Total denitrification and the ratio between N$_2$O and N$_2$ during the growth of spring barley

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Summary Total denitrification (N$_2$O + N$_2$) and nitrous oxide emission were measured on intact soil cores using the acetylene inhibition technique.

Total denitrification from the depth 0–8 cm during the growth period from April to August was 7 kg N/ha from plots supplied with 30 kg N/ha and 19 kg N/ha from plots supplied with 120 kg N/ha. The amounts of precipitation, plant growth, and N application were found to affect the denitrification rate. These factors also affected the ratio (N$_2$O + N$_2$)/N$_2$O, which varied from 1.0 to 7.2. Plant growth and precipitation increased the proportion of N$_2$ produced, whereas a high nitrate content increased the proportion of N$_2$O.

Introduction

From an agricultural point of view denitrification is a very important process since considerable amounts of plant-available N may be lost by this process.

Estimates of denitrification losses have been made in several cases and by various methods$^{1,4,8,11,12}$; and losses varying from a few to about 70 per cent of the applied N have been reported. One source of variation could be, that when total denitrification is estimated only from measurements of N$_2$O, a fixed overall ratio between N$_2$O and N$_2$ production is used, and since this ratio is known to vary depending upon factors such as carbon supply$^{12}$, soil treatment$^{9}$, plant growth$^{14}$, and nitrate content in soil$^{3}$, the estimate may be erroneous.

In the present investigation the acetylene inhibition technique$^{17}$ and measurements of N$_2$O emission have been combined to estimate the total denitrification, and to calculate the proportion of N$_2$O and N$_2$ produced during the growth period of spring barley. Effects of N application, plant growth, and precipitation were also studied.

Materials and methods

Experimental area

Samples were taken from a field plot experiment with continuous barley cultivation started in 1973. The plots are located on a sandy loam soil at Roskilde State Research Station on Plant Science, Sealand. Physical and chemical properties of the soil are described by Vinther$^{15}$.

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Two levels of N fertilization were selected for these studies, one below (30 kg N/ha/year) and one above (120 kg N/ha/year) the normal application to barley in this area (90 kg N/ha/year). The N was applied as calcium-ammonium-nitrate (50% ammonium and 50% nitrate) on April 21, and at the same time the barley (cultivar Zita) was sown. Phosphorus and potassium (400 kg/ha of a PK-fertilizer containing 19 kg P, 49 kg K, and 10 kg Mg) were applied in the autumn the year before. Total precipitation during the growth season was 331 mm and the mean temperatures in the months April, May, June, July, and August were 5.7, 12.5, 13.6, 15.4, and 15.4°C, respectively.

Sampling and treatment of samples

Samples for determination of N₂O production were taken to a depth of 8 cm as intact soil cores in steel tubes 35 mm in diameter. Cores were taken both with and without plants. Samples without plants were taken between two barley rows spaced approximately 10 cm apart. These samples therefore were not free from roots, but the density of roots in samples with plants was considerably higher than in samples without. The size of the incubation vessel and the sampling procedure made it necessary to decapitate the plants about 5 cm above the soil surface before sampling.

Samples for determination of nitrate in the soil by extraction with 2M KCl for 1 h were taken several times during the growth season.

Measurements of denitrification

All samples were taken as pairs with four replicates. From each pair one sample was incubated with acetylene and the other without acetylene, in order to calculate the ratio

\[ \frac{N_2O \text{ produced with } C_2H_2/\text{without } C_2H_2}{N_2O} \]

If acetylene completely inhibits N₂O reduction, the calculated ratio is equal to

\[ \frac{(N_2O + N_2)}{N_2O} \]

Results from samples incubated with acetylene correspond to total denitrification. The loss of N in the form of NO was considered to be negligible.

Immediately after arriving at the laboratory the samples were incubated in glass containers (volume 390 ml) fitted with a rubber septum. Samples to be incubated with acetylene received 10% acetylene after removing 10% of the air with a gastight syringe. To obtain activities as near as possible to field activities the incubated samples were placed under outdoor conditions.

Measurements of N₂O, both in samples with and without acetylene, were performed the day after sampling and again 24 h later and the N₂O production was calculated by difference.

Analytical procedure

N₂O was measured by a gas-chromatograph with an electron capture detector as described by Vinther et al.¹⁶.

Results

Fluctuations of denitrification (N₂O + N₂), NO₃-N in soil and precipitation during the period from April to August are shown in Fig. 1. Before fertilization denitrification was low, probably due to low temperatures and to lack of substrate (nitrate). After application of N denitrification increased only slightly until mid-May while the soil was very dry due to low precipitation. In the last week of May the highest activity occurred, coinciding with heavy rainfall, and thereafter the denitrification rate decreased to a constant low level not