Agriculture-Induced Water Quality Problems in a Maize Irrigated Crop: 1 – Nitrogen Leaching

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ABSTRACT

Water is one of the major means for pollutant transport through the soil. Soil-water fluxes measurement and quality analysis is essential for accessing possible agricultural-related environmental contamination. Few work reported direct measurement of nitrogen leaching. The work's objective was to monitoring water percolation and nitrogen leaching along a maize cycle. Lysimeters were used to allow direct percolation measurement and water sampling. A sprinkler irrigation system was used to apply three water depths: above, equal and bellow the crop water requirement. Leachate samples were analyzed for nitrate and ammonium and used with percolation volumes to determine nitrogen losses. Using an irrigation depth 27.6 % higher than the required caused 143 % more percolation. Deficit irrigation can be a management strategy to help preserve ground water quality. Excess irrigation caused even ammonium, a relatively soil-immobile ion, to leach. Nitrate concentrations higher than 10 mg L^{-1}, which is the acceptable drinking water limit, were observed in the treatment that received excess irrigation. Nitrogen losses through leaching were less than 18 % of the applied amount.

KEYWORDS: Corn, deep percolation, irrigation, nitrate, water contamination.

INTRODUCTION

Nitrogen is one of the major nutrients used in maize crop. In Brazil, maize nitrogen fertilization recommendations are based on crop rotation, soil organic matter content, plant analysis and expected grain yield. Soil inorganic N availability and environmental issues are, in general, neglected. Nitrate leaching is the main nitrogen loss process along maize cycle (Sangoi et al., 2003). Therefore, soil-water dynamics plays an important rule in this process. Nitrogen losses in maize at Cerrado (Savana) Oxisol, vary from 10 to 20 kg ha^{-1} (Coelho et al., 2003). This low nitrogen loss is due, among other factors, to the high anions exchange capacity, low organic content and the presence of amorphous materials in this type of soil sub-surface horizons (Oliveira et al., 2000). Most of the nitrogen leached comes from organic matter mineralization, although chemical fertilization indirectly favors loss process (Addiscott et al., 1991). Majority of the nitrogen losses studies were based on (N^{15}) balance in the soil-plant system. Very few experiment used direct measurements of N dynamic during crops growing season (Oliveira et al., 2002; Sangoi et al., 2003).

The objective of this work was to quantify water percolation and evaluate nitrogen leaching along the cycle of a sprinkler-irrigated maize crop.

METHODS

Field experiments were carried out at Embrapa Maize and Sorghum experimental station, at Sete Lagoas, MG, Brazil. The soil is a Dark Red Latosol, very clayey but with high water intake rate and porosity. A set of integrated drainage lysimeters (Andrade and Alvarenga, 2000) was used to, simultaneously, monitor surface runoff and leaching. Maize hybrid BRS 3060 was sowed in March 20th and harvested in August 22nd. Except irrigation, all necessary practices were done to provide conditions for crop normal development. Mineral fertilization consisted of 400 kg ha^{-1} of 5-20-20 + 0.5 (N, P_2O_5, K_2O + Zn), applied at planting time and 112 kg ha^{-1} of nitrogen as urea, side dressed, 23 days after sowing. Three irrigation depths were applied using a sprinkler system: one above (L7, 716 mm) and one below (L4, 452 mm) the required maize irrigation depth (L6, 561 mm). L4, L6 and L7 stands for lysimeter number 4, 6 and 7, respectively.

Water percolation was measured daily and, in order to access nitrogen leaching, a 25 ml water sample was collected from the drainage plastic drums. Samples were treated with a drop of chloroform and stored in an amber glass flask, kept under refrigeration. Every week, a composed water sample was analyzed for nitrate and ammonium using Kjeldhal method (Buresh et al., 1982). Water nitrate and ammonium concentrations, along with water volumes, were used to quantify nitrogen losses through leaching.

RESULTS AND DISCUSSION

Maize crop grown under normal irrigation conditions (L6) received 561 mm of water, while the treatment underirrigated (L4) received 452 mm, 19.4 % less water. At the overirrigated treatment (L7), crop received 716 mm, 27.6 % more water. Water percolation did not follow the same proportion. While in L4 percolation was 35.5 % less than in L6, in L7 percolation was 143 % higher. As compared to the applied irrigation depth, percolation represented 13.3 % in L4, 16.6 % in L6 and 31.6 % in L7. Even with an active crop extracting soil-water, excess irrigation causes high water percolation (Figures 1A and 1B). This kind of information is essential in order to improve irrigation management and reduce groundwater contamination risk. Irrigation management has to be planned in such a way to keep soil-water storage less then field capacity, especially if there is forecasted rainfall in the upcoming period (Hess, 1999).

Leachate ammonium ($N\text{-}NH_4$) concentrations were low along crop cycle for the three irrigation depths (Figure 2A). However, excess rainfall and irrigation (L7) made ammonium move down, even at the end of crop season.

Leachate nitrate ($N\text{-}NO_3$) concentrations increased up to 36 days after sowing due to low crop nitrogen absorption (Figure 2B). A nitrate leaching peak occurred 14 days after nitrogen side dressing, decreasing afterwards even with high water percolation rates, as observed on the excess irrigation treatment (L7). Peak nitrate leaching (Figure 2B) followed water percolation peaks (Figure 1B). Nitrate concentrations above the Brazilian drinkable water limit of 10 mg L^{-1} (Brasil, 2004) were observed in some moments along maize cycle (Figure 2B).

A mineral nitrogen (nitrate + ammonium) loss peak occurred about 14 days after sowing, for the three treatments (Figure 3A), anticipating the nitrate concentration peak (Figure 2B). Other nitrogen loss peaks occurred along maize cycle grown with excess irrigation. Under normal irrigation (L6), losses practically ceased by 48 days after sowing, while with excess irrigation (L7), losses extended up to 111 days after sowing (Figure 3B).

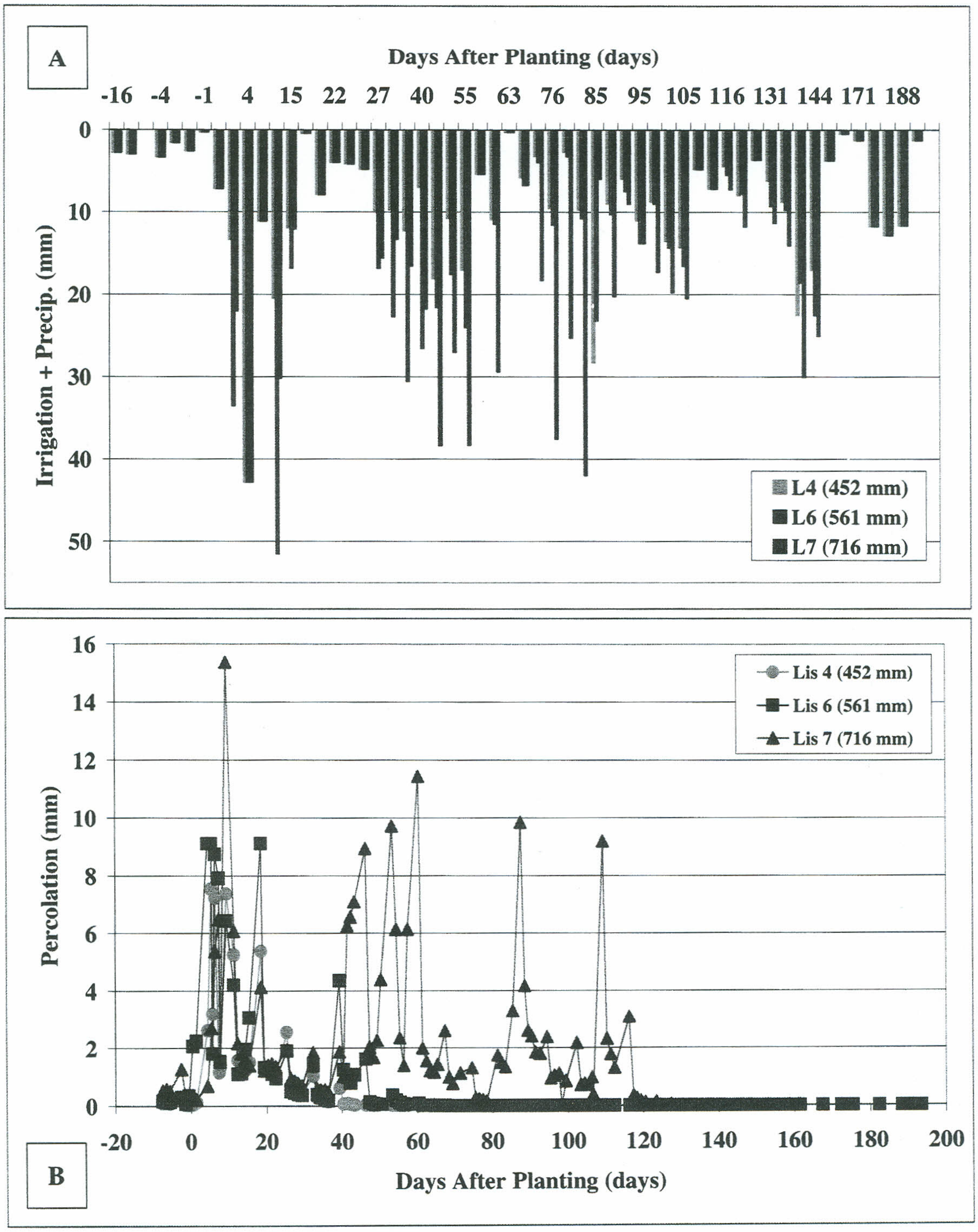

Figure 1. Precipitation plus applied irrigation (A) and water percolation (B) depths along maize crop cycle.

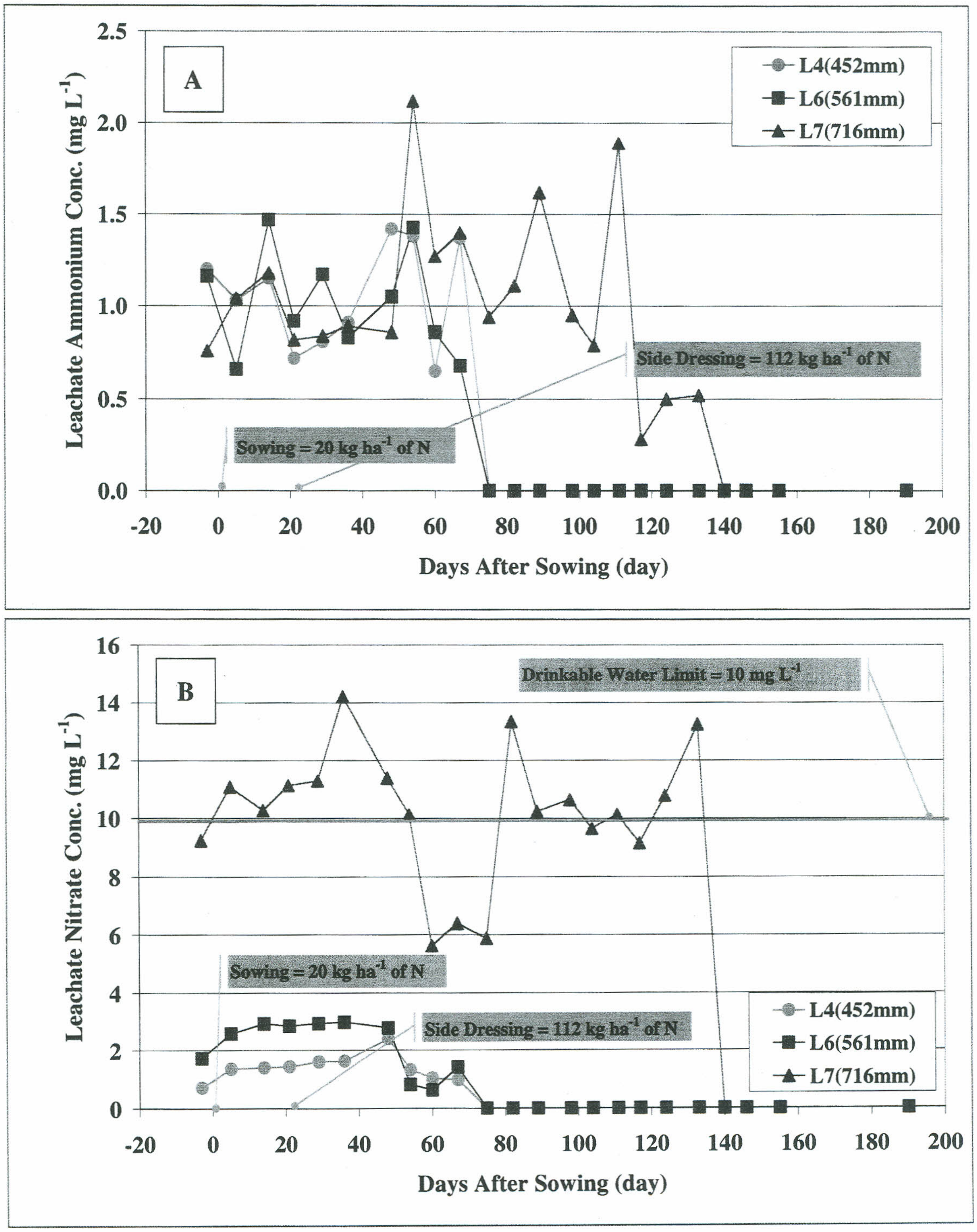

Figure 2. Leachate ammonium (A) and nitrate (B) concentrations along maize crop cycle.

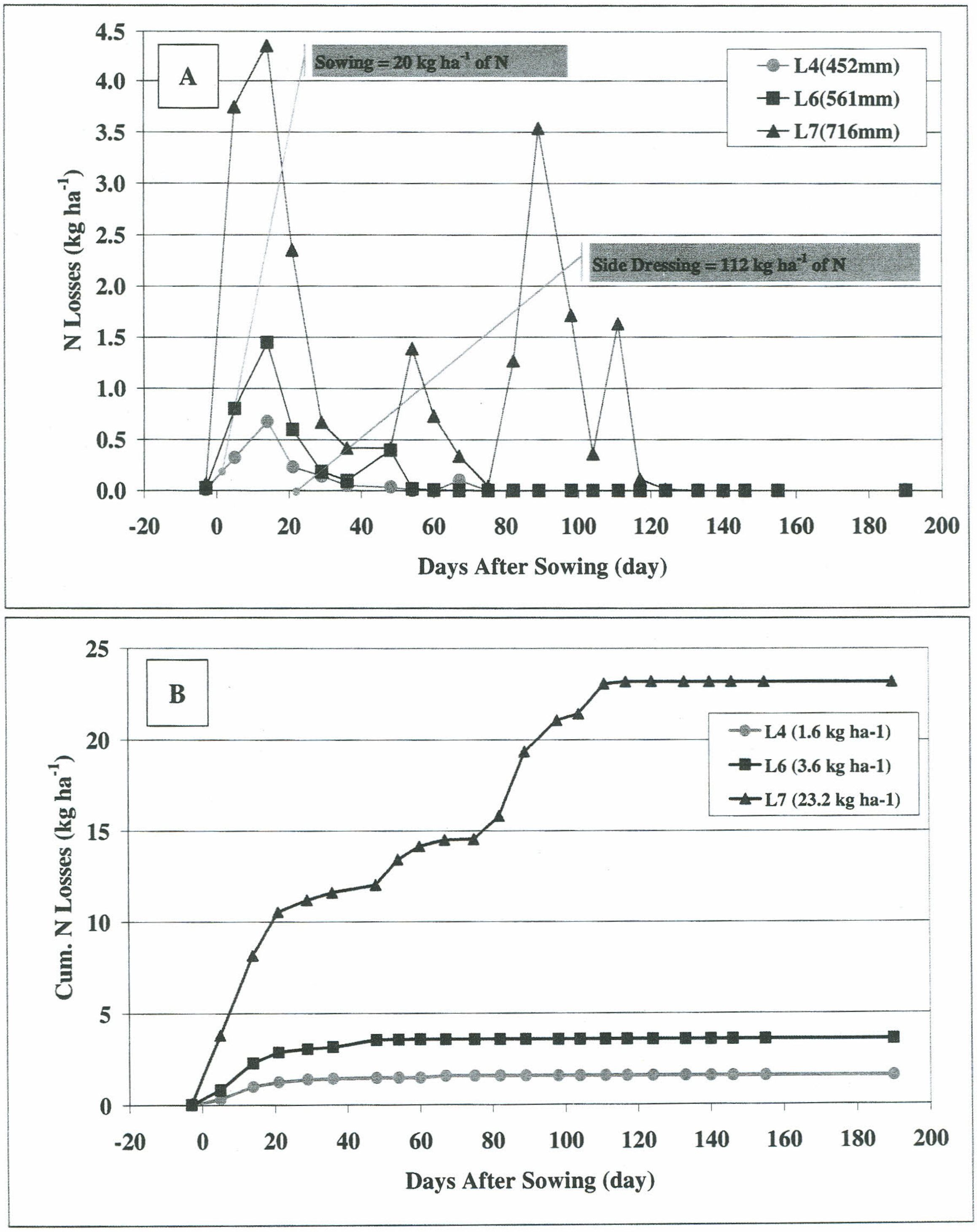

Figure 3. Weekly measured (A) and cumulative (B) mineral nitrogen losses along maize cycle.

With excess irrigation, nitrogen losses along maize cycle summed 23.2 kg ha^{-1}, or 17.6 % of the 132 kg ha^{-1}N provided at planting and by side dressing fertilization (Figure 3B). This loss amount is close to what was reported for maize by França et al. (1994) and Coelho et al. (2003). Other studies indicated losses varying from 2 to 20 kg ha^{-1}, depending on crop and soil types (Bassoi, 1996; Oliveira et al., 2002). In the treatments that received normal or deficit irrigation, leaching nitrogen losses accounted for less than 3% of the amount applied.

CONCLUSIONS

Excess irrigation caused higher water percolation. The larger the excess, the higher is the percolation volume. Leachate nitrate concentration exceeded the drinkable water limit of 10 mg L^{-1} in some times along the maize crop cycle. Nitrate leaching was observed along all irrigated maize crop season, with higher concentrations at the beginning of the cycle. Mineral nitrogen losses were 17.6 % of total amount applied for the excess irrigation treatment and only 3 % for the other two. Results indicate the importance of irrigation management for reducing risks of groundwater contamination by nitrate.

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