

CARBON, NITROGEN AND SULFUR CONTENTS AND RATIOS IN SOME HUNGARIAN SOIL TYPES

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Abstract

The residues of organic matter in the soil are transformed biologically over a shorter or longer time period. In the humification process, a part of the organic decomposition products formed the dark-coloured humus. The other part of the organic matter is also decomposed by the activities of heterotrophic organisms, in which inorganic substances are produced from the organic matter. The direction and intensity of the transformation, however, depends not only on the organic material stock of the soil but also on the organisms in the soil. They are closely related to soil properties, natural fertility, environmental factors and applied agrotechnical processes. The rate and speed of humus formation and mineralization processes determines the soil organic matter stock and the set of nutrients that can be uptaken by plants during the degradation of organic matter. The transformation of alternative plant nutrient, organic matter (composts, green manure, sewage sludge, slurry etc.) is determined by the living organisms with different activities in the soil.

In present publication the results of most important physical and chemical properties of 12 different soil types in eastern part of Hungary (chernozem, meadow, marsh, brown forest soil, blown sand, and solonetz) are analysed. The vegetation of involved soil types were: winter wheat, orchard, oak forest and natural grassland. There were also determined the total content (stock) of some main elements (C, N, S, P) in the soils and their ratios (C/N, C/S, N/S) were compared also. There were investigated the available nutrient content of the soils (CaCl₂ solution extractable nitrate and sulfate content). Based on the results, there was also calculated the proportion of the available and the total element content of soils.

Key words: carbon, nitrogen, sulfur content and ratio, available nutrient, soil types

INTRODUCTION

The inorganic nutrient forms are of primary importance for the nutrient supply of plants.

Most of the total carbon, nitrogen and sulfur content of soils are found in organic compounds. During the transformation and mineralization of organic matter, nutrients will be available for the plants. The chemical forms of carbon, nitrogen and sulfur will be modified by the transformation of soil organic matter content (Oneţ et al., 2013). The inorganic nutrient forms available to plants are of primary importance nutrient supply of plants.

The content and chemical forms of nutrient elements of various soils are considerably different. The C:N:S ratios in Hungarian soils are approximately 100:10:1, respectively (Stefanovits et al., 1999). Brady, 1990 compared the C:N:S ratios of soils were found 147:10:1.4 in Scotland,

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between 114:10:1.6 and 145:10:1.0 in North America, and between 140:10:1.5 and 152:10:1.2 in North-Eastern part of Australia.

The goals of our investigation were, to determine the plant available nitrate-N and sulfate-S content, the total CNS stocks and to calculate the C:N:S ratio in some Hungarian soil types. Furthermore, the plant available ratios of soil's total N and S content were calculated.

MATERIAL AND METHOD

The most important physical (soil texture, plasticity index) and chemical properties (pH in water and KCl solution, hydrolytic acidity, CaCO₃ and salt content) of 12 different soil types (chernozem, meadow, brown forest soil, blown sand, and solonetz) in eastern part of Hungary were analysed by description of Buzás, 1988.

Vegetation of soil types were: maize, orchard, oak forest and natural grassland (Table 1).

Table 1

Location and vegetation of soil types studied (2014)

Sampling code	Soil taxonomy (World Reference Base)	Location	Vegetation
1.CCh	Chernozems	Debrecen Látókép	maize
2.MCh	Chernozems	Debrecen-Látókép	maize
3.ChM	Vertisols	Hajdúböszörmény	maize
4.TM	Vertisols	Hajdúböszörmény	maize
5.MM	Vertisols	Debrecen – Dombos tanya	grassland
6.HSf	Arenosols	Debrecen - Pallag	oak forest
7.HSo	Arenosols	Debrecen - Pallag	orchard
8.BC	Luvisols	Debrecen - Pallag	orchard
9.BR	Cambisols	Pocsaj	grassland
10.BI	Luvisols	Pocsaj	grassland
11.MS	Solonetz	Hortobágy	grassland
12.SS	Solonetz	Pocsaj	grassland

The total C, N and S stocks were measured by using ELEMENTAR VARIO EL (Hanau, FRG) analyser. The plant available nitrate and sulfate content of soils were analysed in 0.01 M/dm³ CaCl₂ extract.

Soil samples were collected in the autumn of 2014. The laboratory measurements were made in 3 replications. The results were analysed statistically with the SPSS.13.0 program. There were calculated one-way ANOVA, and significant difference on 5 % level. The differences are signed in the tables with letters.

RESULTS AND DISCUSSION

The texture of the studied soils were: sand, loam and clays loam. Most of the analysed soils are weakly acidic and neutral, except for MM, which is strongly alkaline and BC, which is acidic. Among the soils, the hydrolytic acidity value of ChM, BC and MS indicates the need for soil amelioration. The lime content of the MM and the total soluble salt content of the MS are remarkable (Table 2).

Table 2

The most important parameters of examined soil types

Code	Texture	Plasticity according to Arany	pH H ₂ O	pH M KCl	Hidrolytic acidity (y ₁)	CaCO ₃ %	Salt %
1. CCh	Loam	46	6.13	5.45	7.85	-	0.039
2. MCh	Clayes loam	51	7.74	7.19	-	1.25	0.041
3. ChM	clay	52	6.40	5.29	11.2	-	0.022
4. TM	Clayes loam	55	6.58	5.46	7.60	-	0.025
5. MM	Clayes loam	58	9.53	8.13	-	26.7	0.022
6. HSf	Sand	38	6.79	6.02	5.07	-	0.005
7. HSo	Sand	26	7.23	6.49	-	-	0.003
8. BC	Sand	28	5.38	4.04	8.16	-	0.002
9. BR	Loam	50	7.34	6.77	-	0.21	0.028
10. BI	Clayes loam	45	7.12	6.32	-	-	0.011
11. MS	Clayes loam	54	5.92	5.11	8.19	-	0.049
12. SS	Clayes loam	48	7.60	7.27	-	1.8	0.259

Total element contents

The total carbon content of soils is the sum of organic and inorganic forms of carbon. The most of organic carbon is present in the soil's organic matter, while the inorganic carbon can be found in carbonate minerals, too. As it is well known, the 56 – 58 % of the organic matter content is organic carbon. Organic carbon in soils can be determined by the differences of total carbon and inorganic carbon contents, too (Nelson, Sommers, 1982).

According to their carbon content, the most of the soils in Hungary are generally in the medium category. On the basis of their nitrogen content they can be classified as poorly or moderately supplied category (Várallyay et al., 2006). Most of the studied soils have carbon content between 1.93 and 3.12 % (Table 3). The soils of ChM, TM and MM have higher carbon

content, and a lower level of carbon was determined in soil types of HSo, BC and SS.

Table 3

Changing of total C, N and S content and their ratios in some Hungarian soil types

Soil types	C (%)	N (%)	S (%)	C/N	C/S	N/S
1. CCh	1.93a	0.21a	0.07a	9.19a	27.57a	3.00a
2. MCh	2.24a	0.22a	0.06a	10.18a	37.33a	3.67a
3. ChM	*4.01b	0.33a	0.06a	12.15a	*66.83b	*5.50b
4. TM	*3.62b	0.30a	0.05a	12.07a	*72.40b	*6.00b
5. MM	*7.20d	*0.47c	0.05a	*15.32b	*144.00c	*9.40c
6. HSf	2.27a	0.21a	0.04a	10.81a	*56.75b	*5.25b
7. HSo	0.84a	*0.08b	0.03a	10.50a	28.00a	2.67a
8. BC	*0.34c	*0.04b	*0.02b	8.50a	17.00a	2.00a
9. BR	2.09a	0.22a	0.04a	9.50a	*52.25b	5.50a
10. BI	1.97a	0.21a	0.04a	9.38a	49.25a	5.25b
11. MS	*3.12b	0.33a	0.07a	9.45a	44.57a	4.71a
12. SS	*0.69c	*0.07b	*0.02b	9.86a	34.50a	3.50a
*LSD _{5%}	1.19	0.13	0.05	5.72	30.17	2.41

Values indicated by various letters are significantly different from each other

The total nitrogen content in the surface layer of most cultivated soils contains between 0.06 and 0.5 % (Bremner, Mulvaney, 1982; Ardelean, 2011). The organic nitrogen ratio is regularly between 97 and 99 % of total N, while the inorganic one is only a few percent. According to nitrogen contents (0.2 to 0.4 %) the most of the analysed Hungarian soil types are moderately supplied. Soil type of MM has a higher (0.47), and soil types of HSo, BC and SS have a remarkably lower (0.04 to 0.08%) total nitrogen contents.

According to Tabatabai, 1982 the organic sulfur ratio of the total one's is mostly higher than 95 %. In the well aerated soils, most of the inorganic sulfur normally occurs in form of sulfate. The total sulfur contents of mineral soils ranges between less than 20 ppm in sandy soils and larger than 600 ppm in heavy texture soils.

The average sulfur content of the Hungarian soils is 0.06 %, but it can reach the extremely high content of 2 % for solonetz, too. From 70 to 90 % of the total sulfur content of soils is found in organic compounds (Debreczeni, 1979). According to our measurements the total sulfur results changed in a narrow intervals (S % = 0.02 - 0.07).

Ratios of total element contents

The C/N ratio in arable soils ranges mostly from 8:1 to 15:1, averaging 10:1 to 12:1 (Brady, 1990). According to our measurements, the analysed soils are in this range, in most cases they are from 9:1 to 12:1.

It is well known, that in the soils the most important feature of plant residues are C:N. If this value is smaller than 80, the plant residues decompose relatively quickly. If the C:N is above 80, the decomposition process of the plant residues is a slow reaction.

It was also found in the literature, that the C:N ratio of soils is around 10:1 (Füleky, Rajkainé Véig, 1999). If the C/N ratio is higher than 30 at the initial decomposition of the soil organic matter, the nitrogen content in the soil is bound. If the C/N ratio is below 20, the mineral nitrogen is released during the mineralization process of the organic materials.

Stevenson, 1986 reported a C:S proportion of 108:1 in the soils. Similarly, Brady and Weil, 2010, found that the C:N:S ratio is 100:8:1 in stable organic matter content of soils.

According to Füleky and Rajkainé Véig, 1999, the ratio of C:N:S in soil's organic matter is around 100:10:1. If the C or N ratio is higher, the S is incorporated into the organic matter. Obviously, if the mentioned ratios are lower, the sulfur content is released during the mineralization.

Based on our results, the 100 C:S ratio varied between 0.69 and 5.88 (Table 4). It is noteworthy that larger values (CCh, MCh, HSo, BC), which exceed the literary values, were found in the agriculturally cultivated soils.

Table 4

Changes in soil use and the ratio of carbon and sulfur in soils

Soil types	C (%)	S (%)	C/S	100 C/S	sulfate S µg S/g soil	land use
1. CCh	1.93a	0.07a	27.57a	3.60	49.69	maize
2. MCh	2.24a	0.06a	37.33a	2.67	28.72	maize
3. ChM	*4.01b	0.06a	*66.83b	1.50	8.20	maize
4. TM	*3.62b	0.05a	*72.40b	1.38	7.03	maize
5. MM	*7.20c	0.05a	*144.00c	0.69	7.35	grassland
6. HSf	2.27a	0.04a	*56.75b	1.76	6.08	forest
7. HSo	0.84a	0.03a	28.00a	3.57	6.19	orchard
8. BC	*0.34c	0.02b	17.00a	5.88	6.97	orchard
9. BR	2.09a	0.04a	*52.25b	1.91	6.58	grassland
10. BI	1.97a	0.04a	49.25a	2.03	7.06	grassland
11. MS	*3.12b	0.07a	44.57a	2.10	43.16	grassland
12. SS	*0.69c	0.02b	34.50a	2.90	18.91	grassland
*LSD _{5%}	1.19	0.05	30.17	-	-	-

Values indicated by various letters are significantly different from each other

Sulfate S also showed higher values in CCh and MCh soil types as well as in MS and SS soils. Higher C/S and sulfate content may be due to regular application of sulfate-containing fertilizers, such as gypsum, containing superphosphate and/or ammonium sulfate.

In the Table 5 it can be found the proportion of plant-available nitrate nitrogen and sulfate sulfur in the ratio of total nitrogen and sulfur content of soils, respectively.

Table 5

The 0.01 M/dm³ CaCl₂ soluble nitrate and sulfate content in a ratio of total nitrogen and sulfur content of some soil types in Hungary (µg/g)

Soil types	NO ₃ ⁻ -N	Total N	NO ₃ ⁻ -N/ Total N	SO ₄ ²⁻ -S	Total S	SO ₄ ²⁻ -S/ Total S
1. CCh	4.95	2100	0.24	49.69	730	6.81
2. MCh	5.60	2200	0.25	28.72	550	5.22
3. ChM	1.29	3300	0.04	8.20	600	1.37
4. TM	1.90	3000	0.06	7.03	540	1.30
5. MM	3.44	4700	0.07	7.35	520	1.41
6. Hsf	0.43	2100	0.02	6.08	400	1.52
7. HSo	0.36	800	0.05	6.19	290	2.13
8. BC	0.51	400	0.13	6.97	200	3.49
9. BR	5.96	2200	0.27	6.58	350	1.88
10. BI	0.39	2100	0.02	7.06	350	2.02
11. MS	0.48	3300	0.01	43.16	680	6.34
12. SS	0.51	700	0.07	18.91	220	8.60

It can be stated that, depending on soil properties and soil use, the soil types CCh, MCh, BC, BR have a higher content of 0.01 M/dm³ CaCl₂ soluble (plant available) nitrate content than the other soils. The soil types of ChM, TM, MM, BR also have a higher content of plant available nitrate too, but in these soils, the organic nitrogen is less mobilizable. The amount of plant available sulfate S, similar to the nitrate, is higher in CCh, MCh, BC soil types, and also, in the soils with elevated salt content.

CONCLUSIONS

It was found that the majority of the analyzed soils have an average stock of organic carbon and nitrogen. All the sulfur content of the soils has changed in a narrow interval.

According to the literature data the C:N ratio of soils changed between 8:1 and 15:1. In the examined soils the C:S proportions are from 100:0.69 to 100:5.88. Literature data are mainly close to 100:1.

The results showed that the sulfur content of investigated soils were higher than average, especially for soils under agricultural cultivation as well as for salty (meadow solonetz and solonchak-solonetz) soil types. The higher sulfur content of cultivated soils is likely due to regular application of sulfate containing fertilizers.

If the CaCl₂ soluble nitrate content reached 0.25-0.27 % of the total ones, it can be considered as outstanding. The higher sulfate-S content is

from 5 to 8 % of the total sulfur content. The CaCl₂ extractable nitrate and sulfate content showed that higher values were found in the cultivated soils, than in the other ones.

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