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LEACHING OF NITRATE FROM A SANDY LOAM SOIL UNDER CORN AND TWO N- FERTILIZATIONS

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Summary: Nitrate losses in two undisturbed soil lysimeters cultivated with corn under irrigation and fertilization (higher in L1 than in L2) were studied. Total drained water volume during the experimental period was higher in L2 than in L1. Differences can be attributed both to different patterns of soil water dynamics and crop development in each lysimeter. Nitrate losses were higher in L1 than in L2 and occurred mainly during the crop season. This abnormal nitrate losses distribution seems to be due to the scarcity and uneven distribution of rainfall during autumn 1992.

Key words: Nitrate losses; drainage water; lysimeter; irrigation; fertilization.

INTRODUCTION

Production of heavy yields depends on the use of large quantities of inorganic fertilizers, specially N-fertilizers, which involves the risk of contamination of groundwater by nitrate [1]. Groundwater contamination with nitrate is of particular concern because drinking water often originates directly from groundwater and adverse effects on health may occur (e.g., methemoglobinemia and cancer) when nitrate contaminated water is ingested in sufficiently high amounts by animals and humans [2]. The objective of this study was to evaluate timing and quantity of nitate leaching from a soil under corn and irrigation receiving two different fertilizations. The experiment was carried out in lysimeters, which offer a good way of conducting controlled experiments under field conditions [3].

MATERIALS AND METHODS

Two monolith lysimeters (L1 and L2, 1 m diameter, 1.5 deep) were constructed without disturbing the soil profile and reinstalled *in situ*. 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%; Kjeldhal-N 599 and 454 kg ha^{-1}; NO_3-N 44 and 61 kg ha^{-1} at 0-50 and 50-100 cm respectively). Lysimeters were provided with a system to collect drainage water (1.2 m deep) and with access for neutron probe.

Two different fertilizations were used. L1 received one of the highest N-fertilizations used by the farmers of SW Andalusia: a deep fertilization with 1000 kg ha^{-1} of a 15-15-15 complex NPK fertilizer and two top dressings with 400 kg ha^{-1} of urea (46% N), equivalent to ca. 500 kg N ha^{-1}. One third of the fertilization of L1 was applied to L2: a deep fertilization with 340 kg ha^{-1} of complex NPK fertilizer and two top dressings with 130 kg ha^{-1} of urea, (ca. 170 kg N ha^{-1}).

Lysimeters were sown with corn (75000 plant ha^{-1}) on 24 March 1992. The corn was irrigated when needed, this depending on climatic conditions and plant development, receiving a total amount of water equivalent to 661 mm (E.C. 2.2 dS m^{-1}; NO_3-N 9.8 mg l^{-1}; Cl 446.6 mg l^{-1}; SO_4-S 44.7 mg l^{-1}). On 22 February 1993 the lysimeters received 80 mm of water during a calibration experiment.

Water drained was collected periodically and analysed for nitrate by ionic chromatography using a solution of 0.0110 M borate-0.0015 M gluconate in acetonitrile (12% v/v) at pH 8.5 as eluent [4]. Rainfall was monitored throughout the experimental period (total rainfall 394.5 mm). In addition, soil water content was determined periodically by neutron probe.

Soil samples were collected at the beginning and end of the experiment at different depths (0-30; 30-60; 60-90 and 90-120 cm) by means of a thin auger. Soil nitrate was extracted by a 2M KCl solution [5]. Nitrate in the extracts filtered through C18 Lida cartridges was determined by UV spectrophotometry [6].

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

RESULTS

Volumes of water drained are related to water supplied by irrigation and rainfall (Figure 1). Concentrations of nitrate in drainage water ranged from 2.8 to 151 mg NO_3-N l^{-1} in L1 and <0.1 to 34.4 mg NO_3-N l^{-1} in L2, being sometimes much higher than the 'maximun admissible concentration' imposed by the EC for potable water (11.3 mg NO_3-N l^{-1}) [7]. The cumulative volume of water drained in L1 (228 mm) was lower than in L2 (296 mm) (Fig. 2), while total losses of nitrate in drainage water were higher in L1 than in L2 (93 and 50 kg NO_3-N ha^{-1} respectively) (Fig. 3).

Three seasons could be distinguished during the experimental period: i) Crop season (10 March 1992-27 August 1992), in which the lysimeters received a total of 661 and 181 mm of water by irrigation and from rainfall respectively and the nitrogen fertilization; ii) Dry season (27 August 1992-15 September 1992), in which the lysimeters received neither water nor fertilization; and iii) Rainy season in which two stages could be considered: the first stage (rainy season 1, 15 September 1992- 21 February 1993) before the calibration experiment, and the second stage (rainy season 2, 21 February 1993-10 March 1993) from the date of calibration up to the end of the experiment. In this season lysimeters received 213.5 mm of rainfall (rainy season 1) and 80 mm

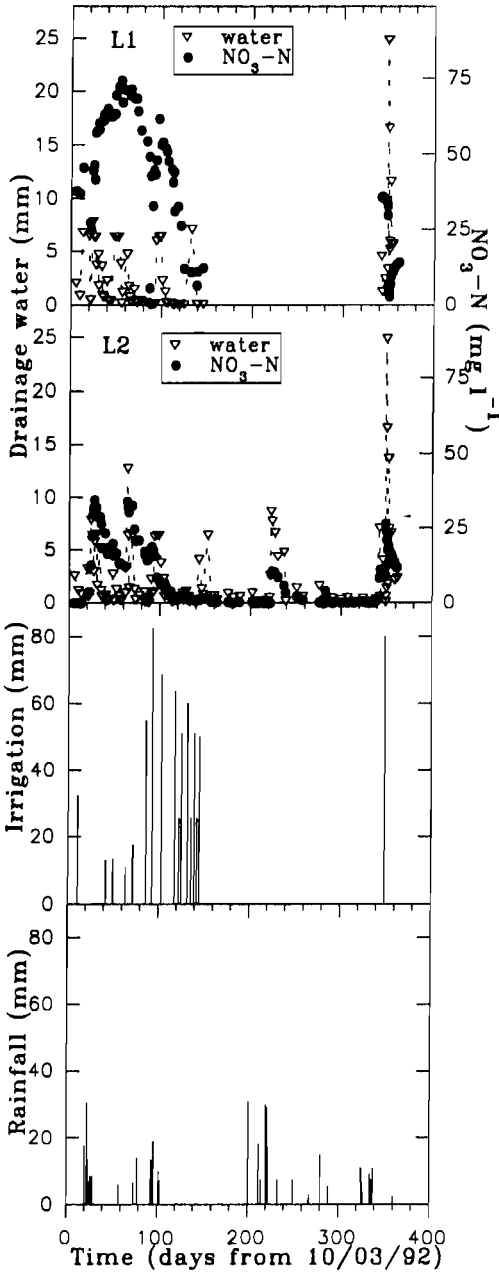

Figure 1. Drainage water, nitrate in drained water, irrigation and rainfall data.

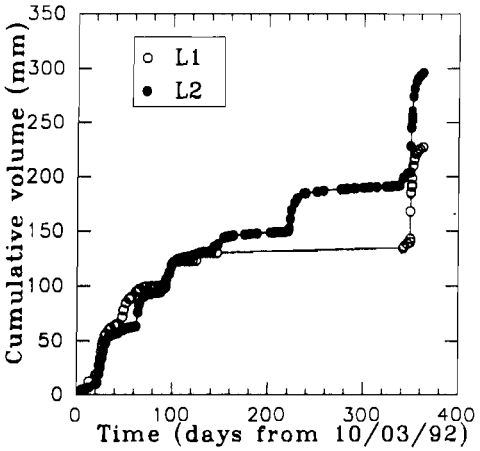

Figure 2. Cumulative volume of drained water.

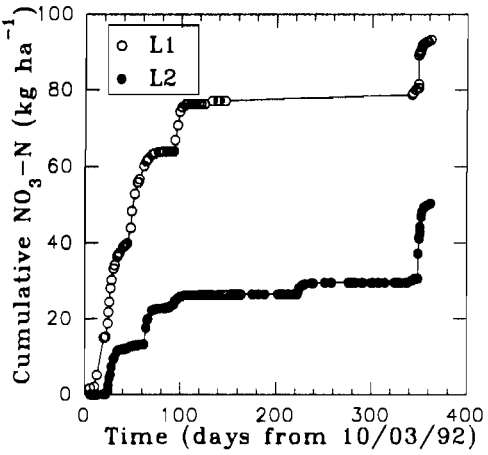

Figure 3. Cumulative nitrate losses.

of irrigation water in the calibration experiment (rainy season 2). Volumes of water drained and amounts of nitrate leached in these seasons are in Table 1.

TABLE 1. Water and nitrate drained.

Season	drained water mm		NO_3-N losses Kg ha^{-1}	
	L1	L2	L1	L2
Crop	131	137	77	26
Dry	---	11	---	0.1
Rainy 1	8	55	3	4
Rainy 2	89	93	13	20
TOTAL (before calib.)	**139**	**203**	**80**	**30**
TOTAL	**228**	**296**	**93**	**50**

DISCUSSION

Drained water

During both the dry season and the first stage of the rainy season the volumes of water drained from L1 were smaller than those from L2 (Table 1). This behaviour could be related to the soil water contents of the lysimeters (Figure 4). At yield (27 August 92), soil water content to a depth of 60 cm was less in L1 than in L2 (Fig. 4a). During the first stage of the rainy season, the evolution of the water content profile of L1 is slow, reaching values close to those for L2 only a few days before the calibration stage (Figs. 4b-d). From these values, higher hydraulic conductivity can be expected in L2 than in L1 during both the dry season and the rainy season 1. After the infiltration of 80 mm of water for calibration, water content profiles were very similar (Fig. 4e), as was the volume of water drained.

The origin of these differences in the water content profiles could be due both to the spatial variability of the physical and chemical properties of the soil found by Moreno *et al.*, 1992 [8], and to the different crop performance in the lysimeters. Table 2 shows that corn plants of L1 were taller than those of L2, and that the yield, mean weight of ears, total Kjeldahl-N in kernel and total N removed by plants were greater in L1.

TABLE 2. Mean values of corn plant height and results of corn performance at harvest.

	Plant height (22/06/92) cm	Plant height (09/07/92) cm	Yield kernel Mg ha^{-1}	Ear mean weight g	kernel Kjel.-N kg ha^{-1}	Removed by plant N kg ha^{-1}
L1	194b	222a	11,5	188,9a	174	304
L2	156a	201a	9,3	143,0a	101	140

Nitrate losses

Most of the nitrate losses occur in the crop season (83 and 50% respectively in L1 and L2) and after the infiltration of water for calibration (rainy season 2; 14 and 40% respectively in L1 and L2), and not during the rains of autumn (rainy season 1) as expected [1,9]. This abnormal distribution of nitrate losses seems to be due to the scarcity and uneven distribution of rainfall

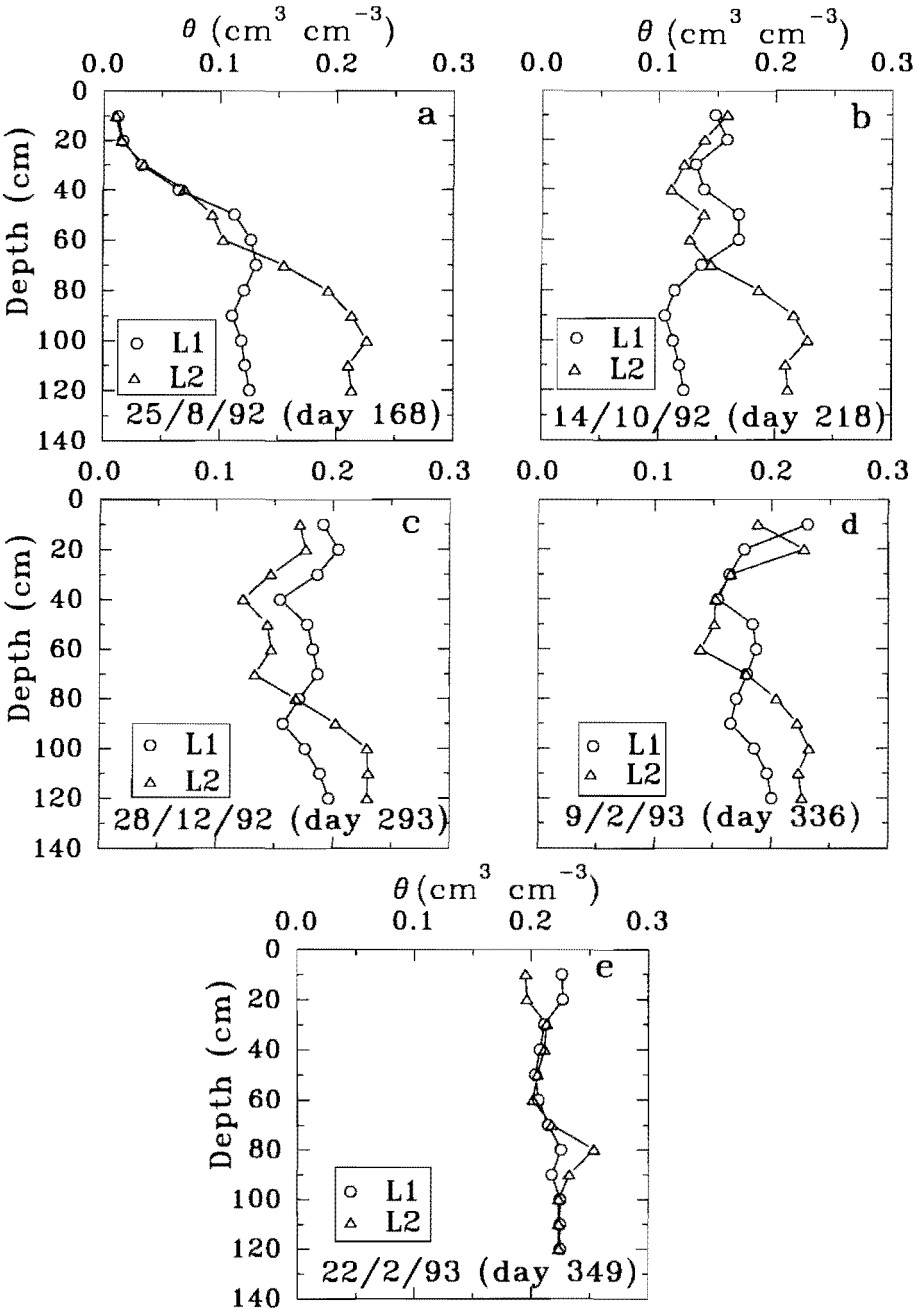

Figure 4. Hydric profile evolution of the lysimeters.

during the autumn (Figure 1). From September 1992 to March 1993, rainfall was 213.5 mm, less than the mean value of the last 21 years (328.6 mm), and most of the autumn rainfall (129.5 mm) occurred in the first 30 days of the season when the water content of the soil profiles was very low (Fig. 4a and b).

Nitrate content of the soil

As a consequence of the dynamics of leaching, nitrate in the soil profile (0-120 cm) at the end of the first stage of the rainy season increased from 44 to 109 kg NO_3-N ha^{-1} in L1 and from 29 to 99 kg NO_3-N ha^{-1} in L2. At the end of the experiment the nitrate content in soil was 96 kg NO_3-N ha^{-1} in L1 and 79 kg NO_3-N ha^{-1} in L2. Nitrate accumulated in the soil profiles is subject to leaching during spring precipitations or is used by the following season's crop.

Plant development

The differeces in crop development in L1 and L2 (Table 2) could initially be thought to be due to the fertilization. However, differences due to fertilization were not found in field experiments, in the same soil, with the same crop and fertilization during two consecutive years [10]. These results show the peculiar characteristics of a crop developed in restricted spaces and the influence of previous soil fertilization management (in 1991 L1 and L2 were under corn and received ca. 500 and 0 kg N ha^{-1} respectively).

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