LOSSES OF NITRATE FROM A SANDY LOAM SOIL UNDER CORN: LYSIMETER EXPERIMENT.

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Abstract

Losses of nitrate from an undisturbed sandy loam soil contained in two monolith lysimeters, L_0 and L_1, (1 m diameter, 1.5 m deep) under corn and irrigation (628 mm) were studied. The crop was fertilized with 0 (L_0) and 800 (L_1) kg N ha^{-1}. Water draining was collected periodically and analysed for nitrate content during the experimental period (20 March 91-23 March 92).

Mean values of nitrate concentration in the drainage water were 3.1 and 41.2 mg NO_3-N l^{-1} in L_0 and L_1 respectively, the latter much higher than the limit imposed by the EC for potable water (11.3 mg N l^{-1}).

Three periods were distinguished during the experiment: i) Crop season, in which the total volume of water drained was 310 and 47 mm respectively in the L_0 and L_1, while the nitrate losses were of the same order in both lysimeters (21 and 17 kg N ha^{-1}, respectively); ii) Dry season, in which there was no water drainage; and iii) Rainy season, in which the total drained water was 157 and 139 mm, and the nitrate losses 5 and 91 kg N ha^{-1} in L_0 and L_1 respectively.

The greater amount of water drained in L_0 is due to the lower crop development (grain yield 4.4 and 21.3 t ha^{-1}; total nitrogen plant uptake 69 and 400 kg N ha^{-1}, in L_0 and L_1 respectively).

Total nitrate losses in L_1 account for 13% of the nitrogen fertilizer applied. Most of these losses occur in the rainy season.

At the end of the experimental period a decrease of the soil nitrate content was observed in both lysimeters.

1. Introduction

Production of heavy yields depends on the use of large quantities of inorganic fertilizers, which can imply an environmental risk: the pollution of groundwater by nitrate. Whatever form of nitrogen fertilizer is used, the end product in the soil is nitrate, which is vulnerable to being washed out of the soil by rain or irrigation. The most decisive factors determining the magnitude of nitrate leaching are nitrogen fertilization, climatic conditions, type of soil, soil management and type of crop (Gustafson, 1983; Duynisveld et al., 1988; Addiscott et al., 1991).

Measurement of nitrate losses under field conditions is difficult. Five methods for measuring the concentration and fluxes of nitrate leaving the soil were outlined by Addiscott (1990). A good approach is the use of monolith lysimeter containing undisturbed soil (Dowdell et al., 1984; Owen, 1990, Bergström and Johansson, 1991).

The aim of this study was to evaluate timing and quantity of nitrate leaching in a highly fertilized soil under corn and irrigation using monolith lysimeters. These are preliminary results of a wider study lasting four years.

2. Material and methods

Two monolith lysimeters (1 m diameter, 1.5 m deep) were constructed without disturbing the soil profile and reinstalled *in situ* in a plot of 0.1 ha. The soil was a sandy loam XEROCHREPT (pH(H_2O) 7.2 and 7.1; $CaCO_3$ 5.2 and 3.1 %; O.M. 0.88 and 0.69 %; Kjeldahl-N 599 and 454 mg kg^{-1}; NO_3-N 7.5 and 10.4 mg kg^{-1} at 0-50 and 50-100 cm respectively. These are mean values of 45 samples). Lysimeters were provided with a system to collect drainage water (1.2 m deep) and with access for neutron probe.

The lysimeters were sown with corn (170000 plant ha^{-1}, 5 April 1991) and fertilized with 0 (L_0) and 800 kg N ha^{-1} (L_1). Fertilizer was applied in three steps: a deep fertilization before sowing (22 March 1991) with 1000 kg ha^{-1} with a 15-15-15 complex NPK fertilizer, and two top dressings with 400 kg ha^{-1} (24 May 1991) and 1000 kg ha^{-1} (7 June 1991) of urea (46 %) respectively. Lysimeters were periodically irrigated (EC 2.0 dS m^{-1}; SAR 2.0 $meq^{1/2}$ $l^{-1/2}$; NO_3-N 10.5 mg l^{-1}) receiving a total amount of water equivalent to 628 mm. Water draining was collected periodically and analysed for nitrate during the experimental period (20 March 1991-23 March 1992) (figure 1). Nitrate in water was determined by ionic chromatography using a mixture of borate-gluconate pH 8.5 as eluent. Soil water content and rainfall were also monitored throughout the experimental period (total rainfall equivalent to 293 mm (figure 1)).

Soil samples were collected at 0-30, 30-60 and 60-90 cm at the end of the experiment by means of a thin auger. Soil Kjeldahl-N was determined by the method described by Hesse (1971). Soil NO_3-N was extracted by 0.2% $Ca(OH)_2$ suspension (Sims and Jackson, 1971) and the extracts analysed for NO_3-N by the method of Scheiner (1974).

Plant height was measured periodically. Yield, mean weigth of ears and total Kjeldahl-N in kernel were determined at harvest.

3. Results and Discussion

Volumes of water drained by L_0 are greater than those drained by L_1, and both are related with the volumes of water supplied by irrigation and rainfall (figure 1). The total comulative volume of water drained by L_0 is also greater than that by L_1 (figure 2). Concentrations of NO_3-N in drainage water ranged from <1 to 41.9 and <1 to 155 mg NO_3-N l^{-1} respectively in L_0 and L_1. Their mean values were 3.1 and 41.2 mg NO_3-N l^{-1} (figure 1), the latter being much higher than the 'maximum admissible concentration' imposed by the EC for potable water (11.3 mg NO_3-N l^{-1}).

Three seasons can be distinguished during the experimental period: i) Crop season (20 March 1991-5 August 1991; ii) Dry season (6 August 1991-30 September 1991); iii) Rainy season (1 October 1991-23 March 1992).

During the 'crop season' the lysimeters received a total of 628 and 55 mm of water by irrigation and rainfall respectively. In this season total water drained was 310 and 47 mm respectively in L_0 and L_1, and total nitrate losses were of the same order in both lysimeters (21 and 17 kg NO_3-N ha^{-1} respectively).

Analysing the hydric profiles of the lysimeters during the maximun development of the crop (figure 3), it can be observed that on 19 July 1991 (a few hours after the beginning of an irrigation), water content decreased throughout the soil profile down to 20 and 70 cm depth respectively in L_0 and L_1. Afterwards water content remained approximately constant at 0.227±0.008 and 0.151±0.004 cm^3 cm^{-3} (mean±SD) respectively in L_0 and L_1. Four days later (23 July 1991), water content at 0-80 cm in L_0 and 0-60 cm in L_1 decreased compared with the situation of 19 July 1991, and the shape of the hydric profile were similar for both lysimeters down to 70 cm depth. From 80 cm down in L_0 and 70 cm in L_1, water contents were nearly constant, 0.226±0.011 cm^3 cm^{-3} in L_0 and 0.141±0.01 cm^3 cm^{-3} in L_1, values similar to those found at the same depth on 19 July. Therefore, during this irrigation event water content in the soil profile of L_0 is always greater than in that of L_1. The same situation was observed in all the irrigation events throughout the 'crop season'.

As total volume of water drained was greater in L_0 than in L_1 (figure 2), it is supposed that water depletion in L_1 is mainly caused by the higher water uptake of the crop in this lysimeter because of the higher plant development. In fact, table 1 shows that corn plants of L_1 were toller than those of L_0, and that the yield, mean weight of ears and total Kjeldahl-N in kernel, was also greater in L_1.

In the 'dry season' there was no water drainage and consequently no losses of nitrate in either of the lysimeters.

During the 'rainy season', total water drained in both lysimeters was similar, 157 and 139 mm in L_0 and L_1 respectively, 66 and 58 % of the total rainfall in this period. However, in the same period nitrate losses in the drainage water were much higher in L_1 (91 kg NO_3-N ha^{-1}) than in L_0 (5 kg NO_3-N ha^{-1}). Nitrate losses in L_1 during the 'rainy season' were the 11% of the N applied as fertilizer.

Total nitrate leached in L_1 was 108 kg NO_3-N ha^{-1}, equivalent to 13% of the total nitrogen applied as fertilizer. This quantity is higher than that reported by Croll and Hayes (60-80 kg NO_3-N ha^{-1}) for spring-sown cereals, and would be sufficient to constitute a serious threat to the maintenance of the EC-recommended level in groundwater (Foster et al., 1982).

At the end of the 'rainy season' it was found that the content of Kjeldahl-N throughout the profile decreased in L_0 (5733 kg N ha^{-1}) and increased in L_1 (6396 kg N ha^{-1}) with respect to the average initial content of the soil (6157 kg N ha^{-1}), although neither of the differences was statistically significant ($P<0.05$) (figure 4). At the same time, nitrate content in the soil profile decreased significantly ($P<0.05$) with respect to the average initial content of the soil (104 kg NO_3-N ha^{-1}) in both L_0 (23.8 kg NO_3-N ha^{-1}) and L_1 (38.9 kg NO_3-N ha^{-1}) (figure 4).

Figure 5 shows a balance of the nitrogen inputs and outputs in L_0 and L_1. It can be observed that at the end of the experimental period it was possible to determine the fate of most of the nitrogen of the system. In fact, in L_0 the difference between the initial and final states (6327 and 5853 kg N ha^{-1} respectively) was not significant ($P<0.05$) and accounts for some 7% of the nitrogen in the initial state. In L_1 total nitrogen in the initial state was 7121 kg N ha^{-1} and in the final one 6958 kg N ha^{-1}, the difference being non-significant ($P<0.05$) and equal to some 2% of the nitrogen in the initial state. These differences, though non-significant, can be explained by the inherent error of the methods, losses by ammonia vaporization from urea, by denitrification, or even by the release of gaseous nitrogen (mainly ammonia) by the plants themselves.

Acknowledgment

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Table 1 - Mean values of corn plant height and results of corn performance at harvest.

Lysimeter	Plant height 18 Jun cm	Plant height 18 Jul cm	Yield kg ha^{-1}	Ear mean weight g	Kernel Total Kjeldahl-N %
L_0	70 a	218 a	4415	54.3 a	1.22
L_1	136 b	247 b	21295	187.3 b	1.53

Values followed by different letters in the same column differ significantly (P<0.05).

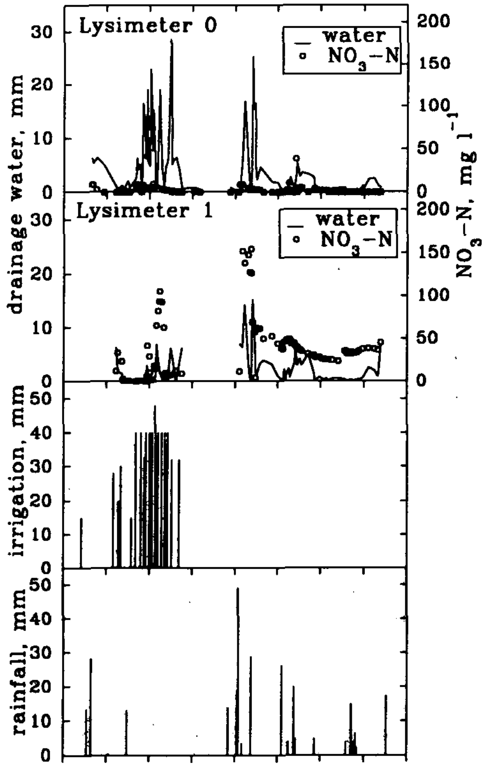

Figure 1 - Drained water, nitrate in drainage water, and irrigation and rainfall data.

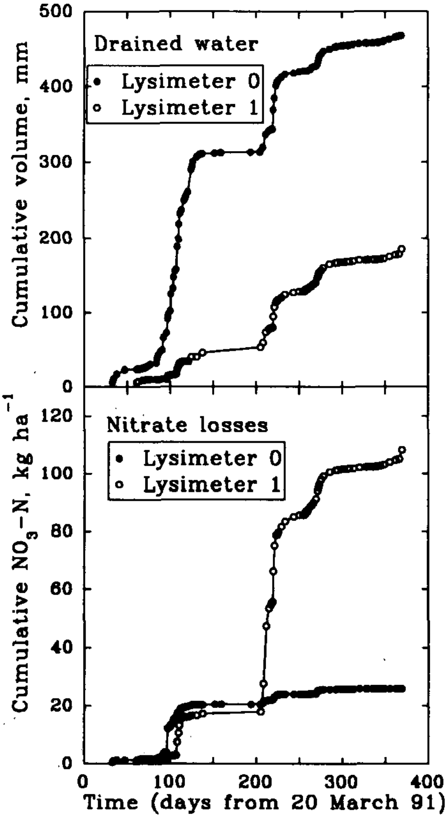

Figure 2 - Cumulative volume of drained water and cumulative nitrate losses.

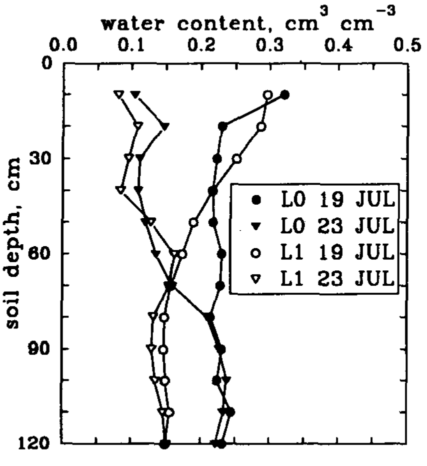

Figure 3 - Hydric profiles of the lysimeters.

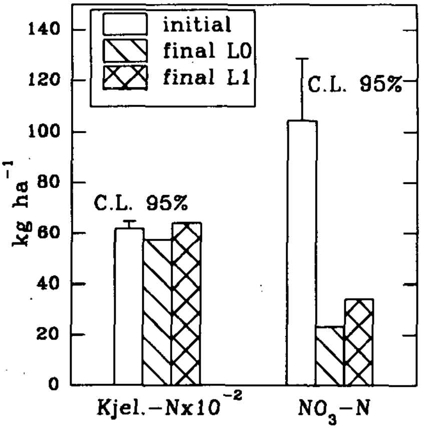

Figure 4 - Contents of Kjeldahl-N and NO_3-N in the soils of the two lysimeters.

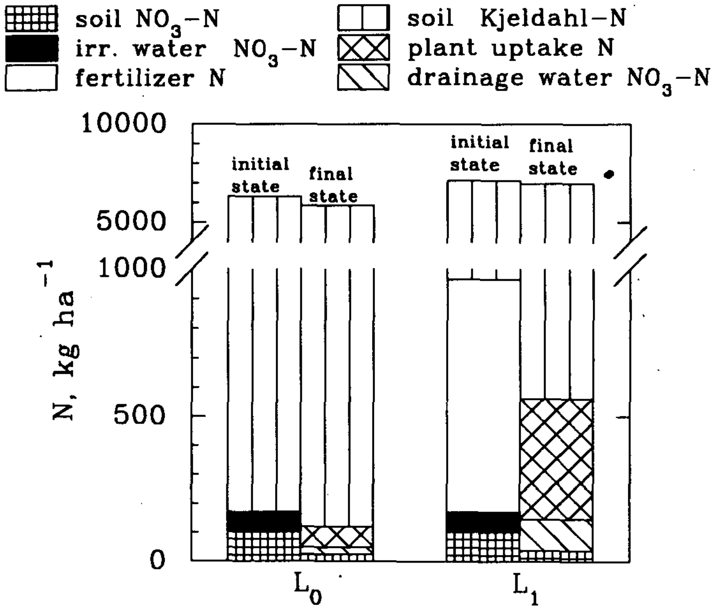

Figure 5 - Nitrogen balance.