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C- and N-transformation dynamics in the soil

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Summary

The C- and N-transformation processes were measured over a 11 day-incubation period under laboratory conditions in a calcareous sandy and a chernozem soil.

The experiment was carried out with and without glucose carbon source under different N nutritional conditions.

The water content of the samples was set to a moisture value corresponding to 70 % of the maximum water holding capacity. The CO_2 production and the ammonium- and nitrate-N content of the soil samples were determined periodically during the incubation period. Between the samplings on day 0 and day 2, the ammonium-N quickly nitrificated. In the presence of glucose, mineral nitrogen was immobilized simultaneously.

Between the samplings on day 3 and day 11, the N immobilization and mineralization processes were approximately equal.

CO_2 production in soil samples incubated with glucose and different quantities of N-supply reached a high value already in the first two days of incubation, except the soil sample incubated with glucose and without N-fertilizer. Later, the intensity of glucose decomposition was controlled by the rate of mineralization of the organic N-compounds of the soil.

Key-words: C- and N-transformation, soil, microbiology.

Die Dynamik der Transformation von C und N im Boden

Zusammenfassung

Der Prozeß von C- und N-Transformation wurde nach elf Tagen Inkubation im Sand und im Tschernosem gemessen. Dabei wurde Glukose als C-Quelle benutzt und mit einer glukosefreien Kontrollprobe verglichen.

Die Bestimmung der N-Transformation erfolgte an der mit N gedüngten Variante.

Im Boden wurden der Ammonium- und Nitrat-N-Gehalt und die Größe von CO_2 gemessen, welche sich durch die elftägige Inkubation bildeten.

In den ersten zwei Tagen wurde durch Nitrifikationen das Ammonium schnell verändert. In Gegenwart von Glukose wurde der mineralische N gleichzeitig immobilisiert. Zwischen dem 3. und dem 11. Tag war der Verlauf von Immobilisierung und Mineralisierung fast gleich. Die Produktion von CO_2 war in den ersten zwei Tagen beim glukosebehandelten Boden sehr intensiv.

Die Intensität des Glukoseabbaues wurde von der Intensität der Mineralisierung des organischen N bestimmt.

Schlüsselworte: C- und N-Transformation, Boden, Mikrobiologie.

1. Introduction

By utilization of organic nutrients and plant by-products about 40 % of plant's mineral nutrient requirement will be met from organic nutrient sources.

The greater part of straw and maize stem are utilizable by ploughing into the soil.

In this case plant pathological, agrochemical and soil biological aspects are to be taken into account.

Agrochemical and soil biological points of view are as follows: mineral nutrients, first of all building of N into microbial biomass is to be judged whether the immobilized N could be remineralized and is available for the plant at the time of maximal nutrient uptake (Bjarnason 1987, Novák 1972).

It is very important to prognosticate the decomposition speed of ploughed organic mass under ecological conditions, characteristic to the given area and soil (Gulyas et al. 1990, Jansen and Kucey 1988).

Similarly, it is essential, how the organic substratum influences the leaching of mineral nutrients (firstly NO_3-N) into soil water, as well as the influence of the added organic matter on the organic matter of soil and the humus itself. The experiments were undertaken to obtain an answer to these questions by examination of the C- and the N-cyclic processes of soils when incubated with glucose.

2. Materials and methods

The C- and N-transformation processes were measured over a 11 day-incubation period under laboratory conditions. The soil samples were collected from the plough-layer of a calcareous chernozem (Nagyhörecök) and a calcareous, slightly humous sandy soil (Őrbottyán).

The main physical and chemical properties of the investigated soil samples are given in the table 1.

Table 1

The main physical and chemical characteristics of the investigated soil samples

Soil properties		Calcareous sandy soil Őrbottyán	Calcareous chernozem Nagyhörcsök
Physical sand: physical clay, %		89: 11	64: 36
pH/H_2O		7,81	7,77
pH/KCl		7,86	7,36
$CaCO_3$, %		8,95	2,91
Organic matter content, %		0,71	2,98
Total N, mg/100 g soil		44,9	176,5
Available	N, ppm (Bremner)	18,1	25,9
	P_2O_5, ppm AL-soluble	114,8	180,1
	K_2O, ppm AL-soluble	116,7	312,4

The respiration experiments were carried out with and without the application of a glucose carbon source.

The treatments of the respiration experiment and the quantity of applied glucose carbon source and N, P, K nutrients are given in table 2.

Table 2

The amounts of applied glucose carbon source and N, P, K nutrients

Treatments	Glucose "C"	N	P_2O_5	K_2O
		mg/100 g soil		
Gl-C_0, N_0	0	0	10	10
Gl-C_0, N_{10}	0	10	10	10
Gl-C_0, N_{15}	0	15	10	10
Gl-C_0, N_{20}	0	20	10	10
Gl-C_{500}, N_0	500	0	10	10
Gl-C_{500}, N_{10}	500	10	10	10
Gl-C_{500}, N_{15}	500	15	10	10
Gl-C_{500}, N_{20}	500	20	10	10

The glucose carbon source and N, P, K nutrients were added to the soil samples as water solutions of pure chemicals.

The nutrient sources were: NH_4NO_3, KH_2PO_4 and $KHCO_3$.

The respiration vessels contained 150 g of air-dried soil.

Soil samples were moistened to 70 % capacity and incubated at 25 °C in a continuous air flow stream.

The experiment was carried out with six replications, evolved CO_2 was continuously trapped and periodically measured.

Soil sub-samples were removed to analyse their nitrate- and ammonium-N content.

The CO_2 produced in the soil samples was adsorbed in alkaline solution and determined by potentiometric titration. The data of CO_2 production of samples corresponded to 100 g air-dried soil in terms of CO_2 "C" values.

Ammonium- and nitrat-N content of the soil samples were determined from 2 M KCl extract by the method of Bremner (1965). Glucose content of soil samples was analyzed from a hot water extract by using the anthrone method (Sikora and McCoy 1990, Umbreit et al. 1964).

3. Results and discussion

The available N content slightly increased in the untreated (control) samples during the incubation (tables 3 and 4).

Similarly the inorganic nitrogen content was changed, when different NH_4NO_3 fertilizer doses were applied without glucose. This available N surplus results from the mineralization of soil organic N-compounds.

Between the samplings on day 0 and 2, the ammonium-N quickly nitrificated. The application of the glucose carbon source caused a very quick N-immobilization. The originally available soil N-compounds and the added fertilizer N were immobilized during the first two days of the respiration period.

After the 3rd day of incubation the intensity of the glucose decomposition was controlled by the rate of mineralization of the organic N-forms of the soil.

In this period the N-mineralization and N-immobilization processes were of approximately equal size. The mineralized N quickly nitrificated in the sandy soil, but remained in the chernozem soil as NH_4-N.

The CO_2 production of different N-treated soil samples incubated without glucose was very low during the testing period (table 5). This indicates that the

Table 3

Available nitrogen content of the soill samples during the incubation

Soil	Treatments	Days of the incubation period							
		0		2 day		4 day		11 day	
		NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N
		mg/100 g soil							
Őrbottyán	Gl-C_0, N_0	1,06	1,06	0,35	2,13	1,16	1,93	1,35	2,12
	Gl-C_0, N_{10}	1,24	5,31	0,53	8,32	1,54	6,55	1,16	9,44
	Gl-C_0, N_{15}	2,66	8,85	0,71	10,80	2,31	8,67	1,35	14,06
	Gl-C_0, N_{20}	2,66	9,38	0,89	15,22	3,08	11,17	1,93	13,49
	Gl-C_{500}, N_0	0,89	0,35	1,24	0,18	0,0	2,12	0,58	0,19
	Gl-C_{500}, N_{10}	2,12	4,96	0,35	0,18	0,39	1,34	1,16	1,16
	Gl-C_{500}, N_{15}	2,66	6,90	0,35	0,71	0,39	1,54	1,35	1,54
	Gl-$C5_{00}$, N_{20}	3,19	9,20	0,53	2,83	0,19	1,73	1,73	4,05

Table 4

Available nitrogen content of the soil samples during the incubation

Soil	Treatments	Days of the incubation period							
		0		2 day		4 day		11 day	
		NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N
		mg/100 g soil							
Nagyhörcsök	Gl-C_0, N_0	0,53	2,48	0	4,07	0,77	4,24	1,35	4,43
	Gl-C_0, N_{10}	3,01	6,55	0	12,57	1,93	10,40	0,58	13,49
	Gl-C_0, N_{15}	3,19	9,55	0	17,35	2,51	13,49	0,96	18,50
	Gl-C_0, N_{20}	4,78	10,62	0	20,71	3,28	16,18	1,16	22,73
	Gl-C_{500}, N_0	0,89	0,88	0	0,71	0,96	0,39	0,77	0,39
	Gl-C_{500}, N_{10}	4,25	5,49	0	0,35	1,35	0,58	1,73	0,77
	Gl-C_{500}, N_{15}	3,54	7,43	0	0,35	2,12	0,58	2,12	0,19
	Gl-C_{500}, N_{20}	4,96	9,38	0	1,24	2,89	0,19	2,89	0,19

mineralizable organic matter content of the soil was limited and the extent of that was not depended on the N-nutrient added.

CO_2 production of soil samples incubated with glucose reached a high value already during the first two days of incubation, except the soil sample without N fertilizer treatment. The mineralization of glucose was limited by the low N-content available.

Table 5

CO_2 production of the soil samples

Soil	Treatments	Days of the incubation			Total liberated
		2	4	11	
		CO_2 "C" mg/100 g soil			
Őrbottyán	Gl-C_0, N_0-N_{20}	12,0	11,2	10,7	33,9
	Gl-C_{500}, N_0	51,4	203,6	82,6	337,6
	Gl-C_{500}, N_{10}	153,2	111,6	71,5	336,3
	Gl-C_{500}, N_{15}	209,8	74,1	53,6	337,5
	Gl-C_{500}, N_{20}	233,8	65,9	40,0	339,7
Nagyhörcsök	Gl-C_0, N_0-N_{20}	13,0	12,5	12,3	37,8
	Gl-C_{500}, N_0	62,6	182,2	58,4	303,2
	Gl-C_{500}, N_{10}	139,5	100,1	64,8	304,4
	Gl-C_{500}, N_{15}	165,6	75,6	61,8	303,0
	Gl-C_{500}, N_{20}	190,2	69,4	45,0	304,6

In case of adding different quantities of N-nutrients, the glucose mineralization, i. e. the CO_2 production was proportional to the given quantity of added N.

The CO_2 production values, measured on the 3rd to 4th day of incubation, indicated that the CO_2 production of soil samples, incubated with glucose and without N, reached very high values. It means that – during such conditions – the heterotroph soil microbe population, multiplicated on glucose, attacked the mineralizable, organic N-content-components of soil and the N, mineralized from soil, caused a significant CO_2 production.

In this case, it must be stated that the measured CO_2 production does not come purely from the glucose during the decomposition of the humic compounds, but the mineralization of 1 mg NH_4-N is going on with the releasing of "C" from about 10 mg CO_2.

On the 3rd to 4th day of incubation the CO_2 production of the soil samples incubated with glucose and different quantities of N-nutrients significantly decreased, correlating with the observation on the first two days of incubation when the N-nutrients added were totally immobilized. Subsequently the extent of respiration is determinated by the N-quantity mineralizable from soil.

In the last column of table 5, the gross respiration values of different treated soil samples are demonstrated, indicating that the gross CO_2 production of the soil samples was practically equalized.

In table 6, the net respiration data of soil samples are given. It is calculated by subtracting the so-called basic-respiration values of soil samples incubated without glucose.

Tabelle 6

CO_2 production in the soil samples incubated with glucose C-source

Soil	Treatments	Days of the incubation			Net respiration	Residual glucose "C"	Decomposed glucose "C"
		2	4	11			
		CO_2 "C" mg/100 g soil				mg Gl "C"/ 100 g soil	
Őrbottyán	Gl-C_{500}, N_0	39,4	192,4	71,9	303,7	220,0	280,0
	Gl-C_{500}, N_{10}	141,2	100,4	60,8	302,4	165,0	345,0
	Gl-C_{500}, N_{15}	197,8	62,9	42,9	303,6	136,0	364,0
	Gl-C_{500}, N_{20}	221,8	54,7	29,3	305,8	102,0	398,0
Nagyhörcsök	Gl-C_{500}, N_0	49,6	169,7	46,1	265,4	230,0	270,0
	Gl-C_{500}, N_{10}	126,5	87,6	52,5	266,6	190,0	310,0
	Gl-C_{500}, N_{15}	152,6	63,1	49,5	265,2	156,0	344,0
	Gl-C_{500}, N_{20}	177,2	56,9	32,7	266,8	134,0	366,0

In the last columns of table 6, the remaining glucose content and the decomposed quantity of glucose of soil samples incubated with glucose are given. Data show that in soil samples incubated without mineral N-nutrient, 44 to 46 % of glucose added was not composed, yet. In case of adding N-nutrient, the glucose quantity remaining in soil decreased about the level of the N-nutrient added.

Data from the incubation experiment with glucose showed that the glucose carbon source added to soil was significantly influencing the organic N-status of soil.

Without adding N, the heterotroph micro-organisms multiplicated on the glucose, mineralized the easily decomposable organic N-components of soil as well as the dead micro-organisms biomass in the soil. Mineralization of the organic N served with mineral N-nutrient for the further use of the glucose C.

Micro-organisms incorporate the mineralizable nitrogen differently into the biomass. While the C/N ratio of a bacteria's biomass is 4 to 5 : 1, this can reach a 15 : 1 value in the case of soil fungi C/N, and a value of 8 : 1 in soil microbe population biomass . It is referring that the change in the quality of soil microflora composition can be induced also by the quantity and the C/N ratio of plant residuals in the soil. The degradation becomes progressively more rapid, so a marked increase in the activity of fungal biomass has a wider C : N ratio than the bacterial biomass itself (ALLISON and KILLHAM 1988, GULYAS et al. 1985, SZEGI et al. 1985).

The speed of the organic matter decomposition and the ratio of N-immobilization and N-mineralization are determinated by the available N-content of soil, the original organic N-content of plant residuals, as well as the N-fertilizer added at ploughing.

According to JANSEN and KUCEY (1988) the aim is to assure the quick remineralization of N which is built into the biomass and the transit from net N-immobiization into net N-mineralization by agrotechnical or agrochemical ways.

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