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THE C/N-RATIO AS A SOIL FERTILITY INDEX *)

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In many parts of the world, the crop production ~~still~~ to a large extent depends on the natural riches of the soil in plant nutrients. There, the principal source of N is the organic matter of the soil. However, also in case of N-fertilizers being sufficiently available, information of the amount of N which the soil itself can supply is wanted to estimate the additional fertilization with mineral N.

There is no evidence of an uptake of any importance of N by plant roots from organic compounds. The role of organic matter as a source of N therefore primarily depends on the rate in which this nitrogen is released as inorganic ions. This means that the factors controlling the rate of decomposition of the organic matter are of great practical importance, a decomposition mainly brought about by the soil microflora.

There are external factor which strongly influence this rate of decomposition such as moisture content, temperature, acidity, aeration, etc. Here we will confine ourselves to the discussion of an intrinsic factor of the organic matter, viz. its C/N-ratio. We will discuss the C/N-ratio as an indicator of the decomposability of soil organic matter and, consequently, of the N-supplying potential of the soil.

This subject is not new. In fact, it is discussed in many publications since the last 40 years. However, the problem appeared, as most problems, to be more complicated than originally expected. One might say, there is no simple interpretation of the C/N-ratio, equal for all individual cases. Or, in other words, the C/N-ratio alone, is insufficient to predict the decomposability of the soil organic matter. Other values and facts have also to be taken into account.

Undecomposed plant residues consist mainly of:

carbohydrates	: ca.	44% C, no N
lignin	: ca.	58% C, no N
proteins	: ca.	50-55% C, 15-18% N (C/N ca. 2,8-3.7).

Thus, the C/N-ratio factually is the ratio total C/protein-N!

The decomposability of carbohydrates is generally good (a.o. depending on the degree of incrustration with lignin). Lignin is much more resistant, whereas proteins usually are readily disintegrated, however, sometimes being inhibited by tanning agents. A higher lignin content is mostly attended with a lower protein content. Therefore, when comparing different undecomposed plant materials, it is evident that generally the rule holds: The wider the C/N, the slower the decomposition.

Examples: 1. Legumes (C/N about 15) are more readily decomposed than crop residues (stubbles and roots) of cereals (C/N may be 60 or even wider). As to nitrogen: with legumes there is a rather rapid release of inorganic N into the soil as a result of microbial breakdown. However, with cereals, microbial degradation is at first even attended with withdrawal of inorganic N from the soil and fixation in organic form. In a second stage this nitrogen is, at least partly, slowly released again.

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2. Wood litter with a narrow C/N-ratio generally decomposes faster and releases more nitrogen (calculated per weight of organic material) than litter with a wider C/N-ratio. This should be kept in mind when virgin soils, covered with forest, are being cultivated.

However, C/N is not always enough to predict the decomposability. According to literature, pine needles are more slowly broken down than cereal residues, although their C/N-ratio is 35-40. Also, peat-moss with C/N 50-60 is much more resistant when added to the soil, than crop residues. (Consequently, there will not be a serious temporary N-fixation when peat-moss is added to the soil, but also afterwards no N-release of any importance.)

It is clear that this rule of thumb - the wider C/N, the slower decomposition - no longer holds when we compare materials of the same origin, but decomposed to a different degree. The process of decomposition is generally attended with a narrowing of the C/N, but this does not involve that the material hereby becomes better decomposable, the more the C/N is decreased. On the contrary, as the decomposition proceeds, the remaining material becomes on the average ever more persistent.

In the same way, the initial decomposition of legumes with C/N ca. 15 is more rapid than that of stable manure with the same C/N. The explanation is, that in (partly) decomposed material, protein is no longer the only N-containing component, but lignin and microbial metabolic products are partly converted into "humus"-compounds, which also contain nitrogen. Of these compounds the humic acids form the most important group with 50-60% C and 2-5% N (C/N is about 10-30). The N in these compounds is firmly bound and scarcely available for the microorganisms. The C/N then is no longer total C/protein N.

In the same way the C/N of a recently cultivated virgin soil, where the bulk of organic matter is still involved in a stormy turn-over process, has not the same meaning as the C/N of an old arable soil where an equilibrium is reached between the supply of fresh material and the breakdown of the humus. Here again, the C/N-ratio alone is insufficient to predict the decomposability and therefore also the N-supplying potential of the soil. The preceding history of the organic material should be taken into account.

But what when we compare the humus in different soils, all of them with this equilibrium more or less reached, and the main part of the organic matter already well-humified? In 1924 Waksman gave the following table for a series of soils:

% N	0.910	1.684	1.860	2.889
C/N	10.0	11.8	12.0	12.4
mg CO_2/100 g soil resulting from microbial activity	120	188	168	231

Waksman concluded: "The wider the C/N ratio, the more readily will the humus decompose, under normal conditions". In 1934, however, Engel remarked that to compare the rate of decomposition, the formation of CO_2 has to be related to the amount of organic C which gives:

mg CO_2/g C	48.2	40.9	33.0	29.3

This points to a conclusion which is just opposite to what Waksman stated.

We checked this for cultivated sandy soils in our country, where the C/N-ratio is widely varying, more or less corresponding with the classification of these soils according to the usual pedogenic criteria (figure 1). The question as to what extent the C/N ratio characterizes the organic matter was answered by determining the C- en N-mineralization during incubation of the soils in the laboratory under standard conditions. Some illustrative figures are:

	% org. matter	C/N	mineralized during 30 d. of incubation			
			% of C_t	% of N_t	mg N/100 g org. matter	mg N/kg soil
brown gley soils (A)	3.8	12	2.9	2.3	90	33
recl. podzol. heath soils (A)	6.9	22	1.3	1.6	36	23
black gley soils (G)	7.3	12	3.1	2.2	87	58

(A = arable land; G = grassland)

Brown gley soils contain on the average much less organic matter than the podzolized heath soils and the C/N is much narrower. The decomposability, however, is much better. In this respect, the humus is of quite different character. The humus of black gley soils, used as grassland, is very similar with that of the brown gley soils, but its amount is as high as in podzolized heath soils.

Figure 2 demonstrates a significant inverse relationship between the C/N ratio and the N-mineralization per 100 g of organic matter. However, the spreading is rather wide. In case of individual samples, the potential N-supply of the soil consequently cannot be deduced from C/N with accuracy, but the general trend is clear.

We have no data on yields of the plots where these samples were taken, but from yields of a series of comparable sandy soils in Germany, Nieschlag derived the following fertility "index":

$$\frac{10.000}{3} \cdot N \cdot \frac{1}{C/N} + 4 \cdot \% \text{ clay}.$$

In other words, for cultivated sandy soils, the clay content and the C/N-ratio in combination with the N-content of the soil provide us with an index of the fertility, which for these soils is inherent with the N-mineralization. We have no reason to believe that for other soil types the C/N-ratio and the N-content will have another meaning. However in their "fertility index", besides the clay content, perhaps also other factors might be important.

Summary

For plant materials and for soil organic matter of comparable degree of decomposition the general trend is: The narrower the C/N-ratio, the more readily C and N are mineralized. This is, however, an approximative rule. Individual differences may also play a, sometimes even dominating, rôle.

Figure 1. Estimated frequency curves of the C/N-ratios of some groups of sandy soils.

x	b.G.	= brown gley soils (arable land).
▽	s.G.	= black gley soils (grassland).
.	b.P.	= brown old arable land (brown "plaggen" soils).
o	s.P.	= black old arable land (black "plaggen" soils).
+	H.p.	= reclaimed podzolised heath soils (arable land).
△	F.	= soils reclaimed from cut-over peat (arable land).

Figure 2. The relation between the nitrogen mineralization and the C/N-ratio of sandy soils.

legend as in Figure 1 except that here:

. = low wet humus podzols.

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