The fate of labelled $^{15}$N urea and ammonium nitrate applied to a winter wheat crop

II. Plant uptake and $N$ efficiency

S. RECOUS$^1$, J. M. MACHET$^2$ and B. MARY$^2$
Station d'Agronomie de LAON, BP 101, F-02004 Laon cedex, France.
$^1$Contrat CIFRE COFAZ, INRA Laon, Univ. Lyon I and $^2$INRA, Departement d'Agronomie

Received 4 February 1988. Revised July 1988

Key words: ammonium nitrate, fertilizer efficiency, $N$ dynamics, $N$ recovery, $^{15}$N field experiment, urea, winter wheat

Abstract

A field experiment was conducted on a winter wheat crop in Northern France with either $^{15}$N-urea or ammonium nitrate, labelled either on $NH_4$ or on $NO_3$. The fertilizer was split between two dressings, one applied in early March and the second in mid-April, labelled separately. $N$ uptake by the crop was measured at 8 successive times after each dressing. The $N$ uptake efficiency of nitrate was higher than that of ammonium or urea over the whole growth cycle for both dressings. The RUC (Real Utilization Coefficient) reached a maximum at anthesis or even before anthesis, and decreased during the grain-filling period, indicative of $N$ turnover in shoots. Thus the annual $N$ use efficiency appeared highly dependent upon the date of measurement. At harvest, the contribution of soil $N$ (residual $N$ + mineralized $N$) to the crop was comparable to that from fertilizer, but the two pools were utilized at different periods.

Introduction

Most studies of fertilizer efficiency using $^{15}$N-labelled nitrogen are restricted to balance-sheets at crop maturity. $N$ fertilizer uptake efficiency had been defined by the Real Utilization Coefficient $- \text{RUC} = - \left( \frac{U_n \times e}{F \times e_o} \right)$, where $U_n$ is the nitrogen uptake and $e$ the isotopic excess in the plant at harvest, $F$ the amount of fertilizer $N$ applied and $e_o$ its isotopic excess.

It is also necessary to meet the needs of the crop throughout its growth and not merely at the end of the growth cycle. Kinetic studies of $N$ transformation and plant uptake help understand the relative contribution of fertilizer and native $N$ (Nielsen and Jensen, 1986). However such studies are still rare, partly because of the heavy experimental burden involved, partly because of the high cost.

The aim of the $^{15}$N-labelled experiment described here was to characterize the dynamics of nitrogen uptake by a winter wheat crop, receiving ammonium nitrate or urea fertilizer, between $N$ appli-
cation and harvest. The efficiency of the residual $^{15}$N for the next crop (sugarbeet) had been determined and will be presented in another paper.

The experimental design has already been described, as have the corresponding data for changes in inorganic and organic nitrogen in the soil (Recous et al., 1988a).

Methods

**Analytical procedures for plant samples**

The dry matter and nitrogen content of the above-ground parts of the plants expressed on an oven-dry basis, were measured on 12 successive occasions. At each date of sampling, the plants were carefully cut just above the soil surface from a 0.3 m² microplot so as not to disturb the soil, and subsequently washed free of soil and fertilizer N. At maturity plants were separated into (straw + chaff) and grain. The dry matter and nitrogen content of the roots were measured in the 0-10 cm layer at each time for sampling, in the 10-30 cm layer at four occasions, and on the whole profile (0–120 cm) at flowering. The soil cores were firstly sampled for determination of inorganic and organic nitrogen. The remaining soil (about 4, 7 and 4 kg of fresh soil for the 0–10 cm, 10–30 cm and 30–60 cm layers respectively) was used to evaluate the root content. Roots were removed from the soil cores after the soil had been dispersed for 12 hours with sodium metaphosphate (50 g l⁻¹) followed by copious washing on a 1-mm mesh sieve. Roots were separated from other plant residues by hand picking.

Shoot and root samples were dried at 80°C and finely ground to powder. Total nitrogen content and $^{15}$N/$^{14}$N ratio were determined in a single determination using a flash combustion technique (Dumas method) with an automatic nitrogen analyser (Carlo Erba ANA 1400) connected with a mass spectrometer (VG SIRA 9).

**Results**

**Production of dry matter and grain**

The yields of dry matter are shown on Fig. 1. These were not significantly affected by the source of nitrogen at any date of sampling. However variability between plots was high (mean c.v. = 8.8%) owing to the small area of the sampling microplots (0.3 m²). That is why we used the mean dry matter data for the different fertilizer treatments at each date of sampling in our N calculations. High yields of above-ground dry matter for straw plus grain were obtained at harvest (18 t ha⁻¹). The grain yield (15% moisture content) averaged 10.4 t ha⁻¹ and 6.6 t ha⁻¹, on fertilized plots (160 kg N ha⁻¹ added) and control plots, respectively.

Root dry matter in the upper layers 0–30 cm increased up to flowering (Fig. 1). Due to the small amount of soil sampled, the variability on root mass was high (mean c.v. = 31%). No difference between the forms of fertilizer was found. The root profile made at flowering time indicated that more than half of the roots were located in the top 10 cm of soil and 20% in the 10–30 cm layer. If we consider that the weight of fine roots passing through the sieve was negligible (less than 1% of the total, according to Barraclough and Leigh, 1984), then root dry matter was about 1200 kg ha⁻¹ at flowering time, equivalent to 10% of total dry matter. At this time there were no significant differences in total root dry matter between fertilized and control plots.

![Fig. 1. Evolution of dry matter in shoots and roots (0–30 cm layer) during the growth cycle (mean of all fertilized).](image-url)