, but also the quality of the production (*Symanowicz et al.*, 2014, *Kron et al.*, 2017).

The aim of this study was to evaluate the changes of selected soil chemical parameters in long-term cultivation of the energy crops *Arundo donax* L. and *Elymus elongatus* Gaertner grown on the Gleyic Fluvisols.

MATERIAL AND METHODS

Field experiment was initiated in 2012 at experimental station of the National Agricultural and Food Centre – Agroecology Research Institute, which is located in Milhostov (48°40′02.3′′N. 21°43′51.2′′E). The experimental station is situated in the central part of the East-Slovak Lowland at an altitude of 101 m. The average annual temperature is 8.9 °C (16.0 °C during vegetation period) and average annual rainfall is 560 mm (350 mm during vegetation period).

Table 1: Soil particle size distribution before experiment establishment

Fraction	*Arundo*	*Elymus*	Average
1st fraction [%] clay (< 0.001 mm)	20.6	20.8	20.7
2nd fraction [%] soft and middle silt (0.001 – 0.01 mm)	19.0	18.8	18.9
3rd fraction [%] crude silt (0.01 – 0.05 mm)	28.7	29.5	29.1
4th fraction [%] soft sand (0.05 – 0.25 mm)	25.6	24.7	25.1
5th fraction [%] middle sand (0.25 – 2 mm)	6.1	6.2	6.2
Content of particle I. category (< 0.01 mm)	39.6	39.6	39.6
Soil evaluation	medium heavy loamy soil	medium heavy loamy soil	medium heavy loamy soil

The soil was Gleyic Fluvisols. According to Novak Classificatory Scale (*Zaujec et al.*, 2009) this soil subtype belongs to medium heavy and loamy soils. Soil particle size distribution before establishment of experiments with energy crops is shown in Table 1. Average content of clay particles was 39,6 %.

The average values of chemical properties of the topsoil (depth from 0 to 0.3 m) measured before starting the experiment are shown in *Table 2*.

Table 2: The chemical properties of the topsoil before starting the experiment

Parameters	*Arundo*	*Elymus*
soil total acidity [mmol kg^{-1}]	13	11
amount of exchange basic cations [mmol kg^{-1}]	335	313
total sorption capacity [mmol kg^{-1}]	348	324
degree of saturation of the sorption complex [%]	96.3	96.6
total nitrogen content [mg kg^{-1}]	1516	1561
available phosphorus content [mg kg^{-1}]	103.9	87.5
available potassium content [mg kg^{-1}]	214.0	227.7
available magnesium content [mg kg^{-1}]	247.9	315.3
exchangeable calcium content [mg kg^{-1}]	4758	4755
soil reaction in KCl	6.82	6.68
soil organic carbon [g kg^{-1}]	14.27	14.64
carbon content of humus substances [g kg^{-1}]	4.10	4.38
carbon content of humic acids [g kg^{-1}]	2.03	2.03
carbon content of fulvic acids [g kg^{-1}]	2.08	2.35
ratio of carbon of humic acids to carbon of fulvic acids	0.98	0.86
ratio of carbon to nitrogen	9.4	9.4

The field experiment was established with two energy crops: *Arundo donax L.* and *Elymus elongatus* Gaertner (*Figure 1*). The energy crops were fertilized with phosphorus in rate 40 kg ha^{-1} and potassium in rate 60 kg ha^{-1} each year in spring. The nitrogen fertilization was not carried out. The variant size was 12 m^2 for *Arundo* and 9 m^2 for *Elymus* and each variant was three times repeated.

Figure 1: The energy crops cultivated – *Arundo donax L.* and *Elymus elongatus* Gaertner

Soil samples were taken from depth from 0 to 0.3 m at the beginning of the experiment in the autumn 2012 and at the end of reference period in the autumn 2018. The disturbed soil samples were analysed using well-known methodologies to determine the following chemical soil parameters: soil organic carbon was determined by Tjurin method (ISO 14235 1998), total nitrogen contents by Kjeldalh method (*Hrivňáková and Makovníková et al.*, 2011), available phosphorus and potassium by Mehlich III method (*Mehlich*, 1984) and exchange soil reaction in 1 mol dm^{-3} KCl solution was determined using potentiometric method (ISO 10390 2005).

The development of selected soil parameters in the time series was evaluated by trend analysis. Multi-factorial analysis of variance (ANOVA) was used to evaluate treatment effects on selected soil parameters. Differences between treatments means were assessed by least significant difference (LSD) test. All statistical analyses were performed using the Statgraphics software package.

RESULTS AND DISCUSSION

Soil organic matter is the most important supply of organic carbon in the biosphere and, depending on conditions, can eliminate or sequestrate greenhouse gases in the environment (*Barančíková et al*., 2019). The quantitative and qualitative status of soil organic matter is the result of long-term soil-forming processes. In our climatic conditions, the decomposition processes are depended on the chemical composition of plant residues. In the case of energy crops *Arundo* and *Elymus*, the soil organic carbon content ranged from 14.22 to 15.95 g kg^{-1} (*Table 3*) and after conversion to the humus its content corresponded to the medium stock (Fecenko and Ložek 2000).

Table 3: Changes in the organic carbon content [g kg^{-1}] in cultivation of energy crops

Year	*Arundo*	*Elymus*	Average
2012	14.27	14.64	14.46
2013	14.31	14.77	14.54
2014	14.29	14.86	14.58
2015	14.22	14.42	14.33
2016	14.29	14.29	14.29
2017	14.46	14.52	14.49
2018	15.08	15.95	15.52
Δ C (2018 – 2012) [g kg^{-1}]	0.81	1.31	1.06
Δ C (2018 – 2012) [t ha^{-1}]	3.65	5.89	4.77
annual Δ C [t ha^{-1}]	0.61	0.98	0.80

where: Δ C (2018 – 2012) – difference of carbon content at the depth up to 0.3 m between year 2018 and the beginning of the experiment with energy crops (2012), annual Δ C – annual difference of carbon content at the depth up to 0.3 m between years 2018 and 2012

The soil organic carbon content was significantly dependent on the year and energy crop. Compared to the baseline, average increase in soil organic carbon recorded in 2018 was 1.06 g kg^{-1} (*Table 4*), in *Arundo* 0.81 g kg^{-1} and *Elymus* 1.31 g kg^{-1} (*Table 3*).

Planting permanent crops suitable in terms of soil conditions is one of the proposed adaptation measures for preserving and increasing the amount of organic carbon in the soil (*Ministry of the Environment of the Slovak Republic, 2014*). It is assumed that the change in land use, i.e., the transition to the cultivation of perennial energy crops, will make it possible to maintain or store carbon in the soil. Mentioned significant increase in soil organic carbon by 0.81 g kg^{-1} in *Arundo* (*Table 3*) represents an increase by 3.65 t ha^{-1} C in topsoil at depth up to 0.3 m. A higher increase in soil organic carbon was found in the *Elymus* (1.31 g kg^{-1}), which in terms of carbon content at a depth up to 0.3 m represents an increase in carbon in the soil by 5.89 t ha^{-1}.

Table 4: Statistical evaluation of selected soil parameters in the energy crops

Source variability	Factor	Observed parameter				
		C	N	P	K	pH/KCl
Crop	*Arundo*	14.42 a	1492 a	84.3 a	223.1 a	6.62 a
	Elymus	14.78 b	1534 b	100.3 b	229.7 b	6.70 b
Year	2012	14.46 ab	1539 c	95.7 c	220.9 ab	6.75 e
	2013	14.54 b	1406 a	96.8 c	232.0 c	6.70 cd
	2014	14.58 b	1408 a	90.9 b	216.8 a	6.74 de
	2015	14.33 a	1547 c	89.6 ab	242.3 d	6.68 c
	2016	14.29 a	1492 b	89.4 ab	222.9 ab	6.62 b
	2017	14.49 ab	1519 bc	88.6 a	224.1 abc	6.60 b
	2018	15.52 b	1683 d	95.0 c	226.1 bc	6.53 a

where: C – soil organic carbon, N – total nitrogen, P – available phosphorus, K – available potassium, pH/KCl – exchange soil reaction, letters (a, b, c, d, e) between factors refer to statistically significant differences (α = 0.05) – LSD test

The annual increase in soil organic carbon at *Arundo* was 0.61 t ha^{-1} year^{-1} and at *Elymus* 0.98 t ha^{-1} year^{-1}, which exceeds the minimum values of 0.25 t ha^{-1} year^{-1} C designed for carbon sequestration (*Volk et al*., 2004). *Similarly, Fagnano et al.* (2015) and *Impagliazzo et al.* (2017) found out, that the *Arundo* cropping can have a positive effect on the storage of carbon in the soil thanks to the absence of soil tillage and abundance of crop residues that every year return to the soil.

The influence of different soil uses on changes of its properties is manifested only after a long time. Time series analysis over a period of five years or more years can provide a more objective view of the development evaluation of a specific soil property and can form the basis for various analyses and forecasting. *Chajdiak* (2005) considers as a time series a set of values of the evaluated parameter, that occur over some period of time. When modelling the time series, the trend component is used, which indicates the direction of development of the evaluated indicator over time. The development trend of soil organic carbon in energy crops was determined using a regression model expressed by the linear equation y = ax + b (*Chajdiak*, 2005), on the basis of which the main development trend can be predicted.

From the average development of the soil organic carbon content in the years 2012 to 2018 results a trend of its increase in the energy crops *Arundo* and *Elymus* (*Figure 2*). With such a trend it can be assumed, that after ten years of growing *Arundo* there will be an increase in soil organic carbon by 0.98 g kg^{-1} (4.41 t ha^{-1} at a depth up to 0.3 m) and after the *Elymus* by 1.02 g kg^{-1} (4.59 t ha^{-1} at a depth up to 0.3 m). The indicated trend in the soil organic carbon content indicates the possibility of carbon sequestration after the conversion of agricultural soil into energy crops.

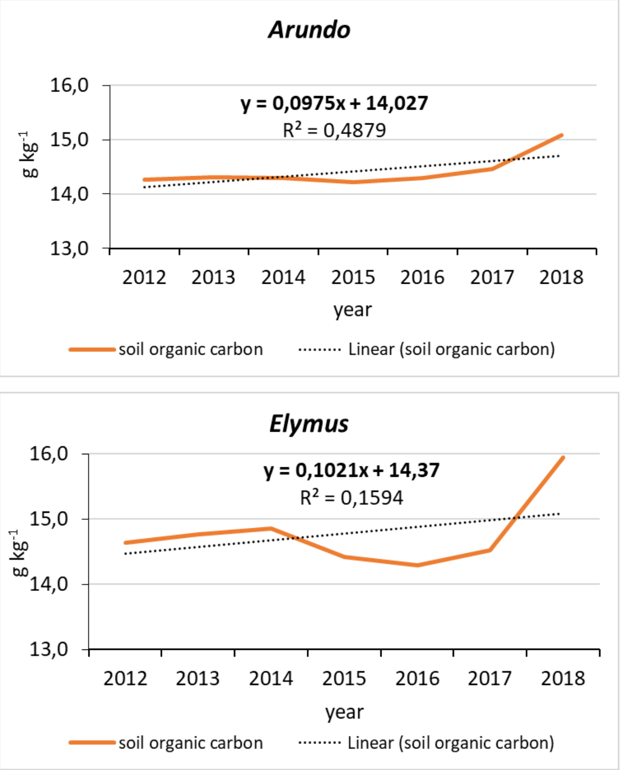


Figure 2: The development trend of soil organic carbon in the energy crops

Changes in soil organic carbon content due to different soil uses are relatively small compared to large soil organic carbon reserves (*Bhattacharyya et al.*, 2013).

The content of total organic carbon is related to the total nitrogen content. Significantly positive dependence (r = 0.72) was confirmed between soil organic carbon and soil total nitrogen. A linear correlation between organic carbon and total nitrogen in the top soil with the value of the correlation coefficient r = 0.94 was recorded by *Růžek et al.* (2009) and r = 0.50 *Wang et al.* (2009).

Table 5: Changes in the total nitrogen content [mg kg^{-1}] in cultivation of energy crops

Year	*Arundo*	*Elymus*	Average
2012	1516	1561	1539
2013	1334	1478	1406
2014	1368	1447	1408
2015	1543	1550	1547
2016	1485	1499	1492
2017	1530	1508	1519
2018	1669	1697	1683
Δ N (2018 – 2012) [mg kg^{-1}]	153	136	145
Δ N (2018 – 2012) [kg ha^{-1}]	689	612	651
annual Δ N [kg ha^{-1}]	115	102	109

where: Δ N (2018 – 2012) – difference of total nitrogen content at the depth up to 0.3 m between year 2018 and the beginning of the experiment with energy crops (2012), annual Δ N – annual difference of total nitrogen content at the depth up to 0.3 m between years 2018 and 2012

At energy crops plots the average content of total nitrogen was in the range from 1334 to 1697 mg kg^{-1} (*Table 5*). The soil total nitrogen content was significantly dependent on the year and energy crop (*Table 4*).

An increase in the soil total nitrogen was found in the monitored energy crops between 2012 and 2018. A higher increase in total nitrogen was found in the *Arundo* (increase of 153 mg kg^{-1}) and a lower increase in the *Elymus* (increase of 136 mg kg^{-1}). In terms of content of the total nitrogen at a depth up to 0.3 m, it represents an increase of 638 kg ha^{-1} N in the *Arundo* and 612 kg ha^{-1} N in the *Elymus*. The annual increase of total nitrogen in the soil in the *Arundo* was 115 kg ha^{-1} year^{-1} and in *Elymus* 102 kg ha^{-1} year^{-1} (*Table 5*).

Fagnano et al. (2015) reported, organic nitrogen in the topsoil is higher, mainly because the environmental constraints (summer drought and winter cold) may have reduced the mineralisation thus enhancing its accumulation in soil organic matter. In monitoring years average annual temperature during vegetation was higher from 0,6 to 2,6 °C and average annual rainfall was lower than long-term normal from 1981 to 2010 and therefore the content of total nitrogen in the soil could increase in the monitored period.

The development trend of the content of the soil total nitrogen in the grown energy crops was also determined using a regression model expressed by the linear equation y = ax + b (*Chajdiak*, 2005). From the average development of the soil total nitrogen in the years 2012 to 2018 results a trend of increase of the total nitrogen in the *Arundo* and *Elymus* (*Figure 3*).

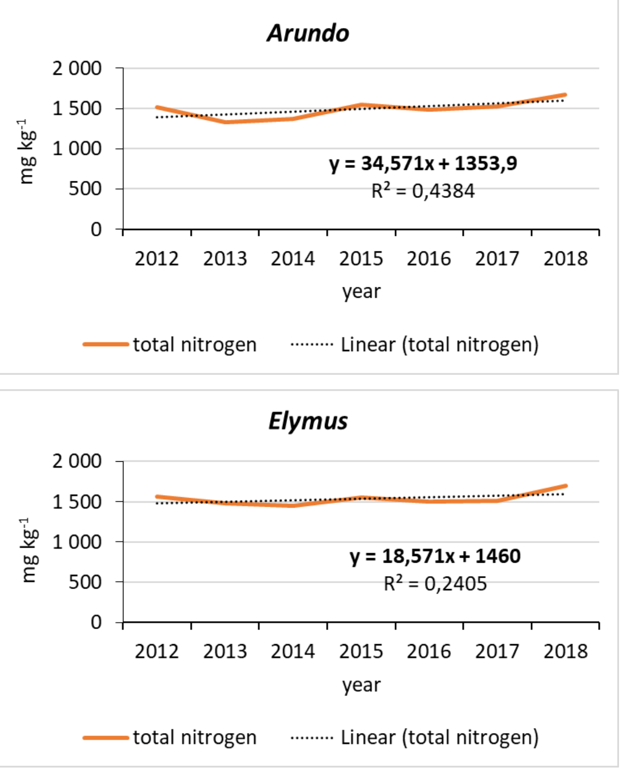


Figure 3: The development trend of total nitrogen in the energy crops

With such a trend it can be assumed, that after ten years of growing *Arundo* there will be an increase in total nitrogen in the soil by 346 mg kg^{-1} (1.56 t ha^{-1} N at depth up to 0.3 m) and after the Elymus by 186 mg kg^{-1} (0.84 t ha^{-1} N at depth up to 0.3 m). This trend of the increase total nitrogen in the soil after the conversion of agricultural soil to the energy crops cultivation is related to the sequestration of carbon in the soil, as nitrogen is part of the created organic matter.

The nutrient contents and the exchange soil reaction belongs to the soil parameters affecting its fertility. In terms of criteria for the evaluation of chemical analysis of the arable soils (*Slovak republic, Regulation No. 151/2016 2016*), detected content of available phosphorus in the soil in energy crops was classified from satisfactory to good content (*Table 6*).

Table 6: Changes in the available phosphorus content [mg kg^{-1}] in cultivation of energy crops

Year	*Arundo*	*Elymus*	Average
2012	103.9	87.5	95.7
2013	101.3	92.2	96.8
2014	98.2	83.6	90.9
2015	98.5	80.7	89.6
2016	100.7	78.0	89.4
2017	97.5	79.7	88.6
2018	101.8	88.2	95.0
Δ P (2018 – 2012) [mg kg^{-1}]	-2.1	0.7	-0.7
Δ P (2018 – 2012) [kg ha^{-1}]	-9.6	3.2	-3.2
annual Δ P [kg ha^{-1}]	-1.6	0.5	-0.6

where: Δ P (2018 – 2012) – difference of available phosphorus content at the depth up to 0.3 m between year 2018 and the beginning of the experiment with energy crops (2012), annual Δ P – annual difference of available phosphorus content at the depth up to 0.3 m between years 2018 and 2012

The content of available phosphorus and potassium in the soil in our experiment depended on fertilization and on the uptake by energy crops. The content of available phosphorus in the soil was decreased by 0.7 mg kg^{-1} between years 2012 and 2018 (Table 6). This decrease was not significant.

In terms of energy crops, decreased available phosphorus was found in the *Arundo* (-2.1 mg kg^{-1} P) and a maintenance of the available phosphorus content in the soil in the *Elymus*.

The trend of development of available phosphorus contents in both energy crops (*Figure 4)* indicates its slight decrease in the soil. The linear trend points to an annual decrease of available phosphorus by 0.40 mg kg^{-1} for *Arundo* and by 1.02 mg kg^{-1} for

Elymus (*Figure 3*). It was found that *Arundo* and *Elymus* yearly fertilization by phosphorus at a dose of 40 kg ha^{-1}, could expected to slightly decrease of the available phosphorus content in the soil. This is probably related to the phosphorus uptake by *Arundo* and *Elymus* and perhaps even to the constant changes in the forms of organic and mineral phosphorus in the soil.

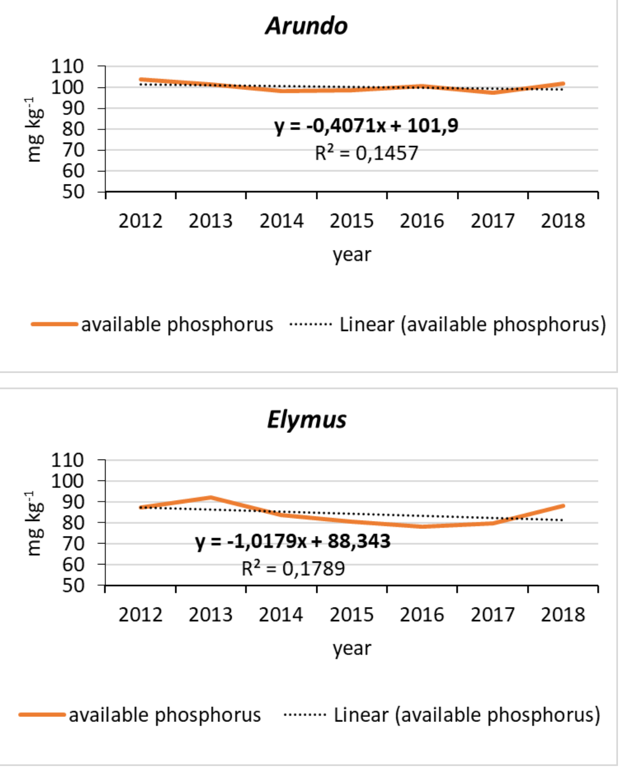


Figure 4: The development trend of available phosphorus in the energy crops

From the point of view of crop nutrition, it is important that sufficient potassium in the soil is present in a form available to plants. The content of available potassium in the soil of energy crops (Table 7) ranged from 204.1 mg kg^{-1} to 250.2 mg kg^{-1}. In terms of criteria for the evaluation of chemical analyses of arable soils (*Slovak republic, Regulation No. 151/2016 2016*), the content of available potassium in the soil in energy crops was classified as good (*Table 7*).

Table 7: Changes in the available potassium content [mg kg^{-1}] in cultivation of energy crops

Year	*Arundo*	*Elymus*	Average
2012	214.0	227.7	220.9
2013	224.0	240.0	232.0
2014	204.1	229.4	216.8
2015	234.3	250.2	242.3
2016	226.9	218.9	222.9
2017	228.5	219.7	224.1
2018	230.1	222.1	226.1
Δ K (2018 – 2012) [mg kg^{-1}]	16.1	-5.6	5.3
Δ K (2018 – 2012) [kg ha^{-1}]	72.5	-25.2	23.7
annual Δ K [kg ha^{-1}]	12.1	-4.2	4.0

where: Δ K (2018 – 2012) – difference of available potassium content at the depth up to 0.3 m between year 2018 and the beginning of the experiment with energy crops (2012), annual Δ K – annual difference of available potassium content at the depth up to 0.3 m between years 2018 and 2012

The available potassium content was significantly dependent on the year and energy crop (*Table 4*). The available potassium content in the soil under the *Arundo* stand increased by an average of 16.1 mg kg^{-1} and decreased by 5.6 mg kg^{-1} in the *Elymus* between 2012 and 2018. The available potassium content in the soil depends on fertilization and on the potassium uptake by energy crops and the decrease in available potassium in the soil in the *Elymus* was related to its higher uptake and insufficient potassium fertilization. An annual potassium fertilization at a dose 60 kg ha^{-1} was sufficient for the *Arundo* cultivated.

The trend of the development of available potassium contents in the energy crop *Arundo* pointing out a slight annual increase by 2.9 mg kg^{-1} K and in the energy crop *Elymus* a slight decrease by 2.4 mg kg^{-1} K (*Figure 5*).

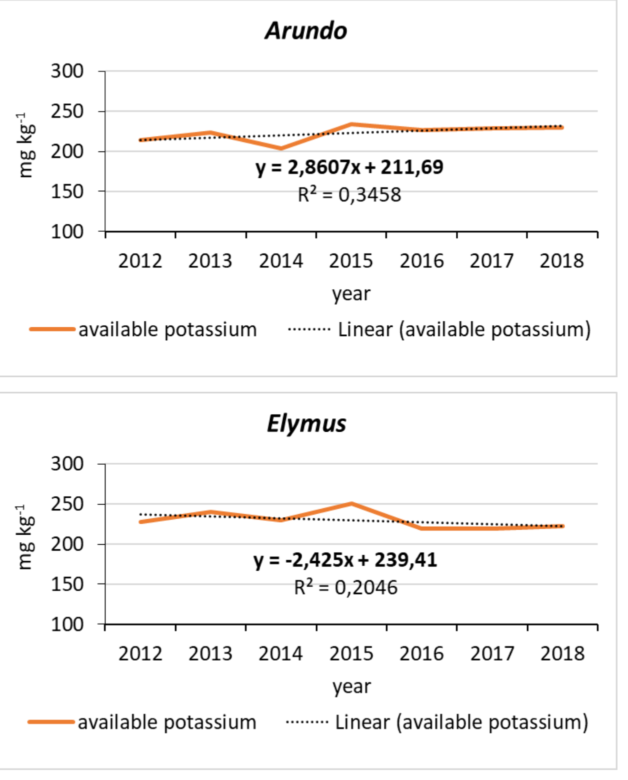


Figure 5: The development trend of available potassium in the energy crops

An important indicator of agrochemical characteristics of soils is the soil reaction, which affects the growth and development of cultivated plants, the activity of microorganisms in the soil and have great importance in the soil-forming process (L*ožek et al*., 1995). Soil acidity affects the mobility and accessibility of the most important plant nutrients, especially phosphorus and potassium.

The exchange soil reaction ranged between the 6.51 to 6.82 (Table 8) in the soil under cultivated energy crops and this range is classified as neutral with respect the assessment criteria (*Slovak republic, Regulation No. 151/2016 2016*). This exchange soil reaction is optimum for energy crops. *Di Tomaso* (1998) found out, that *Arundo* can grow in all types of soils, from clay to sand, with soil pH ranging from 5.0 to 8.7.

The values of the exchange soil reaction were significantly dependent on the year and energy crop. Significantly higher soil reaction was measured at the beginning of the experiment (in 2012). Insufficient replacement of annual calcium losses caused a moderate decrease in soil reaction from 6.82 to 6.54 in the *Arundo* and from 6.68 to 6.51

in the *Elymus* in 2018 (*Table 8*). Annual losses of calcium from the soil, by leaching and by the fertilizers are reported by *Bizík et al.* (1998) at level 350 kg ha^{-1} CaO. To prevent soil acidification, regular soil liming is necessary. With the current trend, the soil reaction may be reduced more rapidly in the following years. The higher decrease in soil reaction (-0.28) was found in *Arundo* and a lower decrease in soil reaction was found in Elymus (-0.17).

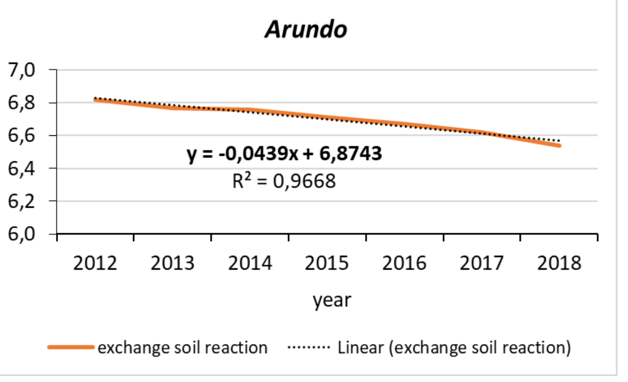
Table 8: Changes in the values of exchange soil reaction in cultivation of energy crops

Year	*Arundo*	*Elymus*	Average
2012	6.82	6.68	6.75
2013	6.77	6.62	6.70
2014	6.76	6.72	6.74
2015	6.71	6.64	6.68
2016	6.67	6.57	6.62
2017	6.62	6.58	6.60
2018	6.54	6.51	6.53
Δ pH/KCl (2018 – 2012)	-0.28	-0.17	-0.23

where: Δ pH/KCl (2018 – 2012) – difference of exchange soil reaction at the depth up to 0.3 m between year 2018 and the beginning of the experiment with energy crops (2012)

The soil reaction affects the availability of nutrients. When growing selected energy crops, a decrease in available phosphorus was found at higher soil acidity ($r = 0.46$). The relationship between soil reaction values and phosphorus in soil was also noted by *Dong et al.* (2009).

The development trend of exchange soil reaction in energy crops was also determined using a regression model expressed by the linear equation. From the average development of the values of exchange soil reaction in the years 2012 to 2018 results a trend of the soil reaction decrease in *Arundo* and *Elymus* (*Figure 6*).



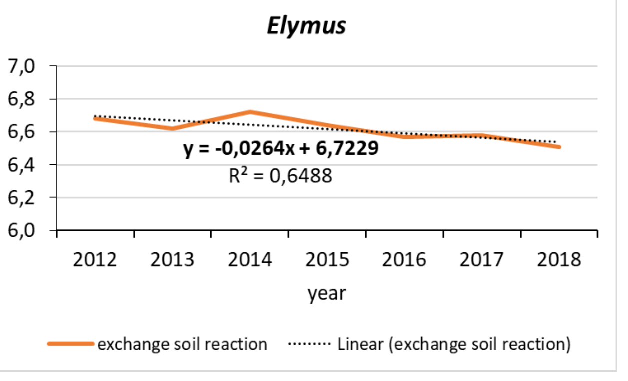


Figure 6: The development trend of the values of the exchange soil reaction in the energy crops

With such a trend, it can be assumed that after ten years of growing energy crops, there will be a slight decrease in the soil reaction by 0.44 in *Arundo* and by 0.26 in *Elymus*.

CONCLUSIONS

The change in land management, the conversion to the perennial energy crops cultivation, was reflected in changes in the soil organic carbon content depending on the cultivated crop. In *Arundo*, an increase in soil organic carbon an average by 0.81 g kg^{-1} was found during the study period, which, after conversion, represents an increase by 3.65 t ha^{-1} C in the top soil (0 - 0.3 m). In *Elymus*, the soil organic carbon content increased an average by 1.31 g kg^{-1}, which represents an increase of 5,89 t ha^{-1} C in the top soil for six years. The annual increase in soil organic carbon at *Arundo* was 0.61 t ha^{-1} year^{-1} and at *Elymus* 0.98 t ha^{-1} year^{-1}.

The total nitrogen content increased after six years of *Arundo* by 153 mg kg^{-1} (689 kg ha^{-1} in the top soil up to 0.3 m) and *Elymus* 136 mg kg^{-1} (612 kg ha^{-1} in the top soil up to 0.3 m) cultivation. The annual increase of total nitrogen in the soil in *Arundo* was 115 kg ha^{-1} year^{-1} and in *Elymus* 102 kg ha^{-1} year^{-1}.

Decrease in available phosphorus content in the soil was recorded between the baseline and the final year of the experiment in *Arundo* (-2.1 mg kg^{-1}) and a maintenance of the available phosphorus content in the soil in *Elymus*. Conversely, the available potassium content in the soil was increased in *Arundo* (+16.1 mg kg^{-1}) and decreased in *Elymus* (-5.6 mg kg^{-1}).

Exchange soil reaction was decreased between the baseline and the final year 2018. The higher decrease in soil reaction (-0.28) was found in *Arundo* and a lower decrease in soil reaction was found in *Elymus* (-0.17).

The development trends of the content of selected soil parameters in the grown energy crops, which was determined using a regression model expressed by the linear equation pointed out the assumed development of the given soil parameter.

A KIVÁLASZTOTT TALAJKÉMIAI PARAMÉTEREK VÁLTOZÁSA AZ *ARUNDO DONAX* L. ÉS AZ *ELYMUS ELONGATUS* GAERTNER HOSSZÚ TÁVÚ TERMESZTÉSE SORÁN

ŠOLTYSOVÁ BOŽENA – DANILOVIČ MARTIN – PORVAZ PAVOL

Nemzeti Mezőgazdasági és Élelmiszeripari Központ - Agroökológiai Kutatóintézet, Michalovce,

Szlovákia

ÖSSZEFOGLALÁS

A kiválasztott talajkémiai paraméterek változásait glej öntéstalajokon vizsgáltuk. A szántóföldi kísérletet két energianövénnyel (*Arundo donax* L., *Elymus elongatus* Gaertner) állítottuk be.

Az energianövényeket minden év tavaszán 40 kg/ha foszforral és 60 kg/ha káliummal trágyázták. Nitrogéntrágyázást nem végeztünk. A talajmintákat a kísérlet kezdetén, 2012

őszén és a referencia-időszak végén, 2018 őszén vettük 0-0,3 m mélységből. A kiválasztott talajparaméterek idősoros alakulását trendelemzéssel értékeltük. A földművelés megváltoztatása - a piaci növények termesztéséről az évelő energianövények termesztésére - befolyásolta a kiválasztott talajkémiai paramétereket. A talajban lévő szén éves növekedése az *Arundo* esetében 0,61 t ha^{-1} $év^{-1}$ C, az *Elymus* esetében pedig 0,98 t ha^{-1} $év^{-1}$ C volt. Ugyanakkor a növényeknek az összes nitrogéntartalomra, a rendelkezésre álló foszfor- és káliumtartalomra és a talajreakcióra gyakorolt hatása is azonos volt. A kísérletek megkezdése óta a talaj összes nitrogéntartalmának növekedését is megállapítottuk. A talaj összes nitrogéntartalmának éves növekedése az *Arundo* esetében 115 kg/ha^{-1} $év^{-1}$ N, az *Elymus* esetében 102 kg/ha^{-1} $év^{-1}$ N volt. Feljegyeztük, hogy mindkét kultúrnövény csökkentette a talaj reakcióját. A rendelkezésre álló foszfor tartalma nem változott jelentősen, a rendelkezésre álló káliumtartalom pedig nőtt az *Arundo* termesztése során, és fordítva, az *Elymus* termesztése során kissé csökkent. Az *Arundo* és az *Elymus* hosszú távú termesztése során a talajcsere-reakció jelentősen, 0,28, illetve 0,17 %-kal csökkent. Mindkét energianövény esetében a lineáris tendenciák a hagyományos növénytermesztésről az energianövény-termesztésre való áttérés utáni szénmegkötést jelzik. A termesztett energianövények adatainak trendelemzése alapján a talajban lévő összes nitrogén szignifikáns növekedését és a talajcsere-reakció szignifikáns csökkenését találtuk. A kiválasztott talajparaméterek tartalmának fejlődési tendenciái az energianövényekben, amelyet a lineáris egyenlet által kifejezett regressziós modell segítségével határoztunk meg, rámutattak az adott talajparaméter feltételezett fejlődésére.
Kulcsszavak: *Arundo donax* L., *Elymus elongatus* Gaertner, glej öntéstalaj, szerves szén, nitrogén, foszfor, kálium,

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