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# Fate of nitrogen fertilizer applied on two main arables crops, winter wheat (*Triticum aestivum*) and sugar beet (*Beta vulgaris*) in the loam region of Belgium

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*Key words:* Broadcast, loam soil, $^{15}N$, N losses, N recovery, row application, split dressing, sugar beet, winter wheat.

## Abstract

Since 1986, the fate of fertilizer N ($NH_4NO_3$ or $NaNO_3$) applied in field conditions on two main arable crops, winter wheat (*Triticum aestivum*) and sugar beet (*Beta vulgaris*), has been studied using $^{15}N$. Up to a rate of 200 kg $ha^{-1}$ of N, mean recovery of fertilizer by winter wheat was 70%, provided it had been split applied. Single application (with or without dicyandiamid) was less effective. For sugar beet, in 1990, 1991 and 1992, 40% of fertilizer N was found in the crop at harvest when $NH_4NO_3$ had been broadcast at 100 to 160 kg N $ha^{-1}$ at sowing time. For the same N rate, recovery was 50% when row applied near the seeds and 60% for 80 kg N $ha^{-1}$. For the two experimental crops, residual fertilizer N in soil was exclusively organic. It ranged from 15 to 30% of applied N and was located in the 30 cm upper layer. Losses were generally lower with winter wheat (12%) than with sugar beet (20-40%) and could be ascribed to volatilization and denitrification. Soil derived N taken up by the plant was site and year dependent.

## Introduction

The loam region of Belgium is characterized by a very intensive farming system. Winter wheat (*Triticum aestivum*) (200,000 ha) and sugar beet (*Beta vulgaris*) (100,000 ha) are the two main crops receiving between 140 and 200 kg $ha^{-1}$ of mineral fertilizer nitrogen. To assess environmental risks due to pollution of drinking water by nitrate and release of $N_2O$ in the atmosphere, it is important to investigate the fate of this nitrogen. This is only possible by using $^{15}N$, stable isotope, as a tracer. This paper gives an overview of results obtained between 1986 and 1992.

## Material and methods

### *Soil and climate*

The experiments were carried out on silt loam soils (hapludalf) made up of clay (12%), silt (82%) and sand (6%). Average N concentration was 0.11% in the upper 0-30 cm layer and C concentration was lower than 1%.

The climate of the loam region of Belgium is temperate (average temperatures are 5°C in winter, 10°C in spring and autumn and 17°C in summer) The rainfall of 800 mm is regularly distributed all over the year.

*Experimental design*

For winter wheat, $^{15}N$ tagged fertilizer ($^{15}NH_4{}^{15}NO_3$ or $Na^{15}NO_3$) at 2.5 or 5 atom% $^{15}N$ was split applied (total rate ranging from 130 to 240 kg N $ha^{-1}$) in 3 equal dressings (GS25, 30 and 37) in stainless steel cylinders (length 53 cm, diameter 30 cm) pressed into the soil in a well established stand. Treatments were replicated 4, 5 or 6 times and distributed according to a randomized block layout.

*Sampling procedure*

For winter wheat, the aerials parts of the plants were collected from each cylinder. Soil was removed completely in 10 cm layers to a depth of 30 to 50 cm, mixed and subsampled. Peripheral parts of the sugar beet plots, where tracer distribution was likely to be irregular, were excluded (2 external rows of 6 rows plot). All the plants were collected. A central 90×90 cm square of soil, corresponding to the 2 innermost beet rows, was removed by 10 cm layers, homogenized and subsampled.

*Sample preparation*

Plant and soil samples were freeze-dried and finely ground with a hammer mill. Analysis for total N was carried out using Kjeldahl method modified to include nitrate with selenium as a catalyst (Bremner, 1965) or by Dumas technique [Roboprep, Europa Scientific (U.K.)]. The isotopic composition was determined by mass spectrometry [SIRA 12 VG Isogas (U.K.)] with the natural isotopic abundance of N (0.3663%) taken as reference. Total inorganic N (nitrate and ammonium) was extracted with a 0.5 N-KCl solution from fresh soil samples (Guiot et al., 1991) and analyzed for their isotopic composition.

## Results and discussion

*Recovery of fertilizer N*

When fertilizer N was split into 3 equal applications, as previously observed (Destain et al., 1989 and 1991), mean recovery by winter wheat was 69.8% of N applied (Table 1). N recovery by the crop increased from GS25 to GS37 dressing; simultaneously, residual N in soil decreased. Total recovery was 88.4 but reached 100% in some cases (GS30 and 37, Destain et al., 1989). The deficit was ascribed to gaseous losses - mainly denitrification. Leaching can be ruled out in our climate conditions for spring application; moreover $^{15}N$ could not be detected below 50 cm.

It appears that the GS25 dressing is the most critical for the environment. In a study conducted in 1987, crop uptakes of 31% of applied N were observed 16 after the GS25 dressing and 70% after 44 days. For the GS30 application, it amounted to 75% after 28 days. When N fertilizer was applied at the same time and at the same rate (60 kg N $ha^{-1}$) on a fallow soil, losses were 16% after 53 days and

*Table 1.* Percent recovery of harvest of winter wheat of labelled fertilizer N applied in 3 equal dressings

| Mean N applied (kg $ha^{-1}$) | Dry Weight (t $ha^{-1}$) | N (kg $ha^{-1}$) | Time of split application | | | |
|---|---|---|---|---|---|---|
| | | | GS25 | GS30 | GS37 | Total |
| 172 | | | | | | |
| Plant | 19.7 (2.1) | 223 (43) | 60.8[a] (9.0)[b] | 70.0 (7.8) | 78.7 (9.3) | 69.8 (7.2) |
| Soil | | | 23.6 (1.6) | 19.0 (2.2) | 13.1 (1.4) | 18.6 (1.2) |
| Total recovery | | | 84.4 | 89.0 | 91.8 | 88.4 |

[a] For both plant and soil, recoveries for the times of application were all significantly different at $P < 0.05$.
[b] ( ) = standard deviation of the mean

cumulative rain of 61mm, 27% after 77 days and 184mm, and 28% after 142 days and 260mm. Immobilization never exceeded 13% of applied N (Table 2) and was comparable to immobilization under winter wheat, assuming that the observation made by Recous et al. (1992) that fertilizer N in soil is equally distributed between roots and microbial organisms applies here. In these conditions, mineral nitrogen remaining from fertilizer is a potential source of leaching as shown in Figure 1. In farming practice, the risk is highest for wet and cold conditions after the GS25 dressing. The rate of N absorption by the crop must be low. In 1992, the recovery of the GS25 application of 20, 60 and 100 kg N $ha^{-1}$ were 28, 12 and 7% after 17 days and 64, 68 and 46% after 46 days. However the GS25 dressing is necessary, but its amount must be tuned to the need of the cereal. Split dressing of fertilizer N is always better than single application.

For example, a recovery of more than 10% higher was obtained in 1988 with the variety Odeon when fertilizer was split (Table 3). Similarly in 1990, a year characterized by very hot spring and summer, crop recovery of a 180 kg N $ha^{-1}$ dose incorporating a nitrification inhibitor dicyandiamid (DCD) was 10% lower when applied in one dressing at GS25 than when split applied.

In 1990, 1991 and 1992, recoveries of broadcast and row-applied $^{15}NH_4{}^{15}NO_3$ (rates from 60 to 155 kg $ha^{-1}$) to sugar beet were

*Table 2.* Recovery of fertilizer N (60 kg $ha^{-1}$) applied on a fallow soil in April (% of N applied)

| | Days after application | | |
|---|---|---|---|
| | 53 | 77 | 142 |
| Mineral N | 78.3[a] (6.3)[b] | 59.9 (6.0) | 62.6 (5.8) |
| Immobilized N | 5.5 (1.2) | 12.7 (2.2) | 9.1 (2.3) |
| Total Recovery | 83.8 | 72.6 | 71.7 (7.4) |

[a] Values are the mean of four applications
[b] Standard deviation of the mean

*Table 3.* Recovery by winter of fertilizer N divided (3 dressings) or not (% N applied)

| Site and crop variety | N applied (kg $ha^{-1}$) | Recovery | |
|---|---|---|---|
| | | Divided | Not divided |
| Ernage 88 | 150 | | |
| Odeon | | 72.9 (5.4) | 61.1 (6.1) |
| Camp Remy | | 70.0 (2.7) | 67.6 (2.3) |
| Cortil 90 | 180 | | |
| var. Capitaine | | 62.3 (2.5) | 50.7 (2.0) with D.C.D. |

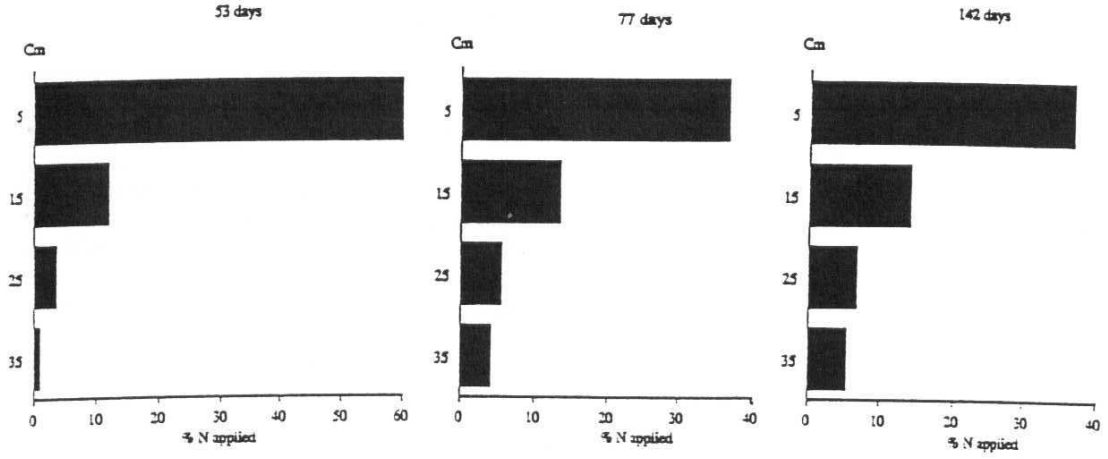


*Fig. 1.* $^{15}$N-mineral nitrogen in soil after applying 60kg N $ha^{-1}$ (as $Na^{15}NO_3$) on a fallow soil in April

*Table 4.* Yield, N content and percent recovery of labelled N applied in sugar beet (leaves and roots) and soil [Fertilizer N - $^{15}N$ broadcast (B) or row applied (R)]

| Mean N applied (kg ha$^{-1}$) | Yield of dry Matter (t ha$^{-1}$) | N (kg ha$^{-1}$) | Recovery | | | |
|---|---|---|---|---|---|---|
| | | | Leaves | Roots | Plant | Soil |
| 135 B | 22 | 236 | 21.6 | 20.3 | 41.9 | 25.0 |
| 135 R | 24.4 | 247 | 28.2 | 22.9 | 51.1 | 25.5 |
| 62 R | 20.9 | 198 | 27.6 | 26.6 | 54.2 | 26.5 |

compared (Table 4). Recovery by plant of row-applied fertilizer was 10% higher than fertilizer broadcast and reducing the rate of fertilizer still increased plant recovery.

However, in most cases, yields were not affected by the rate or by the technique of fertilizer application used. Total recovery (plant + soil), was lower than for winter wheat, and was higher when N was row applied. Higher N losses for broadcast N applications were attributed mainly to volatilization (fertilizer spread on soil surface with a pH higher than 7.0) and to possible higher denitrification losses. Row applied N was absorbed more quickly as preliminary results had shown. Leaching losses must be ruled out in both cases as $^{15}N$ could not be detected below 30 cm.

*Table 5.* Soil derived nitrogen taken up (SDN) by plant (kg ha$^{-1}$)

| Plant and site | N applied (kg ha$^{-1}$) | S D N | |
|---|---|---|---|
| W. wheat - Ernage 86 | 135 | 144.3 | (16.3) |
| | 180 | 135.8 | (6.5) |
| W. wheat - Liroux 87 | 150 | 65.4 | (8.0) |
| | 240 | 57.4 | (7.5) |
| W. wheat - Cortil 90 | 180 | 125.8 | (13.8) |
| W. wheat - Marbais 91 | 150 | 75.0 | (7.1) |
| W. wheat - Marbais 92 | 200 | 78.4 | (18.8) |
| Sugar beet - Mean of 3 sites (Broadcast or Row applied) | 135 B | 179 | |
| | 135 R | 178 | |
| | 69R | 161 | |

*Soil Derived Nitrogen*

With $^{15}N$, soil contribution to plant N c assessed. Table 5 gives some results obtai experiments carried out on the same soil Soil N uptake varied widely from site to si from year to year and was higher for suga than for winter wheat. It was sometim major source of nitrogen for the particularly for sugar beet.

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