

QUELQUES NOTICES SUR L'IMPORTANCE DE LA MINÉRALISATION ET DE
L'IMMOBILISATION DE L'AZOTE POUR LES RECOMMANDATIONS DE FUMURE

H. VAN DIJK

INSTITUT POUR L'ETUDE DE LA FERTILITE DU SOL

B.P. 30003

9750 RA HAREN (Gr.), PAYS BAS

RESUME

Des résultats de champs d'expériences aux PAYS BAS indiquent que les différences de minéralisation nette de l'azote contribuent pour beaucoup moins de 50% à la variation des besoins en azote des cultures.

Ces différences de minéralisation expliquent mieux les variations de teneur en azote de l'humus récemment formé que celles de l'humus total et la répartition de l'azote dans les fractions obtenues par hydrolyse acide.

Une partie de l'azote minérale appliquée au Printemps peut être immobilisée temporairement, la quantité augmente à mesure que la richesse en azote minéral du sol diminue.

SUMMARY

Results of Dutch field experiments indicate that, in general, differences in net mineralization of nitrogen contribute far less than 50% to the variation in nitrogen fertilizer requirement of crops.

These differences are better explained by variations in amount and N-content of recently formed humus than by differences in total humus or by the distribution of nitrogen over fractions obtained by acid hydrolysis.

Part of the fertilizer nitrogen given in spring may be immobilised temporarily, the extent of which is greater as the mineral-nitrogen content of the soil is lower.

ISN = 69906

SOME NOTES ON THE IMPORTANCE OF MINERALISATION AND IMMOBILISATION OF NITROGEN IN
MAKING FERTILIZER RECOMMENDATIONS

H. van Dijk

Institute for Soil Fertility, Haren-Gr., The Netherlands

The amount of nitrogen in the soil, available to a nonleguminous, well fertilised crop during the growing season mainly consists of:

- *mineral nitrogen already present at the beginning of the season;
- *plus the net difference between the amount of nitrogen mineralised from organic matter during the growing period of the crop and the amount immobilised by microbial action;
- *plus fertilizer nitrogen;
- *minus possible losses due to leaching, denitrification, volatilisation as NH_3 , and sometimes NH_3 -fixation by clay minerals.

Through careful sampling and analysis, mineral N in the soil profile can be determined with satisfactory accuracy. The work of *Borst and Mulder* (1971) and of *Ris* (1974, 1978; *Ris et al*, 1981) may be summarised as follows:

A total of 33 field experiments with winter wheat carried out during 6 years ('67-'72) on different soil types gave a statistically significant negative correlation ($r = - 0.53$) between amount of mineral N in the profile about 1 March and the optimum rate of fertilizer-N, i.e. the amount required to obtain maximum yield. That the correlation was not better is partly due to severe disease problems, particularly mildew, in a number of years.

A total of 28 field experiments with potatoes, again on different soil types, carried out by *Ris* during 4 years ('73-'76) gave a statistically significant correlation ($r = - 0.65$).

From 68 field experiments with sugar beet, conducted in 4 years ('74-'77) a correlation coefficient of $- 0.75$ could be calculated. This means that, roughly speaking, 50% of the variation in fertilizer requirement can be explained by differences in amount of mineral N in the soil profile at the start of the season.

No doubt, part of the variance is due to sampling and analytical errors, to climatic variations between years and within years, to differences in incidence of crop diseases and pests and perhaps also to differences in plant performance on different soils not due to effects from nitrogen. Therefore, probably much less than 50% of the variance in N requirement must be due to soil nitrogen factors other than initial mineral N in the soil profile, such as

net mineralisation of nitrogen during crop growth

In soil a rapid turnover occurs from inorganic into organic N and vice versa. Immobilisation - i.e. the conversion of inorganic to organic N compounds through the action of microbes - and the reverse process, mineralisation, occur simultaneously.

In soils not recently supplied with organic materials, mineralisation generally dominates. Numerous methods have been proposed to estimate the net mineralisation potential either by incubation techniques or from chemical soil nitrogen indices. When soils are very uniform, it is rather immaterial which index is chosen for the mineralisation potential; total-N content is often as good an index as any other. When soils are heterogeneous, the correlation coefficients between indices for the mineralisation potential and yield or nitrogen uptake by the crop are always much lower and, though some indices turn out to be better than others, so far no index unambiguously emerges as being always the best one (Van Dijk, 1972).

The different indices are often poorly correlated with one another as is illustrated in figure 1.

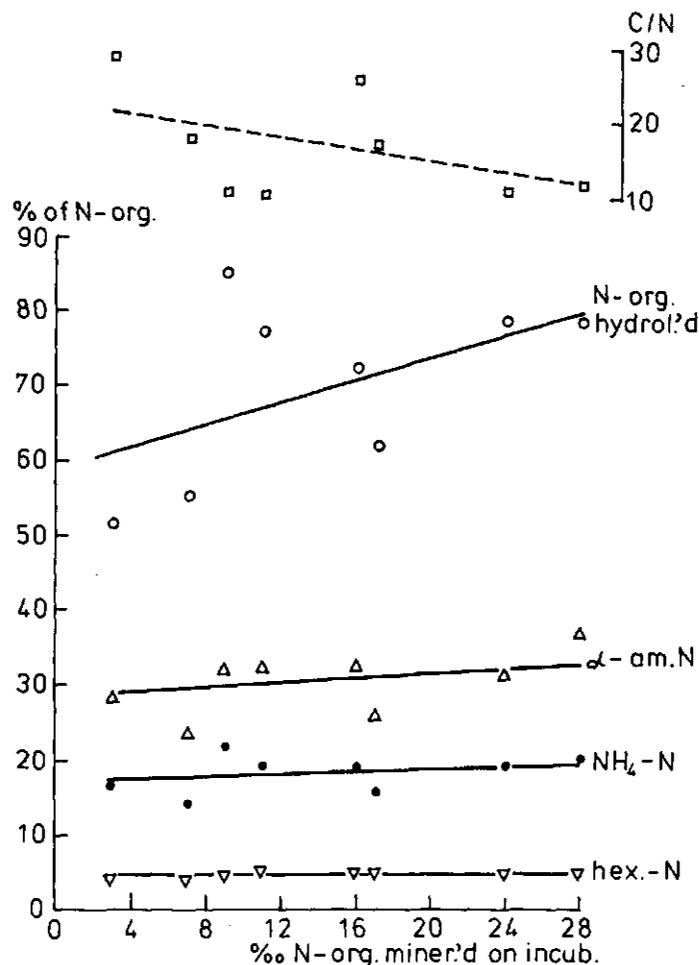


Figure 1. Carbon-nitrogen ratio and percentage of soil organic nitrogen hydrolysed by hydrochloric acid in relation to per mill of soil organic nitrogen mineralized during 4 weeks of incubation.

(α-am.N = α-amino acid N; NH₄-N = "amide"-N; hex-N = hexose amine N)

Samples of 8 sandy soils showing a large variation in N-mineralisation during 4 weeks of incubation and in carbon-nitrogen ratio were subjected to hydrolysis with hydrochloric acid according to *Bremner* (1965).

When the hydrolysate-N-fractions, expressed as % of total organic N, were plotted against the ‰ of N mineralised in 4 weeks, no relation with hexose amine-N was found. There is an indication of a relation between $\text{NH}_4\text{-N}$, α - amino acid-N, total hydrolysable N and C/N - ratio (on the ordinate) and mineralisation rate (on the abscissa). However, the scattering is large. The explanation could be that hydrolysability reflects a property of the total organic matter, whereas mineralisation especially responds to differences in amounts of young, i.e. recently formed, humus. This is suggested by results obtained on the "Three Organic-Matter Farms" in the Northeastpolder, The Netherlands. During 25 years a farming system in which only mineral fertilizers were used was compared with one that included green manures, and with a ley-farming system including farmyard manure.

Table I shows some data. It is apparent that after 25 years the divergence in net nitrogen mineralisation (determined in a 6-week laboratory incubation experiment) is much larger than that in the organic-matter or total nitrogen contents or (not shown in the table) acid-hydrolysable nitrogen fractions. The same is true for the enzyme activities which to a certain extent reflect the microbial activity.

TABLE I. Some data on the soil of the "Three Organic-Matter Farms" after 25 years of farming under different systems.

	mineral fertilizer only	min. fert. + green manure	min. fert.+ ley farming (livestock)
% soil organic matter (S.O.M.)	2.09	2.26	2.57
% N_t	0.107	0.120	0.135
N-content of S.O.M. (%)	5.1	5.3	5.2
N-mineralis. in 6 w. incub. (mg.kg^{-1} soil)	14	17	25
id. in the field (kg.ha^{-1} , 0-100 cm; 1976)	150		280
Dehydrogenase act. ($\mu\text{l H}_2$)	11	15	22
Fosfatase act. (V_{max} in $\mu\text{mol. g}^{-1}.\text{h}^{-1}$)	60	90	110

B.H. Janssen (Agric. Univ. Wageningen; unpublished results) calculated the amounts of humus formed during these 25 years from the annual fresh inputs, assuming a time-dependent (i.e. decreasing) degradation rate for every fresh input.

For the total of these contributions to the humus content accumulated during 25 years, the "young humus", he calculated an average degradation rate of 13.5-15%. For the "old humus", older than 25 years, he calculated an average rate over the last 25 years of 1.83%, decreasing to 0.7% over the last 6 years. With these data he calculated nitrogen mineralisation in the 25th year. The results are shown in table II. The divergence in nitrogen mineralisation so calculated correlates with the divergence in nitrogen mineralisation measured in the incubation experiment and in the field (table I).

TABLE II. Calculation of annual mineralisation of nitrogen on the "Three Organic-Matter Farms" after 25 years of different regimes of organic matter input (after Janssen).

	mineral fertilizer only	min. fert. + green manure	min. fert.+ ley farming (livestock)
% "young humus"			
built up in 25 year	0.2	0.4	0.6
average rate of degradation (%.yr ⁻¹)	14.5	15.0	13.5
C/N ratio	12	12	12
bulk density of soil (g.cm ⁻³)	1.50	1.45	1.35
<i>N</i> -mineralised (kg.ha ⁻¹ .yr ⁻¹)			
A. "young humus" (< 25 yrs)	42	84	105
B. "old humus" (2%; degrad. rate 0.7%.yr ⁻¹ (C/N = 12)	20	20	20
(A + B) total	62	104	125

Of course, not only the amount of recently added organic material but also its N-content determines the net N-mineralisation, as is demonstrated in figure 2.

There is much need for a better yardstick for the content of energy-yielding material in organic amendments. It is the ratio of this content and the organic N-content which determines the net N-mineralisation rate. When this ratio is high, net mineralisation may still be negative after seven months (figure 2). (In a sandy soil, however, the net N-mineralisation at the highest C/N_{org} -ratio was just becoming positive after seven months, presumably due to a smaller extent of N-immobilisation. So, the net N-mineralisation rate depends also on the type of soil).

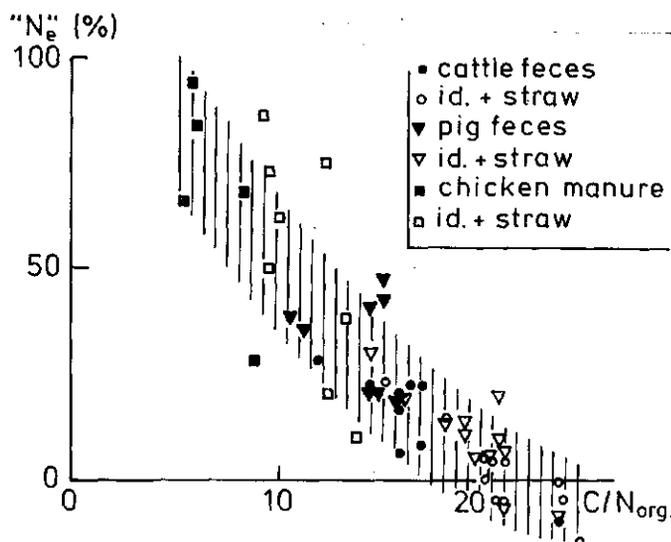


Figure 2. Net N-mineralisation in a sandy loam soil at the end of 1st season (" N_e ", in % of added organic N) of feces and feces-straw mixtures in relation to C/N_{org} of the added materials.

Finally, I wish to make some remarks on the third nitrogen source for the crop, viz.,

fertilizer nitrogen

It is often thought that when there is a net mineralisation in soil, no matter how small, an addition of fertilizer-N only enlarges the pool of mineral N available to the plant. This is not true. *Broadbent* (1965) found that the rates of ^{15}N - ^{14}N exchange resulting from biological activity increased with increasing levels of fertilizer-N applied. And in 1968 he reported that "substantial quantities of inorganic N are immobilized even when fresh organic residues to promote the biological activity have not been added". This would result in a reduction of the net mineralisation after application of N-fertilizers which has indeed been observed more than once. Some investigators, however, reported that addition of fertilizer resulted in

an enhanced net mineralisation, a kind of "priming effect". The following observations of *Ris* (unpublished results) may shed some light on these seemingly contradictory results. *Ris* examined whether the amount of N-fertilizer applied in February for potatoes and sugar beet should be supplemented later in the season. Therefore the amount of mineral N in the soil profile was checked on about 1 June, i.e. shortly before the young plants start to take up significant amounts of N. Apparent losses were at first assumed to be real, i.e. losses due to leaching and/or denitrification. However, *Ris* often observed that the ultimate N-uptake by the crop contradicted real losses.

By plotting the "losses" of fertilizer-N that apparently had occurred by the end of May against the amount of mineral N in the soil on about 1 March (before the fertilizer was applied), he obtained a remarkable diagram over 5 years ('73-'77) involving 78 field experiments on different soil types (figure 3).

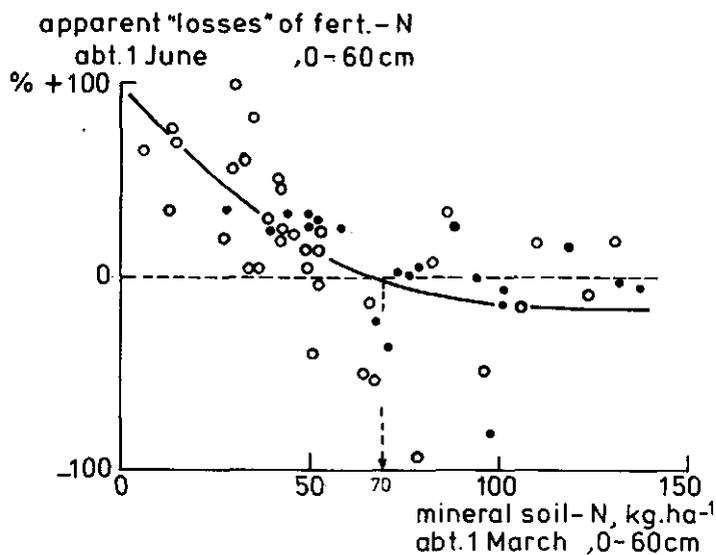


Figure 3. Relation between apparent "losses" of fertilizer nitrogen between 1 March and 1 June and the amount of mineral nitrogen present in the soil profile on about 1 March.

Mainly soils that were low in mineral nitrogen on 1 March and that therefore received much fertilizer-N showed an apparent "loss" of mineral N. As a contrast, in soils rich in mineral N on 1 March, and therefore supplied with a much smaller dose of fertilizer-N, a small "gain" is indicated.

Following Broadbent, my hypothesis is that the addition of a large amount of fertilizer-N accelerates the turnover and that the added N is partly stored in organic forms. It is a kind of "buffering action", as a result of rapid immobilisation which increases with increasing disturbance of the "equilibrium". Later, remineralisation of the stored N occurs, perhaps stimulated by depletion of the mineral N due to plant uptake.

It can be assumed that in soils rich in mineral N on 1 March a steady state exists between this nitrogen and that in N-rich organic matter (including biomass).

The addition of a small amount of fertilizer-N may slightly accelerate the turnover, in this case resulting in an increased net mineralisation, thus exerting a priming effect. It must be said, however, that unlike the "loss", the "gain" in figure 3 is statistically not significant. As yet, this is only a hypothesis.

References

- Borst, N.P. and Mulder, C (1971) *Bedrijfsontwikkeling*, Ed. Akkerbouw 2, no. 3, 31-36.
- Bremner, J.M. (1965) in: *Methods of Soil Analysis, Part 2* (Ed. C.A. Black) Agronomy Series no. 9, 1247-1255.
- Broadbent, F.E. (1965) *Soil Sci. Soc. Am., Proc.* 29, 692-696.
- Broadbent, F.E. (1968) *Proc. of the Symp. on the use of isotopes and radiation in soil organic-matter studies*, Vienna, 131-140.
- Ris, J. (1974) *Stikstof* 78, 168-173.
- Ris, J. (1978) *Landbouwkd. Tijdschr. /PT* 90, 148-151.
- Ris, J., Smilde K.W. and Wijnen G. (1981) *Fertilizer Research*, In press.
- Van Dijk, H. (1972) *Z. Landwirt. Forsch. Sonderh.* 27/II, 138-145.

COMMUNICATION N° 15

Question posée par Monsieur NANNIPIERI

You have shown that N applied as fertilizer was not really lost because it was recovered later. You explained such a recovery as due to mineralization of immobilized N applied as fertilizer.

Sometimes, there is an N cycle in the plant. Are you sure that the "apparently" lost N was not stored in the roots ?

Réponse de Monsieur VAN DYK

Firstly, the immobilized fertilizer N had already disappeared in May at which time Sugar beets have not developed so far that they could have taken up that amount of nitrogen. Secondly, in two pot experiments without plant, I found the same phenomenon : a rapid immobilization, particularly of ammonium-N, followed by a slower remineralization which was completed within some months (which by the way is considerably faster than "normal" biomass-N, synthesized from mineral nitrogen upon addition of a carbon (and energy) source).

Question posée par Monsieur FLAIG

What is the explanation for the increase of the data especially in the case of enzyme activities in Tabl. 1 column min. fert. + ley farming ?

Réponse de Monsieur VAN DYK

The larger input of organic in system 3 (ley farming and live-stock + manure) compared to farming system 1 where only crop residues (roots and stubbles) from the input gives rise to a larger biomass, ^{is} attended with a higher respiration and dehydrogenase-activity and, as can be assumed, a higher phosphatase activity.

COMMUNICATION N° 15 (SUITE)

Additional remark

In some lectures, given during this meeting, the question of stabilization of organic matter by clay minerals was discussed. I want to emphasize that the stability of ~~old~~ humus is also depending on the parent plant material from which it is formed. For example, humus formed from material rich in lignin and poor in protein (e.g. debris and roots of heather) is more stable than humus of the same age formed when the arable land originally had a grass cover.