Dossier on min-till techniques and water quality

Nitrogen transfer and mineralisation

Impact of soil cultivation is minimal

The technique used to cultivate the soil has very little impact on through leaching. Conversely, it has a greater impact on gaseous loss of nitrogen, without, however, being very significant when considered over a whole cropping season. Here is a detailed review of the reference data that has been gathered for each stage of the nitrogen cycle in the soil.

In general, underground nitrogen transfer occurs in winter. To limit it, the implementation of a catch crop is more efficient than changing soil cultivation method.

Soil cultivation, whether it involves ploughing or not, in itself has very little impact on the stages of the nitrogen cycle. Other techniques associated with it, such as the establishment of a winter cover crop or organic material inputs, often have a greater influence on nitrogen flow. Nitrogen is very mobile in the soil. It is extremely soluble, mainly in the form of NO_3 nitrate, and travels easily with water. The affect of soil cultivation techniques on underground nitrogen transfer through lixiviation (or leaching) is very limited. Rather contradictory trial results have been obtained regarding this point: transfer levels can be higher in ploughed soil than with no tillage, and vice versa, but the differences remain minimal *(table 1)*.

A winter cover crop has a greater impact than soil cultivation on limiting nitrogen transfer through leaching.

Conversely, a catch crop has a much greater impact on reducing leaching. At the Boigneville research station (near Paris), measurements taken over a 15 year period show loss reduced on average by 10 to 14 kg N/ha/year. From that point of view, the presence of a catch crop has a much more determining effect than any possible changes made to the way the soil is cultivated.

The absence of tillage increases nitrogen loss through denitrification

The absence of tillage increases gaseous loss of nitrogen. Such losses are mainly due to two mechanisms: volatilization in the form of ammonia (NH_3) and denitrification in the form of nitrous oxide (N_2O) and nitrogen gas (N_2).

Volatilization is a physical and chemical process which affects the $N\text{-}NH_4$ nitrogen form found both in mineral and organic fertilisers. Denitrification is linked to biological activity in the soil that extracts oxygen from nitrate and produces N_2O or N_2 gases, depending on local conditions. The denitrification process is heightened when the top soil is saturated or in a state of hypoxia (deprived of oxygen).

Soil cultivation and nitrate leaching *(tab. 1)*			
Location	Nitrogen lost through lixiviation kg N/ha *(or mg NO_3/l)*		
	Direct drilling	Shallow cultivation	Ploughing
Boigneville (near Paris) (33 years site) (LIXIM calculation model, 10/2003 - 04/2004)	24	21	15
Boigneville (near Paris) (15 years site) (porous candles, 15 years average)			
without catch crop	23 *(65)*		31 *(87)*
with catch crop	13 *(38)*		17 *(50)*
Parisot (southwestern France) 10 years) (with catch crop)	*no difference*		
La Jaillière (western France) 11 years, catch crop (drainage experiment, average of all years)	*no difference*		

Soil cultivation techniques have very little impact on nitrogen transfer through nitrate leaching.

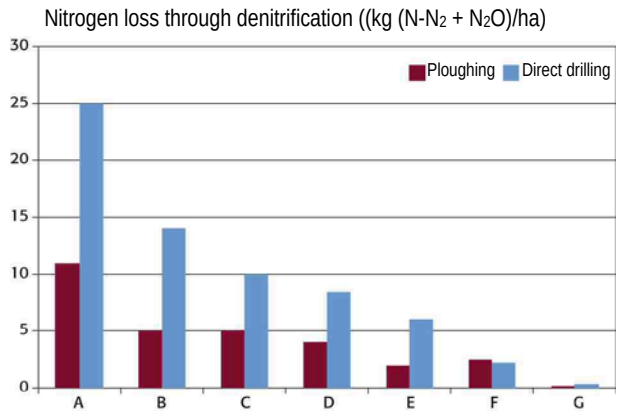
In spite of the fact that gaseous loss of nitrogen is difficult to evaluate, all the articles published on this subject concur that denitrification levels are higher when the soil is not ploughed. In such cases, surface anoxia is greater and more prolonged at the end of winter. But the differences measured between direct drilling and ploughed fields remain minimal, just a few kilos, up to around 10 kg N/ha/year *(figure 1)*.

When considered within the complete nitrogen balance, this level of loss is minimal. Consequences are much greater as regards the environmental assessment, nitrous oxide being a powerful greenhouse effect gas. 1 kg of N_2O is the equivalent of 310 kg of CO_2.

Soil cultivation seems to have a greater impact on air quality than on water quality.

Although they are fewer and tend to contradict each other more regarding volatilization also follow this trend. The absence of tillage seems to cause a few additional kilos of nitrogen, even up to 10, to volatilize. The reasons given to explain this are linked to plant residue. The presence of plant residue seems to increase the exchange area between fertiliser, soil and atmosphere, in particular with liquid forms. Under the mulch, in the absence of tillage, the topsoil is apparently denser, which would slow down the transfer of the nitrogen solution from the surface to underground layers.

Soil cultivation and denitrification *(fig. 1)*



A to G: Various foreign bibiographical references (direct measurements, in fields or on columns of soil)

Loss through denitrification is greater in the absence of tillage, but differences in kg N/ha/year are minimal.

Is not necessary to add more nitrogen while using min-till techniques

Mineralisation: very small difference

The level of nitrogen mineralisation in the soil varies little whether the soil is ploughed or not *(table 2)*.

However, everyone agrees that the absence of tillage causes organic materials, and therefore organic nitrogen, to accumulate in the top few centimetres of the arable layer. In the soil cultivation trial which has been running at Boigneville (near Paris) for 33 years, organic nitrogen stocks to a depth of 28 cm, are greater where direct drilling has been implemented (4.4 t N/ha) than where the soil has been ploughed (4.1 t N/ha).

Nevertheless, this difference is not necessarily reflected in the amount of nitrogen that is mineralised (kg N/ha/year) and available for the crops.

Soil cultivation and mineralisation *(tab. 2)*		
French sites	Kinetics of mineralisation (kg N/ha/normalised day)	
	Minimum Tillage Techniques	Ploughing
Boigneville (near Paris), 33 years(K. Oorts& al.)*	0.61	0.60 (NS)
Boigneville (near Paris), 15 years (K. Oorts & al.)*		
without catch crop	0.60	0.64 (NS)
with catch crop	0.63	0.60 (NS)
La Jaillière (western France, 17 years) (with catch crop)	0.48	0.48 (NS)

On long term, minimum tillage has low effect on annual nitrogen mineralisation

* Oorts K., Laurent F., Mary B., Thiébeau P., Labreuche J. and Nicolardot B., 2007 – Experimental and simulated soil mineral N dynamics for long-term tillage systems in northern France. Soil and tillage research, vol. 94, Iss. 2, p. 441-456.

The differences observed by foreign researchers were obtained after short periods of differentiated soil cultivation, and show small differences, amounting to just a few kilos of nitrogen per hectare per year, which is not very significant: the quantity of nitrogen released through mineralisation seems to increase slightly when the soil is cultivated.

However, in French trials, where the phenomenon was measured in 15 and 35 year trials, this amount remains the same, with or without tillage.

It is worth noting that neither soil cultivation, nor the presence of a catch crop (mustard, destroyed when approaching 2 tonnes at the beginning of winter) made any difference to nitrogen mineralisation in the Boigneville trial.

Conversely to a few foreign findings, we did not notice in our trials any difference in the immobilisation phase ("nitrogen starvation") at the end of the winter between different cultivation techniques.

This lack of difference in mineralisation levels can be explained by a more intensive mineralisation process in the top few centimetres of soil when it is not ploughed, but less intensive further down. Direct drilling seems to also protect organic materials by "trapping" them in macroaggregates which are more stable in the absence of tillage.

No impact on nitrogen dose

In the absence of tillage, the increase in organic nitrogen stocks in the soil does not always result in increased mineralisation.

French trials showed that there was an impact on the way the nitrogen contained in fertiliser was used by crops. There is a trend showing that the apparent nitrogen fertiliser utilisation ratio and the actual nitrogen fertiliser utilisation ratio, are slightly better when the soil is ploughed than with direct drilling. We do not have data for all the parameters that would help to explain those discrepancies, be it gaseous loss or speed of growth.

In addition, conversely to general belief, the reference data available does not allow us to say that nitrogen fertiliser dose must be systematically increased if the soil is not ploughed. In the long-term Boigneville trial, after 35 years of experiments, nitrogen fertilisation and yields remained identical regardless of the soil cultivation methods that had been implemented.

In France, four long term experimental sites permit to measure nitrogen flows evolution in the soil. Two trials in Boigneville (near Paris), one in La Jaillière (West of France), the last in Parisot (South).

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