Some Soil Biological Questions of Intensive Fertilization

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In classical agricultural systems the nutrient supply of the plants depended directly on the activity of the microorganisms present in the soil. The microbial biocoenoses of the soil decomposed plant residues as well as organic manures and the humus materials of the soil. In this way they supplied mineral nutrients for the plants. The cultivation of legumes in crop rotations resulted in a considerable quantity of nitrogen compensation. As a result of the wide-scale application of chemicals the situation has now changed to a certain extent. Mineral nutrients are applied in large quantities and these can be utilized by plants directly, without the assistance of microorganisms. At the same time, microorganisms incorporate the mineral nutrients added to the soil into their bodies and become consumers of artificial fertilizers. Therefore, taking their form of nutrition into consideration, they appear as competitors of the higher plants.

The difference between higher plants and saprophytic soil microbes is that the latter are heterotrophic and satisfy their carbon requirements from the organic compounds present in the soil. It is logical that the idea arises, that the effectiveness and influence of mineral fertilizers could be controlled somehow through the plant residues entering the soil. In the present research connections were sought between the physical and chemical properties of soils and the intensity of the decomposition of organic residues.

The investigations took the form of model experiments involving cellulose tests on soil samples collected from 25 territories under agricultural cultivation, representing the main soil types of Hungary, and tests using the respiration method.

Two treatments were used in the cellulose tests: in the first no mineral nutrients were added and in the second NPK nutrients were applied. In the latter case the mineral nutrients /15 mg N, 15 mg P_2O_5, 15 mg K_2O active agent/100 g air-dry soil/ were dissolved in the water used for moistening. The soil samples were incubated, after which the quantity of decomposed cellulose was determined from the reduction in weight occurring during the cellulose tests.

The cellulose decomposition data measured in soil samples which were just moistened /basic cellulose decomposing values/ give information for the estimation of the actual biological activities of different soils, while the values measured when NPK was added /induced cellulose decomposing data/ allow conclusions to be drawn on the potential biological activity.

The respiration experiment consisted of four treatments:

1. Soil samples moistened with distilled water
2. Soil + NPK
3. Soil + 1% cellulose
4. Soil + 1% cellulose + NPK

The moisture content of the soil samples was adjusted to 65% of maximum water holding capacity, as was done in the cellulose test experiment. The cellulose carbon source was introduced into the soil in the form of powdered cellulose, while the NPK nutrients were dissolved in the water used for moistening. /In terms of active agents the quantity of NPK was 7.5 mg per 100 g of air-dried soil. The period of respiration lasted for 8 weeks, during which time the CO_2 production was measured at regular intervals by potentiometric titration of soil samples placed in respiratory dishes.

The closeness of the correlations existing between the experimentally determined indices for the intensity of cellulose decomposing activity, soil respiration and soil characteristics was evaluated by multivariate linear regression analysis.

The results achieved showed that the intensity of cellulose decomposing activity and the soil respiration depended on soil characteristics.

The multivariate linear relationship between the cellulose decomposing ability of the soil and the soil properties may be described as follows:

$$Y = \%\ \text{cellulose decomposition} = b_o + b_N.N + b_p.P + b_K.K + b_{Ca}.Ca + b_{Mg}.Mg + b_{pH}.pH + b_{clay}.clay\%.$$

Under the given experimental conditions the cellulose decomposition of untreated soils /basal cellulose decomposition/ depended primarily on the available P and N content of the soils. The consideration of further soil properties, such as exchangeable Mg content, pH value and clay content, further confirmed the closeness of the relationship between cellulose decomposition and soil properties /Table 1/.

When NPK nutrients were added, the induced cellulose decomposing values /Table 2/ did not depend on the quantity of nutrients /N, P, K/ originally present in the soil. Correlations significant at the 95% level of probability were only found for the clay content and pH of the soil.

When calculating the linear regression between the CO_2 production of the soil samples and the soil testing parameters, the gross CO_2 production of the whole respiration period, corresponding to 100 g air-dried soil was taken into consideration. This value was converted to CO_2"C" content to facilitate computer processing.

The basal respiration /soil samples only moistened/ of the investigated soils is determined mainly by the organic matter content of the soil /Table 3/. The closeness of the correlation increased when further soil characteristics were taken into consideration. Among the nutrients an increase in the available potassium content stimulated the rate of basal respiration to the greatest extent. The dependence on the soil properties of respiration induced by a cellulose carbon source is illustrated in Table 4.

Table 1

Relationship between cellulose decomposition /Y = basal activity/ and soil properties of the untreated soils

b_o	Partial regression coefficients							R^2
	b_N	b_P	b_K	b_{Ca}	b_{Mg}	b_{pH}	b_{clay}	
44.003		5.276^{xx}						0.2676^{xx}
38.242	2.265^{xx}	3.814^{+}						0.3477^{xx}
42.642	2.810^{xx}	3.119^{+}			0.121			0.3999^{x}
25.552	3.121^{xx}	3.184^{+}			0.107	2.584		0.4394^{x}
19.957	2.670^{xx}	3.991^{+}			0.168	2.340	0.221	0.4693^{x}

Levels of significance: ^{xxx} 99.9%; ^{xx} 99%, ^{x} 95%, $^{+}$ 90%.
N = available N, mg/100 g soil /according to WARRING-BREMNER/
P = available P, mg/100 g soil /OLSEN/
K = available K, mg/100 g soil
Ca = exchangeable Ca, mg/100 g soil
Mg = exchangeable Mg, mg/100 g soil
pH = pH /KCl/
clay = clay content, %

When a cellulose carbon source was introduced into the soil without an NPK nutrient supplement, the respiration depended primarily on the available nutrient content /NPK/.

The CO_2 production of soil samples fertilized with NPK and enriched with cellulose depended on the available nitrogen and phosphorus content /Table 5/. Increasing N and P contents stimulated the CO_2 production of the soil, while an increase in the exchangeable Mg^{2+} and the pH value decreased it.

The results of the investigations on cellulose utilization and soil respiration combined with a knowledge of chemical and physical soil parameters may help in detecting the causes of differences in the productivity of soils by exploring the factors that stimulate or inhibit the soil biological processes.

Table 2

Relationship between cellulose decomposition /Y = induced activity/ and soil properties of soils treated with NPK

b_o	Partial regression coefficients							R^2
	b_N	b_P	b_K	b_{Ca}	b_{Mg}	b_{pH}	b_{clay}	
99.152							-0.237^{x}	0.2272^{x}
100.064						-1.66	-0.241^{x}	0.2942^{x}

Table 3

Relationship between soil respiration /Y = basal respiration/ and properties of the soils only moistened

b_o	Partial regression coefficients						R^2
	b_N	b_P	b_K	b_{Mg}	b_{pH}	b_H	
48.861						4.614^{xxx}	0.5450^{xxx}
30.027					2.526^{xx}	4.231^{xxx}	0.6327^{xxx}
33.472				-0.053	2.177^{xx}	4.570^{xxx}	0.6578^{xxx}
31.933			0.344^{xx}	-0.084^{+}	1.970^{x}	4.059^{xxx}	0.6933^{xxx}

H = organic matter content, % /according to TYURIN/

Table 4

Relationship between soil respiration /Y = respiration induced by cellulose/ and soil properties

b_o	Partial regression coefficients						R^2
	b_N	b_P	b_K	b_{Mg}	b_{pH}	b_H	
46.130	14.814^{xx}						0.3949^{xx}
66.107	26.247^{xxx}		4.002^{xx}				0.5930^{xxx}
50.966	22.174^{xxx}	14.219^{xxx}	3.715^{xx}				0.7594^{xxx}
32.861	22.776^{xxx}	13.976^{xxx}	3.878^{xx}		3.18		0.7673^{xxx}

Table 5

Relationship between soil respiration /Y = induced respiration by cellulose and NPK/ and soil properties

b_o	Partial regression coefficients						R^2
	b_N	b_P	b_K	b_{Mg}	b_{pH}	b_H	
115.184	15.980^{xxx}						0.4134^{xxx}
129.119	18.417^{xxx}			-0.534^{x}			0.5502^{xxx}
206.060	18.489^{xxx}			-0.620	-12.414^{x}		0.6600^{xxx}
195.302	15.657^{xxx}	10.691^{xx}		-0.537^{x}	-12.695^{xx}		0.7416^{xxx}

Information on soil physical and chemical parameters combined with a knowledge of soil temperatures and soil moisture contents obtained in laboratory investigations supplemented by field experimentation, will lead to the prediction of the speed of mineralization of the plant residues in the soils. This in turn will mean that the decomposition of mineralizable organic matter in the soil can be controlled by means of agro-technical and agrochemical methods.

Summary

Investigations were carried out under laboratory conditions to determine the biological activity of soil samples collected from 25 locations representing the main soil types of Hungary. The investigations included the study of cellulose decomposing activity, respiration activity, the correlation between these indices, and basic physical and chemical soil properties. The correlations between soil properties and the indices of soil biological activity were evaluated using multivariable linear regression analysis.

The results of the analyses indicated that the cellulose decomposing activity depended on the available nutrient content of the soil. In the case of a good supply of phosphorus and nitrogen certain unfavourable soil properties limited the cellulose decomposition.

An even closer correlation was detected between the intensity of soil respiration and the soil properties. The basal respiration of the untreated soils was definitely determined by the quantity and quality of the organic matter in the soil. The degree of respiration induced by a cellulose carbon source depended primarily on the quantity of available nutrients. The intensity of the respiration of soil samples fertilized with NPK and enriched with cellulose was also influenced by the available phosphorus and nitrogen contents. The results of investigations on cellulose utilization and soil respiration combined with a knowledge of chemical and physical parameters may help in detecting the causes of differences in the productivity of soils.