Available online at www.sciencedirect.com
ScienceDirect
Soil & Tillage Research 97 (2007) 117–121
Soil & Tillage Research
www.elsevier.com/locate/still

Short communication

Fertilizer ^{15}N recovery in cereal crops and soil under shallow tillage

Ingrid K. Thomsen *, Bent T. Christensen

Department of Agroecology and Environment, Faculty of Agricultural Sciences, University of Aarhus, Blichers Allé 20, P.O. Box 50, DK-8830 Tjele, Denmark

Received 23 January 2007; received in revised form 11 September 2007; accepted 11 September 2007

Abstract

We examined the effect of tillage system on crop recovery of soil and fertilizer N. ^{15}N-labelled ammonium nitrate was applied in the spring to small confined plots at five experimental sites where shallow tillage (ST) and mouldboard ploughing (MP) had been practised for up to 36 years. Winter wheat was grown on three sites and spring barley on the other two. Grain yields were similar under ST and MP at all sites, and total N uptake was similar under MP and ST at four of the five sites. Grain and straw recovered 59–64% of the applied ^{15}N fertilizer except at the most sandy site where crop recovery was 37% (ST) and 44% (MP). At two sites, crop ^{15}N recovery was lower under ST despite similar total N uptake for the two tillage systems. Recovery of ^{15}N in crop and soil was 74–75% at the most sandy site and 86–92% at the other sites. Conversion from MP to ST tillage appeared to have little influence on the fertilizer N balance at each site.

Keywords: Crop ^{15}N recovery; ^{15}N-labelled fertilizer; Soil tillage; Spring barley; Winter wheat

1. Introduction

No-till and shallow tillage systems are not widespread in Scandinavia (Rasmussen, 1999). Arable soils in Denmark are mostly derived from morainic deposits relatively low in clay and high in sand. These soils tend to compact when ploughing is omitted. Such compaction may restrict gas exchange, root penetration and water movement within the soil profile (Munkholm et al., 2003).

Mouldboard ploughing provides a more uniform distribution of crop residues in the upper soil layer than shallow tillage which leaves plant residues at or near the soil surface. Compared with residues on the soil surface, crop residues incorporated into the soil by ploughing will be more exposed to microbial colonization and decomposition (Silgram and Shepherd, 1999). Thus no-tillage may impede residue decomposition compared to conventional ploughing. In Denmark no-plough tillage is based mainly on shallow tillage where most of the plant residues are incorporated into the upper 5–15 cm soil layer. This may improve conditions for decomposition as compared with plant residues left on the soil surface or ploughed into the deeper soil layers (Christensen, 1986). A greater microbial activity in the tilled layer under shallow tillage than in ploughed systems may affect the pattern of mineralization and immobilization of soil and fertilizer N (Kitur et al., 1984; Rice and Smith, 1984; McCarty et al., 1995).

The potential reduction in fuel consumption, labour and machinery costs has renewed the interest in no-plough tillage among Danish farmers. This warrants an evaluation of the influence of shallow tillage on crop uptake of soil and fertilizer N under the cool and humid conditions that prevail in NW Europe. Here we evaluate the effect of shallow tillage and mouldboard ploughing on the availability of mineral N fertilizer and soil N to the main cereal crops in Denmark.

* Corresponding author. Fax: +45 89991719.
E-mail address: ingrid.thomsen@agrsci.dk (I.K. Thomsen).

0167-1987/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.still.2007.09.004

Table 1
Concentrations (g C kg^{-1} soil) of C (March/April 2004) and N (August 2004) in soil under mouldboard ploughing (MP) and shallow tillage (ST)

Site	Start of experiment (year)	Crop 2004	Organic C			Total N			
			MP (0–20 cm)	ST (disturbed top layer)	ST (undisturbed bottom layer)	MP (0–5 cm)	MP (5–20 cm)	ST (0–5 cm)	ST (5–20 cm)
Dronninglund	2001	Winter wheat	58 a	66 a	60 a	3.28 b	3.26 b	3.86 a	3.40 b
Bygholm	2000	Winter wheat	16 b	19 a	16 b	1.80 b	1.78 b	2.23 a	1.79 b
Nakskov	1999	Winter wheat	15 b	18 a	16 b	1.64 bc	1.58 c	1.94 a	1.69 b
Jyndevad	1968	Spring barley	22 b	31 a	22 b	1.25 b	1.24 b	2.10 a	1.27 b
Bramstrup	1996	Spring barley	10 b	13 a	11 b	1.26 b	1.21 bc	1.37 a	1.19 c

Values followed by the same letter within a row are not significantly different ($p > 0.05$).

2. Materials and methods

2.1. Soils and experimental sites

The study was carried out at five sites in Denmark where field experiments comparing different tillage systems have been running for 4–36 years (Table 1). The five sites included two sand soils (Dronninglund and Jyndevad), two loamy sand soils (Bygholm and Bramstrup) and one sandy loam soil (Nakskov). At each site, treatments with non-inversion shallow tillage (ST) and with conventional mouldboard ploughing (MP) were included. Annual tillage operations on soils under ST were 1–2 harrowings to 5–10 cm depth. Soil under MP was ploughed annually to 20–23 cm depth and harrowed 1–2 times for seedbed preparation. Schjønning and Thomsen (2006) provide further details on soil characteristics and tillage procedures.

Soil for C analyses was taken in the spring 2004 (Table 1). At each site, eight soil cores were sampled from the 0–20 cm soil depth in the MP plots and bulked. In the ST plots, each soil core was divided into a top and a bottom section, the top section representing soil disturbed annually by harrowing (to 5–10 cm depth depending on site) whereas the bottom section (to 20 cm depth) represented soil that was undisturbed by tillage.

2.2. Fertilizer ^{15}N recovery

In March (winter wheat) and April (spring barley) 2004, polyvinyl chloride cylinders (30 cm diameter, 30 cm length) were inserted 25 cm into the soil growing either winter wheat (*Triticum aestivum* L.) or spring barley (*Hordeum vulgare* L.) (Table 1). For each of the two soil tillage systems, three cylinders were inserted in each of three blocks, providing a total of 18 cylinders for each site. The usual N fertilizer dressing was withheld from the cylinders. Instead the soil confined within the cylinders received an aqueous solution of $^{15}NH_4{}^{15}NO_3$ (5 atom% ^{15}N), applied into 1 cm deep drills in three rows and subsequently covered with soil. Winter wheat received 16 g N m^{-2} plus 3 g P m^{-2} and 9 g K m^{-2} and spring barley 10 g N m^{-2} plus 1.5 g P m^{-2} and 6.2 g K m^{-2}. The crops were harvested at maturity in August by cutting just above the soil surface. The upper 0–5 cm soil was removed, mixed and subsampled. Six soil cores were then retrieved from the 5–20 cm depth and bulked.

2.3. Analyses

Total C in soil was determined by dry combustion using a LECO CNS-1000 analyser (Leco Corporation, St. Joseph, MI). Shoot material from the cylinders was separated into grain and straw using a small-plot threshing machine. The plant material was dried at 80 °C and ground in a centrifugal mill (Retsch Ultra-Centrifugal Mill, Type ZM 1, Haan, Germany). Subsamples were further ball-milled for 20 min (Retsch Ball Mill, Type S 1). The soil sampled after harvest was dried (80 °C), sieved (2 mm) and ball-milled for 20 min. The plant and soil samples were weighed into tin capsules and analysed for contents of total N and ^{15}N by ANCA-MS (Europa Scientific, UK). The ^{15}N contents were corrected for natural ^{15}N abundance (0.3664 atom% ^{15}N). The data were analyzed with general linear models statistically using SAS (1988).

3. Results and discussion

3.1. Organic C and total N in soil

Except for Dronninglund, ST introduced C concentrations in the disturbed upper soil layer that were higher than found in the undisturbed soil below and in the ploughed soil (Table 1). At all sites the 0–5 cm soil under ST was significantly higher in organic N than the