CONTENTS AND PROPORTIONS OF DIFFERENT CARBON AND NITROGEN FORMS IN SOME SOIL TYPES OF HUNGARY

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Abstract: *A considerable proportion of the soil's carbon and nitrogen content can be found in the form of organic materials. But, by evaluating the nutrient supply of plants, the directly available inorganic nutrients are of primary importance. As a result of the decomposition and mineralization of different organic compounds, nutrients become available for the plants. The amount of carbon and nitrogen forms in the soils changes considerably during the decomposition of organic compounds. The transformation of the two elements is closely related, since the decomposition of organic materials has a significant effect on both. To get a better knowledge on the nutrient supply of the different soils, the amount of some carbon and nitrogen forms were examined in 12 extremely different soil types collected from different sites of eastern part of Hungary. The analysis of the soils' carbon content and the amount of specific carbon forms is necessary because the transformation of carbon compounds is related to the nitrogen cycle, which has primary importance in the nutrient supply of plants. That is why we have to measure the different forms of carbon and nitrogen in soils.*
The total carbon and total nitrogen content of the soils examined was measured by an ELEMENTAR VARIO EL CNS analyser (Hanau, FRG). The organic carbon content was measured according to Tyurin with destruction method. The amounts of organic compounds, which potentially can be easily decomposed, and two of the most important nitrogen containing ions were measured also after an extraction by 0.01 M/dm^3 $CaCl_2$ solution. After our research hypothesis they may correspond to the part of the total amount of organic compounds which potentially easily mineralise. Therefore, they may play an important role in the available nutrient supply of the different soil types as well as in plant nutrition.

Key words: *carbon and nitrogen forms of soils, plant nutrition*

INTRODUCTION

When evaluating the nutrient supply of plants, the directly available inorganic nutrients are of primary importance.

Besides the amount of nutrients, the nutrient supply of plants is significantly influenced by the acidity of soils (FÜLEKY et al., 2006; SIMON et al., 2006) and by the type of the chemical bond in which the nutrient can be found. A considerable proportion of the soil's carbon and nitrogen content can be found in the form of organic compounds, which are not directly utilizable. As a result of the breakdown and mineralization of organic compounds, nutrients become available for the plants. The speed of this process is influenced also by the soil compaction (KRISTON at al., 2009). Numerous processes are known which effect the nutrient forms in the soils (NÉMETH, 1996).

The amount of nitrogen and carbon forms in the soils changes with the transformation of organic materials. The transformation of the two elements is closely related, since the decomposition of organic materials has an effect on both of them (BALLA KOVÁCS et al., 2003).

By reducing the use of artificial fertilizers, the importance of the natural nutrient supply of the soil increases. We have proved that even under intensive fertilizing the original N content of the soil greatly contributes to the N supply of the plant (PESCHKE et al., 1999). The longer time passes after last fertilization, the higher the significance of the soil's original N content is (FILEP T. et al, 2008).

According to our experiments with ^{15}N isotope, 24-38 % of the N taken up by the plants originates from the soil's original nitrogen content in Hungary (LOCH et al., 1997a), while this value ranged between 15 and 23 % on German soils (PESCHKE et al., 1999).

The element contents and the amount of the specific nutrient forms greatly differ on different soils. Therefore, it is advisable to carry out the examinations on several soil types.

MATERIAL AND METHODS

The examinations were carried out on 12 extremely different soil types originates from the eastern part of Hungary in four replications (Table 1).

Table 1

Location and vegetation of the soils examined

Number and type of soils	Location	Vegetation
1. Calcareous chernozem soil	**Debrecen, Látókép**	**winter wheat**
2. Chernozem meadow soil	**Debrecen, Látókép**	**winter wheat**
3. Meadow solonetz	**Hortobágy**	**natural grassland**
4. Chernozem-like meadow soil	**Hajdúböszörmény**	**winter wheat**
5. Typical meadow soil	**Hajdúböszörmény**	**winter wheat**
6. Humus sand soil	**Debrecen-Pallag**	**oak forest**
7. Humus sand soil	**Debrecen-Pallag**	**orchard**
Brown forest soil with alternating thin layers of clay substance*	**Debrecen-Pallag**	**orchard**
9. Marshy meadow soil	**Debrecen, Dombos tanya**	**natural grassland**
10. Brown forest soil (Ramman type)	**Pocsaj**	**natural grassland**
own forest soil with clay illuviation	**Pocsaj**	**natural grassland**
12. Solonchak-solonetz soil	**Pocsaj**	**natural grassland**

***("kovárvány")**

The basic and general physical and chemical parameters of the soils were determined (Table 2). Knowledge of these is essential, since they have primary importance in the carbon and nitrogen cycle.

The total carbon, nitrogen and sulphur contents of soils were measured with an ELEMENTAR VARIO EL (Hanau, FR of Germany) element analyser (NAGY, 2000).

The organic carbon content was measured according to Tyurin with destruction method, while the nitrogen content was determined by Kjeldahl's method.

The easily soluble nitrogen forms were determined by using of 0.01 M/dm^3 $CaCl_2$ extracting solution. 5.00 g of air-dried soil samples were shaken for 2 hours with 50 cm^3 of extracting solution, then the amount of the nitrogen forms was determined from the filtrate with a SKALAR Contiflow continuous flow photometer (LOCH et al., 1998).

For measuring the total extractable nitrogen content, the soluble organic nitrogen compounds mixed with $K_2S_2O_8$ were put into an UV destructor, where the dissolved organic nitrogen content turned into nitrite and nitrate, so it was measured with the Gries-Ilosvay method. The extracted organic nitrogen content was calculated by differential method from the total and the inorganic nitrogen content (LOCH et al., 1997b).

RESULTS AND DISCUSSIONS

Soils with extremely different characteristics were chosen for the experiment. The basic physical and chemical parameters are shown in Table 2 and Table 3.

Table 2.

Main parameters of the soils examined, part 1

Soil number	Physical soil type	Soil plasticity index, K_A*	pH value in		
			H_2O	KCl	$CaCl_2$
1.	**loam**	**46**	**6.13**	**5.45**	**5.91**
2.	**clayey loam**	**51**	**7.74**	**7.19**	**6.90**
3.	**clayey loam**	**54**	**5.92**	**5.11**	**5.50**
4.	**clay**	**52**	**6.40**	**5.29**	**5.65**
5.	**clayey loam**	**55**	**6.58**	**5.46**	**5.86**
6.	**sand**	**38**	**6.79**	**6.02**	**6.07**
7.	**sand**	**26**	**7.23**	**6.49**	**6.35**
8.	**sand**	**28**	**5.38**	**4.04**	**4.62**
9.	**clayey loam**	**58**	**7.60**	**7.27**	**6.98**
10.	**loam**	**50**	**7.34**	**6.77**	**6.90**
11.	**clayey loam**	**45**	**7.12**	**6.32**	**6.51**
12.	**clayey loam**	**48**	**9.53**	**8.13**	**7.75**

*** Plasticity index of soils is in a strong connection to the inorganic (clay) and organic colloid contents of soils**

Table 3.

Main parameters of the soils examined, part 2

Soil number	Physical soil type	Hydrolytic acidity, y_1	$CaCO_3$ %	Salt %
1.	**loam**	**7.85**	**-**	**0.039**
2.	**clayey loam**	**-**	**1.25**	**0.041**
3.	**clayey loam**	**8.19**	**-**	**0.049**
4.	**clay**	**11.2**	**-**	**0.022**
5.	**clayey loam**	**7.6**	**-**	**0.025**
6.	**sand**	**5.07**	**-**	**0.05**
7.	**sand**	**-**	**-**	**0.003**
8.	**sand**	**8.16**	**-**	**0.002**
9.	**clayey loam**	**-**	**26.7**	**0.022**
10.	**loam**	**-**	**0.21**	**0.028**
11.	**clayey loam**	**-**	**-**	**0.011**
12.	**clayey loam**	**-**	**1.8**	**0.059**

The extreme values for the main parameters were as follows: Plasticity index 26 (humus sand, 7) - 55 (typical meadow, 5); saline content: 0.002 % (brown forest soil with alternating thin layers of clay substance ”kovárvány”, 8) - 0.059 % (solonchak-solonetz, 12); pH value in $CaCl_2$: 4.04 (brown forest soil with alternating thin layers of clay substance ”kovárvány”, 8) - 8.13 (solonchak-solonetz, 12). In half of the soils hydrolytic acidity could be measured, while four soils contained carbonate.

The total carbon and nitrogen content of soils measured by element analyser and the organic carbon content determined by Tyurin's method are included in Table 4.

The total carbon content of the soils (similarly to other parameters) varied greatly, the smallest content (0.34%) was measured in brown forest soil with alternating thin layers of clay substance ''kovárvány" (8), while the highest (7.2 %) was obtained in marshy meadow soil (9). The organic carbon content measured according to Tyurin with destruction method also varied greatly, the values were: 0.26 % (brown forest soil with alternating thin layers of clay substance "kovárvány") and 1.77 % (chernozem meadow soil (4) and marshy meadow soil (9). The extremely high total carbon content of marshy meadow soil (9) was due to the very high $CaCO_3$ content of the soil besides its high organic carbon content (1.75 %).

Table 4.

Total nitrogen and carbon contents measured by element analyser and organic carbon contents (Tyurin) of the examined soils

Soil number	Total content measured by element analyser		Total C/total N proportion	Organic carbon (Tyurin), %	Organic C/total C % proportion
	carbon (%)	nitrogen (%)			
	a	b	a/b	c	100*c/a
1.	1.930	0.206	9.35	0.97	50.3
2.	2.236	0.216	10.33	0.92	41.1
3.	3.117	0.326	9.55	1.37	44.0
4.	4.012	0.329	12.21	1.77	44.1
5.	3.618	0.299	12.11	1.58	43.7
6.	2.271	0.208	10.91	1.21	53.3
7.	0.837	0.079	10.64	0.45	53.8
8.	0.340	0.043	7.97	0.26	76.5
9.	7.200	0.473	15.24	1.75	24.3
10.	2.090	0.221	9.47	0.98	46.9
11.	1.970	0.214	9.20	0.83	42.1
12.	0.694	0.067	10.42	0.36	51.9

As is shown by the data, the organic carbon content of soils is 25-50 % of the total carbon content. The soils examined are extremely different in this aspect also: in the marshy meadow soil (9) with extremely high calcium-carbonate content, the ratio of the organic carbon was the lowest, 24.3 %, although the organic carbon content itself was high. The ratio of the organic carbon fraction was the highest (76.5 %) in the soil with the lowest total carbon content (brown forest soil with alternating thin layers of clay substance "kovárvány", 8).

Table 5.

The amount of N forms extractable with a 0.01 M $CaCl_2$ solution, the total organic nitrogen content (Kjeldahl) and their proportions in the soils examined

SoilNr.	Soluble in $CaCl_2$ (mg/kg)					Total organic N %*	Soluble organic/soluble total N (%)	Soluble organic/total organic N(%)	Soluble inorganic/ total N (%)
	NO_3^--N	NH_4^+-N	Inorganic N	Organic N	Total N				
	d	e	f=(d+e)	g	h	i	100*g/h	0.01*g/i	0.01*f/b
1.	4.95	3.67	8.62	0.59	9.21	0.148	6.40	0.040	0.418
2.	5.60	0.60	6.20	0.66	6.85	0.135	9.60	0.049	0.286
3.	0.48	0.46	0.94	0.97	1.90	0.232	51.05	0.042	0.029
4.	1.29	0.34	1.62	0.28	1.90	0.290	14.64	0.010	0.049
5.	1.90	0.41	2.32	0.25	2.56	0.204	9.66	0.012	0.077
6.	0.43	0.45	0.87	0.43	1.31	0.126	33.14	0.034	0.042
7.	0.36	0.36	0.72	0.09	0.80	0.062	10.63	0.014	0.091
8.	0.51	0.31	0.82	0.14	0.96	0.034	14.55	0.041	0.193
9.	3.44	0.56	4.00	1.46	5.46	0.280	26.81	0.052	0.085
10.	5.96	0.62	6.58	1.06	7.64	0.163	13.87	0.065	0.298
11.	0.39	0.40	0.79	0.46	1.25	0.149	37.00	0.031	0.037
12.	0.51	0.23	0.73	0.24	0.96	0.034	24.68	0.070	0.110

*** according to Kjeldahl**

The extreme values of the total nitrogen content were: 0.043 % (brown forest soil with alternating thin layers of clay substance “kovárvány”, 8), and 0.473 % (solonchak-solonetz, 12). This tenfold difference demonstrates that the soils greatly differed in this characteristic, too.

The highest organic nitrogen content measured by Kjeldahl’s method (0.29 %) was in typical meadow soil (5), while the smallest (0.034 %) was obtained in brown forest soil with alternating thin layers of clay substance “kovárvány” (8) and solonchak-solonetz soil (12).

Only a small fraction of the soil’s total nitrogen content is directly available to the plants. Therefore, it is also necessary to know the amount of soluble nitrogen fractions. For determining the soluble NH_4^+-N, NO_3^--N, organic N and total N contents, soil extraction with a 0.01 M/dm^3 $CaCl_2$ solution was performed. The results are presented in Table 5.

The total nitrogen content soluble by 0.01 M/dm^3 $CaCl_2$ was the highest on marshy meadow soil (9) (1.46 mg/kg), which is 16 times higher than the lowest value on humus sand (7) (0.09 mg/kg). The organic compounds extracted by $CaCl_2$ solution correspond to the total amount of organic compounds which potentially easily mineralise, therefore, they play an important role in the available nutrient supply of soils as well as in plant nutrition.

The maximum amount of total nitrogen extracted by $CaCl_2$ was measured on calcareous chernozem (9.21 mg/kg), while the minimum was on humus sand (0.80 mg/kg), meaning that the highest value is twelve times higher than the smallest.

When expressing the soluble organic N content as a percentage of the total soluble N content, it can be stated, that values under 10 % were measured in calcareous chernozem (1), chernozem meadow (2) and typical meadow (5) soils under intensive cultivation. The reason for this is that the high N fertilization considerably increases the soluble inorganic N content in the soils. The highest proportion of soluble organic fraction (51 %) was measured in meadow solonetz (3) with natural grass vegetation, which is due to the fact that a considerable part of the organic nitrogen compounds can be found in peptised form in solonetz soils and probably the mineralization of nitrogen is hindered.

When contrasting the soluble organic nitrogen content to the total nitrogen content, the values range between 0.01 % (chernozem-like meadow, 4) and 0.07 % (solonchak-solonetz, 12). In spite of this, the amount of soluble nitrogen cannot be considered insignificant in the nutrient supply of plants, since it is the form that is mineralized most easily.

Finally, calculating the directly available, soluble inorganic nitrogen content (that is the sum of NO_3^--N and NH_4^+-N) as a percentage of the total nitrogen content measured by the element analyser, the maximum value was 0.42 % (on calcareous chernozem, 1). The minimum (0.037%) was measured on brown forest soil with alternating thin layers of clay substance ”kovárvány” (11).

CONCLUSIONS

Our results prove that more than 99 % of the soil’s nitrogen stock becomes available for the plant only after a transformation. This draws the attention to the importance of knowledge on and influencing of the nitrogen transformation processes in the soil. Since the transformation of nitrogen compounds is done by soil microbes, it is necessary to study and know their activities.

To gain a better knowledge of the nutrient supply of the different soils, the amount of some carbon and nitrogen forms were examined in 12 extremely different soil types in Eastern Hungary. The examination of the soils’ carbon content and the amount of specific carbon forms is necessary because the transformation of carbon compounds is related to the nitrogen cycle, which has primary importance in the nutrient supply of plants.

The **total carbon** content of the soils examined was measured by a CNS element analyser. Similarly to other soil parameters, it ranged between wide boundaries, the lowest carbon content (0.34 %) was measured in brown forest soil with alternating thin layers of clay substance ("kovárvány"), while the highest value (7.20 %) was obtained in marshy meadow soil.

The **organic carbon** content measured according to Tyurin with destruction method also varied greatly, the values were: 0.26 % (brown forest soil with alternating thin layers of clay substance "kovárvány") and 1.77 % (chernozem-like meadow soil and marshy meadow soil). The extremely high total carbon content was due to the very high calcium-carbonate content of the soil besides its high organic carbon content (1.75 %).

Among the **nitrogen** forms having a primary importance in plant nutrition, the total nitrogen content was measured by a CNS element analyser. The extreme values of the total nitrogen content were 0.043 % (brown forest soil with alternating thin layers of clay substance "kovárvány") and 0.473 % (solonchak-solonetz). The tenfold difference demonstrates that the examined soil types were also very different in this respect.

The **organic compounds** extracted by 0.01 M/dm^3 $CaCl_2$ solution correspond to the total amount of organic compounds which potentially easily mineralise, therefore, they play an important role in the available nutrient supply of soils as well as in plant nutrition. The total nitrogen content soluble by 0.01 M/dm^3 $CaCl_2$ was the highest on marshy meadow soil (1.46 mg/kg), which is 16 times higher than the lowest value on humus sand (0.09 mg/kg). The maximum amount of total nitrogen extracted by the $CaCl_2$ was measured on calcareous chernozem (9.21 mg/kg), while the minimum was on humus sand (0.80 mg/kg).

It can be stated that the nitrogen content differs greatly in the different soils, but the ratio of the nitrogen forms is similar apart from a few exceptions. This indicates that the nitrogen forms are continuously transforming into other forms in order to create a balance. If the ratios do not follow this general trend, then the transformation is probably hindered somewhere.

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