

DISTRIBUTION OF NITROGEN FROM SOIL AND FROM FERTILIZER INTO THE WINTER WHEAT (*Triticum aestivum* L.) PLANT AT GRAIN MATURITY

Nadia BOULELOUAH¹, Jean Pierre DESTAIN², Bernard BODSON³, André FALISSE³

¹Département des Sciences Agronomiques, Université Hadj Lakhdar, Batna (UHLBatna), nadiaboulelouah@yahoo.fr

²Centre Wallon de Recherches Agronomiques (C.R.A.W), rue du Bordia n°4, 5030 Gembloux, Belgique, destain@cra.wallonie.be

³Université de Liège, Gembloux Agro Biotech, Unité de Phytotechnie des Régions Tempérées, 5030 Gembloux, Belgique, b.bodson@ulg.ac.be, falisse_a@hotmail.com

Corresponding author e-mail: falisse_a@hotmail.com

Abstract

In this experiment, the distribution within the plant of nitrogen originating from fertilizer and from soil was followed at six periods between anthesis and grain maturity. Fertilizer rate of 180 kg N.ha⁻¹ was applied following two splitting schedules T2 (1/3-1/3-1/3) and T5 (0-1/3-2/3) at GS25, GS30 and GS37 resp. and compared to unfertilized control T1. Aerial parts of the plant were divided into several compartments i.e. S1 (organs under the fore-last node), S2 (fore-last node and stem portion), S3 (last node and stem), L2 (fore-last leaf), L3 (flag leaf), EC (ear chaff) and EG (grain). ¹⁵N labelled NH₄NO₃ was used to determine the recovery of nitrogen applications, and the part of fertilizer and soil nitrogen in each plant compartment. At maturity, fertilizer N recovery varied significantly in the whole plant and ranged from 68.14 to 78.62 % and in grain from 55.91 (± 5.28) % to 69.11 (± 5.07) % for T2 and T5 respectively. Total amounts of N in the whole plant (11.3; 26.4 and 26.4 g N.m⁻² for T1, T2 and T5 respectively) were distributed in S1 (1.1; 1.9 and 1.0 g N.m⁻²), in S2 (0.2; 0.3 and 0.2 g N.m⁻²), in S3 (0.23; 0.52 and 0.41 g N.m⁻²), in L2 (0.18; 0.47 and 0.38 g N.m⁻²), in L3 (0.26; 0.67 and 0.61 g N.m⁻²), in EC (0.57; 1.34 and 1.17 g N.m⁻²), and in EG (8.8; 21.2 and 22.6 g N.m⁻²).

Split nitrogen application affected the recovery of fertilizer nitrogen (FNR). By suppressing the first split application (GS25) and increasing the latest (GS37), the splitting schedule T5 (0-1/3-2/3) exhibited the highest total and grain recoveries of fertilizer nitrogen.

Key words: soil nitrogen, fertilizer nitrogen, nitrogen distribution, nitrogen fertilizer recovery, ¹⁵N labelled NH₄NO₃

INTRODUCTION

Improving grain quality, increasing grain yield and minimizing N losses from the crop-soil system represent the aims in cereal production. These objectives can be reached by a finely tuned management of the fertilization

In Belgium, fertilizer nitrogen applied to winter wheat (*Triticum aestivum* L.) is usually divided into three split dressings applied at tillering (GS25), stem elongation (GS30) and flag leaf (GS37) [4]. Several studies showed that recovery of N from the first application at tillering was lower than for late application [2] and this was explained by leaching and immobilisation. Recent results of applied research [1] proposed a splitting schedule in two fractions, avoiding the application at tillering and privileging flag leaf fraction. This two split-applications schedule was proven to

be slightly positive on N recovery and grain protein content.

The aim of this experiment is to determine how the splitting schedules of fertilizer nitrogen influence the distribution of nitrogen originating from fertilizer and from soil within the plant in the post-anthesis phase.

MATERIAL AND METHOD

A field trial was conducted at Gembloux (50.34N, 04.41E, 161m above sea level, 800 mm mean annual rainfall; 9°C mean annual temperature) in the loamy region (Hapludalfs) during the growing season 2005 on winter wheat cv 'Corvus'.

The experimental design was a randomised complete block with four replicates. ¹⁵N labelled NH₄NO₃ (2.16 At % ¹⁵N) was used to determine the total and grain recoveries of

fertilizer (FNR) applications and the part of fertilizer and soil nitrogen in each plant compartment. A ^{15}N fertilizer rate of $180 \text{ kg } ^{15}\text{N ha}^{-1}$ was applied following two splitting schedules T2 (1/3-1/3-1/3 or 60-60-60) and T5 (0-1/3-2/3 or 0-60-120) at growth stages: GS25, GS30 and GS37 (Zadoks et al., 1974) respectively and compared to the unfertilized control T1 (0N).

^{15}N labelled NH_4NO_3 was used in stainless-steel cylinders (length, 30 cm; internal

diameter, 30 cm) pressed in spring into the soil of the young winter wheat crop (microplots). At six periods between anthesis and grain maturity, every 10 days, all plants of each microplot were harvested. Aerial part of the plant was divided into several compartments i.e. S1 (organs under the fore-last node), S2 (fore-last node and stem portion), S3 (last node and stem), L1 (fore-last leaf), L2 (flag leaf), EC (ear chaff) and G (grain) (Fig. 1).



Fig. 1. Phases of dissection and different compartments and layers of plant. As **Compartment**: S1 (organs under the fore-last node), S2 (fore-last node and stem portion), S3 (last node and stem), L1 (fore-last leaf), L2 (flag leaf), EC (ear chaff) and G (grain). As **Layer**: layer A=S1, layer B=S2+L1, layer C= S3+L2+EC.

The samples were oven-dried at 80°C until constant weight, weighed and milled. Plant N content and its isotopic composition were determined by mass spectrometry (Europa scientific) coupled to a Dumas combustion apparatus.

The total recovery of fertilizer N (% FNR) was calculated for the whole plant as the sum of N recovered in the different compartments.

Data were analysed with software SAS, V8 procedure (SAS Institut, INC, Cary, NC).

RESULTS AND DISCUSSIONS

1. Recovery of fertilizer nitrogen (FNR)

In this experiment, nitrogen was efficiently absorbed by the plant in the two treatments with total recovery higher than 68% (Table 1). The total fertilizer nitrogen recovery (FNRT) and grain fertilizer nitrogen recovery (FNRG) were significantly higher for T5 than for T2 (+ 13% FNRT and + 10.5%, FNRG).

Table 1. Total and grain recovery of fertilizer nitrogen (FNR,%)

	Total FNR (%)	Grain FNR (%)
T5 (0-1/3-2/3)	78.62 (± 5.96) ^a	69.11 (± 5.07) ^a
T2(1/3-1/3-1/3)	68.14 (± 5.73) ^b	55.91 (± 5.28) ^b
probability	**	***
CV (%)	2.01	1.32
LSD	3.31	1.86

(\pm , standard deviation). ** $p < 0.01$, *** $p < 0.001$. Values with the same letter are not significantly different at 5% level (LSD method).

2. Fertilizer and soil-derived nitrogen

The fertilizer and soil-derived nitrogen amounts were determined in each compartment of the whole plant (above-ground only) between anthesis and grain maturity. Figure 2 illustrates the amount of fertilizer nitrogen (^{15}N , $\text{kg}\cdot\text{ha}^{-1}$) and soil-derived nitrogen (N_{soil} , $\text{kg}\cdot\text{ha}^{-1}$) present at maturity in the whole plant, in the grains and in the stem (all compartments minus grains) for the three treatments (T1, T2, T5). The total amounts of nitrogen at maturity increased from $113\pm 14 \text{ kgN}\cdot\text{ha}^{-1}$ (T1) to $264 \text{ kgN}\cdot\text{ha}^{-1}$ (T2, T5), no significant differences

were found between T2 and T5 ($T2=264\pm 20$, $T5=264\pm 21 \text{ kgN}\cdot\text{ha}^{-1}$).

At maturity, the amount of ^{15}N was higher in grain than in the stem. The average values of ^{15}N in the grain rose from $100 \text{ kgN}\cdot\text{ha}^{-1}$ at T2 to $125 \text{ kgN}\cdot\text{ha}^{-1}$ at T5 (Fig. 2), with no significant differences being recorded between the two treatments. The amount of ^{15}N in stem T2 and stem T5 was around 18% and 13%, respectively, of the total ^{15}N in plant.

For the soil derived-nitrogen, the total amount found in treatment T2 was significantly higher than those of the treatment T5 and unfertilized control T1, indicating that soil N absorption was not reduced by mineral fertilization.

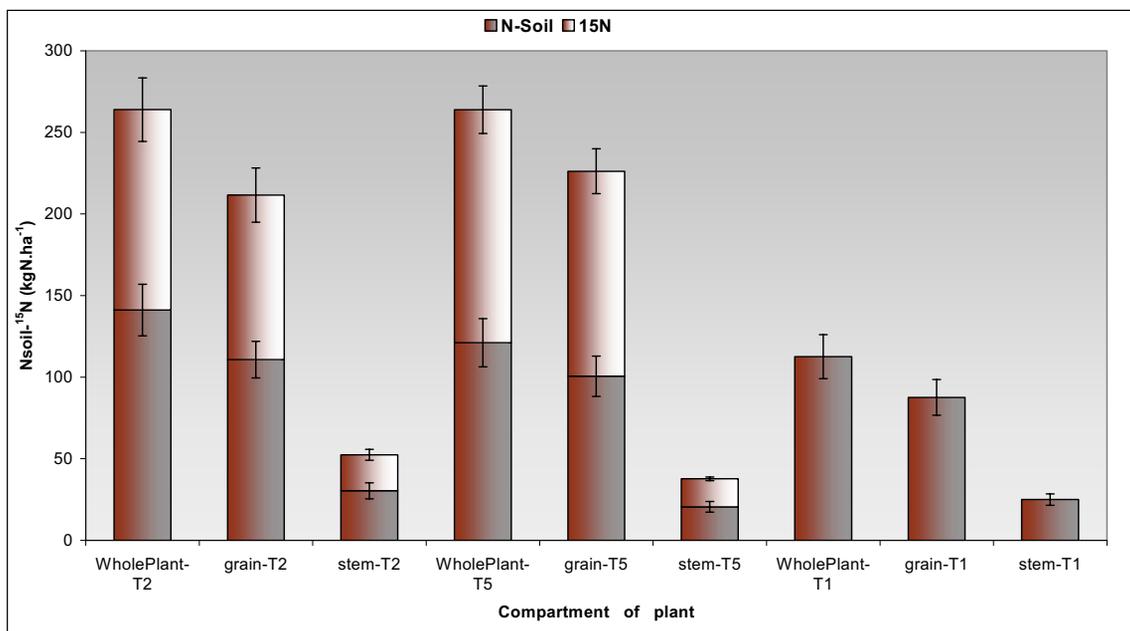


Fig. 2. Amounts of fertilizer nitrogen (^{15}N , $\text{kg}\cdot\text{ha}^{-1}$) and soil nitrogen (N_{soil} , $\text{kg}\cdot\text{ha}^{-1}$) present at maturity in whole plant (stem + grain), in grain and in stem (all compartments excepted grain) for two splitting schedules (T2, T5) and unfertilized control T1 (0N). Vertical bars represent S.E. Data in ordinate are in $\text{kgN}/\text{ha}^{-1}$ instead of m^{-2}

Fig. 3 presents the evolution of total amounts of nitrogen, fertilizer nitrogen and nitrogen originated from soil. The two treatments (T2, T5) showed similar evolution of total grain N all along the anthesis to maturity period. Plants of unfertilized control (T1) started flowering earlier than the two treatments and differences at 250°C days after anthesis (base 9°C) in evolution of nitrogen derived from soil was detected between fertilized and unfertilized treatments. It would be assumed that nitrogen translocation had a longer duration in fertilized treatments than in unfertilized one.

At anthesis, nitrogen from the soil in plant layer A (lower part of the stem) was significantly different between treatment. The process of N translocation to the grain – originating as well from the soil as from the fertilizer - is similar for the three treatments (Fig. 4a and 4b).

N was translocated from the lower layer (LA) to upper layers (LB and LC) and to the grain. Positive and significant correlations were detected between grain nitrogen at maturity and N concentration (data not shown) of different layers along grain filling process as supported by another study [3]. No difference was detected between layers (LA, LB, LC) in

amount of ^{15}N translocated to grain between anthesis and maturity. The total amounts of nitrogen at anthesis and grain nitrogen content

at maturity were positively correlated ($R^2=0.92$, $p<0.001$).

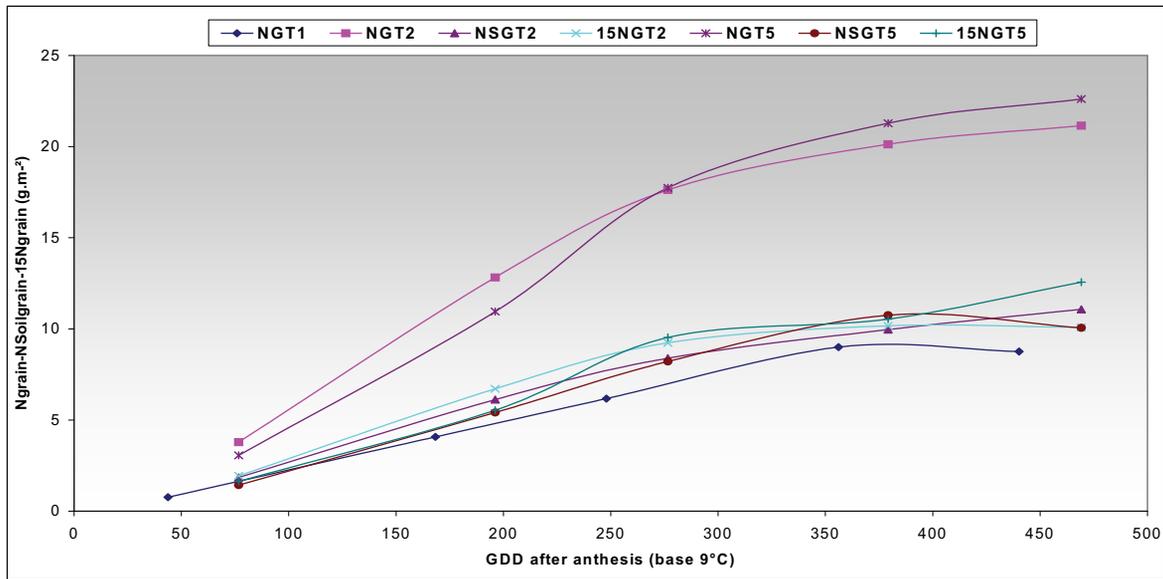


Fig. 3. Evolution of total amount of nitrogen (Ngrain, g.m^{-2}), fertilizer nitrogen ($^{15}\text{Ngrain}$, g.m^{-2}) and soil nitrogen (Nsoil grain, g.m^{-2}) in grains for two splitting schedules (T2, T5) and unfertilized control T1 (0N) between anthesis and maturity. GDD (growth degree days after anthesis with 9°C as base temperature)

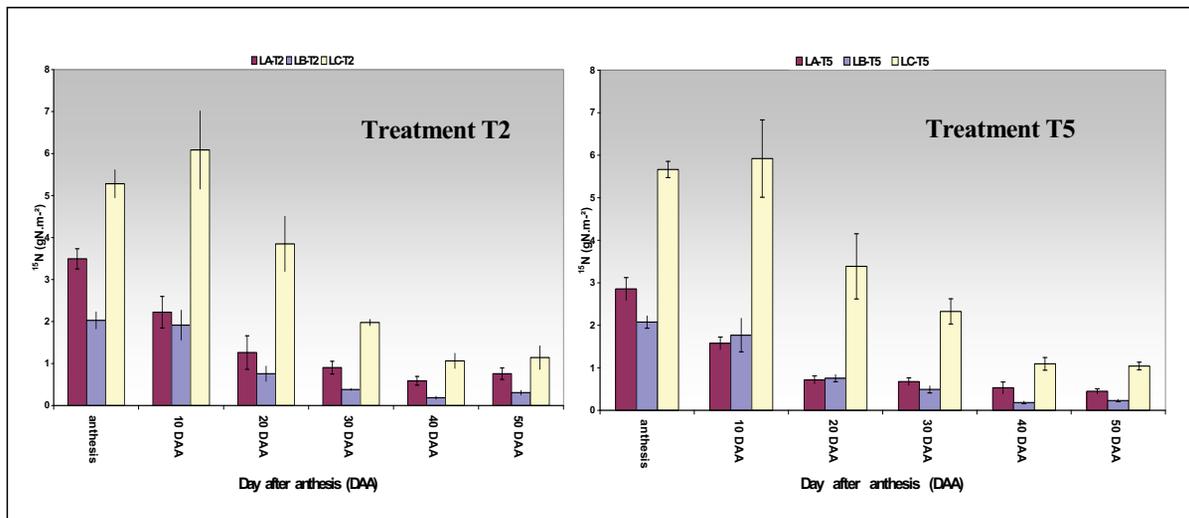


Fig. 4(a). Quantities of fertilizer nitrogen (^{15}N , gN.m^{-2}) in different layers of the plant **without grains** (Layer A= S1, Layer B=S2+L1 and Layer C=S3+L2+EC) between anthesis and grain maturity for two splitting schedules (T2, T5). Days after anthesis (DAA)

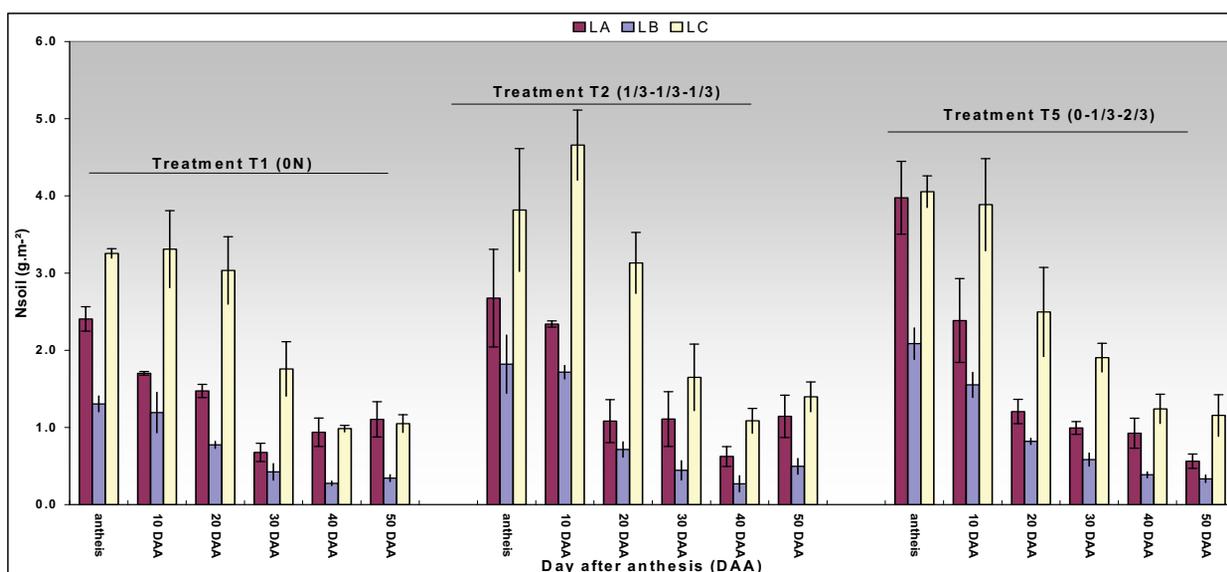


Fig. 4(b). Quantities of soil nitrogen (Nsoil, g.m⁻²) in different layers of the plant **without grains** (Layer A= S1, Layer B=S2+L1 and Layer C=S3+L2+EC) between anthesis and grain maturity for two splitting schedules (T2, T5) and unfertilized control T1 (0N). Days after anthesis (DAA)

CONCLUSIONS

Split nitrogen application affected the recovery of fertilizer nitrogen (FNR). By suppressing the first split application (GS25) and increasing the latest (GS37), the splitting schedule T5 (0-1/3-2/3) exhibited the highest total and grain recovery of fertilizer nitrogen.

The evolution of grain nitrogen content was not influenced by splitting nitrogen application. Grain nitrogen content was positively correlated to total nitrogen content within whole plant at anthesis.

The same total amounts of N were absorbed by the plants for the two fertilizers splitting schedules, but translocation to the grain was higher for the schedule T5, indicating a more intense activity of the plant in the very late period before maturity.

REFERENCES

- [1] Bodson, B., Vancutsem, F., Destain, J.P., Herman, J.L., Couvreur, L., Frankinet, M. & Falisse, A., 2005. Actualités dans le domaine de la fumure azotée, partie fractionnement de la fumure, 1-11. In: A. Falisse and P. Meeus, eds. Fumure et protection phytosanitaire des céréales, Gembloux.
- [2] Destain, J.P., Bodson, B., Herman, J.L., François, E. & Franc, J., 1997. Uptake and efficiency of split applications of nitrogen fertilizer in winter wheat. In Plant nutrition for sustainable food production and environment. T. Ando et al., eds. Kluwer Academic, Tokyo, p. 633-634.
- [3] Wang, Z., Wang, J., Zhao, C., Zaho, M., Huang, W. & Wang, C., 2005. Vertical distribution of nitrogen in different layers of leaf and stem and their relationship with grain quality of winter wheat. Journal of plant nutrition, 28: 73-91.
- [4] Zadoks, J., Chang, T.T. & Konzak, C., 1974. A decimal code for the growth stages of cereals. Weed Res. 14: 415-421.