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Uptake and efficiency of split applications of nitrogen fertilizer in winter wheat

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Abstract

In Belgium, nitrogen fertilizer (140–220 kg N ha^{-1}) is applied to winter wheat in split applications at growth stages GS25, 30 and 37. The aim of this work was to compare the efficiency of the last application (GS37) with that of the preceding ones (GS25 and 30) and to measure the uptake of applied N using ^{15}N. Increasing the rate of the GS37 application from 20 to 100 kg ha^{-1} N raised grain yield by 1000 kg ha^{-1}; efficiency remained almost unaffected (31 kg and 26 kg grain per kg N, respectively), while N recovery in whole plant was highest (77.5%) at 100 kg ha^{-1}, as was grain quality. Conversely, increasing the rate of application at GS25 did not affect yield, and N efficiency plummeted (from 21 kg to 12 kg).

Combining the first two applications (at GS25 and 30) did not always influence efficiency, recovery of N fertilizer and the absorption of N from the soil solution; however, splitting N fertilizer into 3 applications, the late one being relatively high (65 kg N ha^{-1}), is an environmentally friendly practice.

Introduction

Nitrogen fertilization (140–220 kg N ha^{-1}) of winter wheat grown in Belgium is applied in split applications at growth stages GS25, 30 and 37. The content of N in the soil solution and the crop's ability to take up N (determined by growth stage and visual parameters such as color, population density and absence of diseases) are the main parameters to consider when fine tuning each N application to plant needs (Bodson et al., 1994). Plant uptake of N fertilizer generally increases from GS25 to GS37, while N left in the soil decreases (Destain et al., 1993). An increasing number of reports have indicated that late applications of large quantities of nitrogen to modern varieties are an efficient means of achieving high yields of good quality. The aim of the present work is to compare the N uptake and the efficiency of late (GS37) applications of N fertilizer with earlier ones, combined or not.

Material and methods

The experiments were carried out in 1992, 1995 and 1996 on loam soils at 3 sites (Lonzée, Piéton and Gesves). The mean temperature at Gesves is 0.5°C lower than that at the other 2 sites (7.5°C for the October-July period). Normal rainfall during this period is 700 mm, but was 40% lower in 1995-1996 due to the very dry winter and spring seasons. Winter wheat was sown in October, after sugar-beet, var. Ramsès (Lonzée 92) and var. Torfrida (Lonzée 95 and 96), and oilseed rape, var. Trémie (Piéton and Gesves 96). It was harvested in late July or early August. Yield was measured in 18 m^2 experimental plots replicated 4 times and the uptake of N from each split application was evaluated in microplots (stainless steel cylinders, 53 cm long and 30 cm in diameter, pressed into the soil in a well-established stand) by using $^{15}NH_4$ $^{15}NO_3$ containing 5.3 atom % ^{15}N. Labelled treatments were also replicated 4 times. Nitrogen was applied at the rate of 20, 60 and 100 kg ha^{-1} at GS25 (1992) or at GS37 (1995); the total amount of the other two applications was kept constant at 100 kg ha^{-1} (Table 1). The effect of skipping one of the two split applications (GS25 or GS30) or of combining them was tested in experiments conducted at 3 locations in 1996 (Table 2). N fertilizer was applied in 3 split applications in treatment A, and in 2 applications by combining the first 2 applications in treatment B (at GS25), treatment C (between GS25 and 30) and treatment D (at GS30).

Results and discussion

Yields were unaffected by the rate of N fertilizer when it was applied at GS25 (Lonzée, 1992), but they increased sharply when N was applied at GS37 (Lonzée, 1995). Correspondingly, N recovery by the whole plant was highest at GS37 (76.1% vs. 49.1% for 60 kg N). N fertilizer efficiency (defined as:

Table 1. Effect of N fertilizer levels applied at GS 25 and GS 37 on winter wheat yield, grain quality, N uptake and efficiency

N level (kg ha^{-1}) split applied at GS 25, 30 and 37	Yield t grain ha^{-1}	Recovery of labelled dressing (% N applied) Mean (SD)	Efficiency of total N dressing (kg grain per kg N ha^{-1})	Grain quality Protein %	Zeleny ml
Lonzée 92					
0	6633A[1]	-	-	-	-
*20+40+60	9202B	47.3 (3.1)	21.4	-	-
*60+40+60	9150B	49.1 (4.2)	15.7	-	-
*100+40+60	8950B	47.1 (3.1)	11.6	-	-
Lonzée 95					
0	5280A	-	-	9.1	-
50+50+*20	9049B	64.9 (4.8)	31.4	10.1	30
50+50+*60	9922C	76.1 (3.6)	29.0	10.9	34
50+50+*100	10455D	77.5 (3.8)	26.0	11.9	38

*fertilizer $^{15}NH_4{}^{15}NO_3$ at 5.3 at% ^{15}N.
[1]values followed by the same letter are not significantly different at the 0.05 *p* level.

Table 2. N uptake by winter wheat (%N applied as $^{15}NH_4{}^{15}NO_3$ at 5.3 at% ^{15}N) : effects of split application scheme

	Lonzée 96		Piéton 96		Gesves 96	
Growth stage	N rate (kg ha^{-1})	Mean (SD)	N rate (kg ha^{-1})	Mean (SD)	N rate (kg ha^{-1})	Mean (SD)
Treatment A						
GS25	50	58.0 (1.9)	50	56.0 (3.5)	75	63.6 (2.3)
GS30	50	72.4 (4.6)	50	64.5 (2.1)	75	73.3 (5.3)
GS37	65	73.9 (2.1)	50	73.0 (1.7)	75	76.3 (5.7)
	165	69.3 (1.1)	150	65.5 (1.0)	225	71.1 (4.2)
Treatment B						
GS25	100	62.3 (3.1)	100	59.6 (4.0)	150	64.9 (2.7)
GS37	65	-	50	-	75	-
	165	66.9	150	66.3	225	70.0
Treatment C						
GS25-30	100	68.8 (5.1)	100	63.1 (3.2)	150	71.4 (3.8)
GS37	65	-	50	72.8 (4.2)	75	81.3 (2.0)
	165	70.8	150	66.3 (1.4)	225	75.0 (2.2)
Treatment D						
GS30	100	70.9 (4.5)	100	60.8 (3.6)	150	75.2 (6.1)
GS37	65	-	50	72.3 (2.1)	75	80.4 (5.0)
	165	72.1	150	64.7 (2.9)	225	76.9 (4.0)

[grain yield of fertilized plot - grain yield of control at 0 N]/total N fertilizer applied) decreased sharply when increasing the N rate for the GS25 split application but only slightly for the GS37 application. At harvest, 88% of N originating from the GS37 application was located in the ears. This corresponded to an increase not only in yield but also in grain quality (protein content and Zeleny index increased by, respectively, 1.8% and 8 units between 20 and 100 kg N ha^{-1}). The importance of the GS37 application in achieving good yields and high grain quality led us to make a general recommendation of 50 kg N ha^{-1} applied at GS25, 50 at GS30 and 65 at GS37, adapted to plot characteristics (Bodson et al., 1996). A major simplification of the application scheme, based on a reduction of the number of split applications, may be contemplated in most cases, as suggested by the results presented in Table 2. Total uptake of N fertilizer was not affected by combining the GS25 and GS30 applications in Lonzée and Piéton. In Gesves, where the highest values were obtained – corresponding to a low mineral N content in the soil (only 112 kg N [NO_3^-.+ NH_4^+]) present in a bare plot (0-150 cm) at harvest time – fertilizer N uptake was higher for treatment D than for treatment B. In Piéton, where soil produced 202 kg mineral N, due to the incorporation of large quantities of organic matter, total recovery of fertilizer N was lowest (64-66%). In treatment A, uptake at GS30 and GS37 was not significantly different, except for the plots at Piéton.

In 1996, yields were very high due to the exceptionally high fertility of the ears, and were not affected by treatments (Table 3). Even with high fertilizer rates, efficiency was highest in Gesves (> 25 kg grain per kg N applied) and particularly low in Piéton (< 10 kg). Total N removed by wheat was of the same order of magnitude in all three locations (250 kg ha^{-1}). Soil-derived N (estimated with ^{15}N) was lowest in Gesves (= 100 kg N ha^{-1}) and highest in Piéton (150 kg N ha^{-1}), and was not affected by the split application scheme.

Table 3. Yield, fertilizer N efficiency and N removed by winter wheat : effect of split application scheme

Treatment	Trial	Grain (t ha^{-1})	N efficiency (kg grain per kg N ha^{-1})	N removed (kg ha^{-1}) Total	Soil[1]
A	Lon.	10.7	16.2	245	132
B		10.8	16.7	235	125
C		10.5	15.0	252	135
D		10.9	17.3	239	120
A	Pié.	11.0	9.0	250	153
B		11.1	9.7	244	148
C		11.2	9.6	259	159
D		11.4	8.6	246	149
A	Ges.	11.2	26.3	251	91
B		11.3	27.1	252	100
C		11.5	27.2	261	93
D		11.5	25.6	257	84

At each location, values were not significantly different at the 0.05 *p* level
Yields (t ha^{-1}) for 0 N were : 8.7 (Lonzée) - 9.7 (Piéton) and 5.4 (Gesves)
[1]Removed from the soil (N_{total} - $N_{labelled}$).

Thus, combining GS25 and GS30 N applications seems possible, but one should bear in mind that N uptake of early applications is rather poor. So the practice of splitting N fertilizer into 3 applications may be considered as a means of achieving high yields of good quality without endangering the environment.

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