NITRATE ACCUMULATION IN THE SOIL AFFECTED BY NITROGEN FERTILIZATION

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ABSTRACT

Numerous studies have shown that nitrate movement in the soil follows water movement, and increased downwards water movement from the top soil increases nitrate leaching losses and groundwater pollution, too. With very high fertilizer nitrogen application rates, the proportion of the applied nitrogen taken up by the plant decreases, and the residual fertilizer nitrogen in the soil will be vulnerable to leaching.

Field experiment was started at Szárítópuszta, an experimental station of Gödöllő University Agricultural Sciences in 1970, where the nitrate movement in a brown forest soil was examined as affected by nitrogen fertilization. The study showed that increasing rates of nitrogen fertilizer caused nitrate downward movement.

The object of present study is to analyse the accumulation of nitrate-N in deeper soil horizons. Results showed that the nitrate-N content of the 0-3 meters soil profile decreased by the year of 2003, however at 0 and 90 kgN/ha former fertilizer rates the nitrate-N content of the soil increased. The accumulation ceased, the nitrate content showed equable distribution in the 0-3 meters plots.

INTRODUCTION

The most important climatic factor in respect of the nitrate leaching from soil is the rainfall. It was supported by a study where the rainfall was greater than the normal during a growing season, and this weather created a worst case scenario with respect to NO_3 leaching. As a result of this weather, appreciable increases in NO_3-N in soil-solution occurred as deep as 250 cm in the following N application. A six-fold increase in NO_3-N concentrations was found in groundwater samples collected adjacent to the research plots 2 months after nitrogen fertilization (Lowery et al., 1995).

Nitrogen fertilizer applied in excess of crop needs can cause accumulation of NO_3–N in the soil profile. (Malhi et al., 1991, 2002) Within the confines of the

National Fertilizer Experiment were maesured the influence on nitrate leaching of different rates of N fertilizer. Results showed that the growing fertilizer rates (0-50-150-250 kg/ha) cause exponential growing of the leached nirtrate. In the 3 m layer of soil through the 20 years it means at 130-142-338-674 kg N/ha. (Prém and Füleky, 2004) Another field results showed that the amount of NO_3-N was positively correlated with soil depth up to 220 cm when fertilizer was applied in a single dose. (R. R. Sethi et al., 2005)

Beaudoin et al. (2005) measured the nitrate concentration in two soils. They realised that the nitrate concentration was primarily affected by soil type: it carried from 31 mg/L in deep loamy soils to 92 mg/L in shallow sandy soils, and was linked to the soil water holding capacity. In another study five different slow-release fertilizers were incubated in two soils (sandy loam, clay loam) by Gioacchini et al. (2006), and their nitrogen dynamics was followed for 4 months. They found that the highest accumulation of mineral N as NO_3 was observed in the sandy loam soil for all the treatments.

A field experiment was started at Szárítópuszta, an experimental station of Gödöllő University Agricultural Sciences on a brown forest soil in 1970. 0, 90, 180, 270 and 360 kg N/ha /year doses, respectively have been broadcasted as basal fertilization in the form of ammonium for 16 years. In 1986 the soils of treatments were sampled in 6 replications from 0 to 3 meters depth at every 20 centimetres. The nitrate content of the samples were determined. They found if the dose of nitrogen fertilization was increased, the nitrate content in the soil profile increased too. The 20-40% of the nitrogen fertilizer can be found in the 3-meter layer of the soil profile. The amount of this accumulated nitrate is equal to few hundred kilograms of nitrogen. The maximum of nitrate accumulation front can be found at 160–260 cm. Increasing the dose of nitrogen fertilization the place of maximum accumulation moves downward. In the case of high nitrogen dose nitrate accumulation could be found below 3 meters depth, too. The yearly water surplus was 116 mm what is enough for leaching the amount of nitrate exceeding plant demand into 1-3 meter depth of soil, or into more deeper horizons, but plants can make use of nitrate-N in the 100 cm soil layer, the remaining part of the fertilizer lost for plant uptake and its fate is the leaching. But *Medicago sativa* and *Robina pseudo- acacia* can moderate leaching due to its long roots. The autumn of 1989 Medicago sativa were planted to the experimental area, and the effect was measured in 1989 and 1994. In the year 1995 *Robina pseudo- acacia* were planted there, and its effect was measured in 2003 (Kovács and Füleky, 1991).

The aim of present study is to monitor nitrate movement in a brown forest soil between the years 1994 and 2003.

MATERIALS AND METHODS

The leaching process of nitrate was studied in a long-term field experiment at Gödöllő brown forest soil started in 1970. The texture of the soil is sand in the plough layer and sandy loam, loam in the deeper horizons. The thickness of humic horizon is 35 cm, lime appears at 60 cm. Humus content in the plough layer is 1,3% and below it is less than 1%. Parent material is loess, the groundwater level is below 4 meter.

Nitrogen fertilizer has been applied in increasing rates: 0, 90, 180, 270, 360 kg N/ha, respectively since the autumn of 1970. Phosphorus and potassium fertilizers were applied together in the rates of 0, 60, 120 180, 240 kg P_2O_5/ha /year and 0, 50, 100, 150, 200 kg K_2O /ha/year, respectively. Nitrogen, phosphorus and potassium were applied as basal fertilization in the autumn period. The experiment was not irrigated except of 3 years when 100 mm of water were applied yearly. Maize /Pioneer/ has been grown in monoculture for 16 years. In 1994 and 2003 the plots were sampled in 6 replications from 0 to 3 meters depth at every 20 centimetres. Nitrate content of the samples were determined.

The NH_4^+– N and NO_3^- – N content of the soil sample was measured with Parnas-Wagner distillation.

RESULTS AND DISCUSSION

Statistical analysis was used to assess the measured data. In this statistical evaluation the triple factor variance analysis was used, where factors means the year (1994, 2003), the soil depth (0-3 m) and the former fertilizer dose (0, 90, 180, 270, 360 kg N/ha).

According to the statistical analysis the calculated value of the $SD_{5\%}$ is 2.35, between former fertilizer treatments.

The results of the statistical analysis shown on *Figures 1 and 2.*

The vertical distribution of soil nitrate content showed, at the lower (0 kg N/ha, 90 kg N/ha) fertilizer rates plots the amount of nitrate is – only a few mg/kg – in the 3 meter soil layer. In alignment Malhi et al. (1991,1992), increasing the rate of nitrogen fertilizer (180, 270, 360 kg N/ha) the amount of nitrate- N in the soil profile increases too. At 30-120 centimetres nitrate distribution usually had a minimum for all the former fertilization treatments. The maximum of nitrate accumulation front was found at 160- 260 cm in 1986 (Kovács and Füleky, 1991), and in 1994 in case of the 90 kg N/ha or higher rates of former nitrogen fertilization the maximum of nitrate accumulation front (20-65 mg/kg) was at 140-240 centimetres.

Nitrogen uptake of plants usually effect the nitrate shift by 100 cm depth, but nitrate being in deeper horizons practically is lost for plant uptake and moves downwards with water movement. Accordingly further significant nitrate enrichment can be expected below 3 meters at 180 kg N/ha or higher rates of nitrogen fertilization.

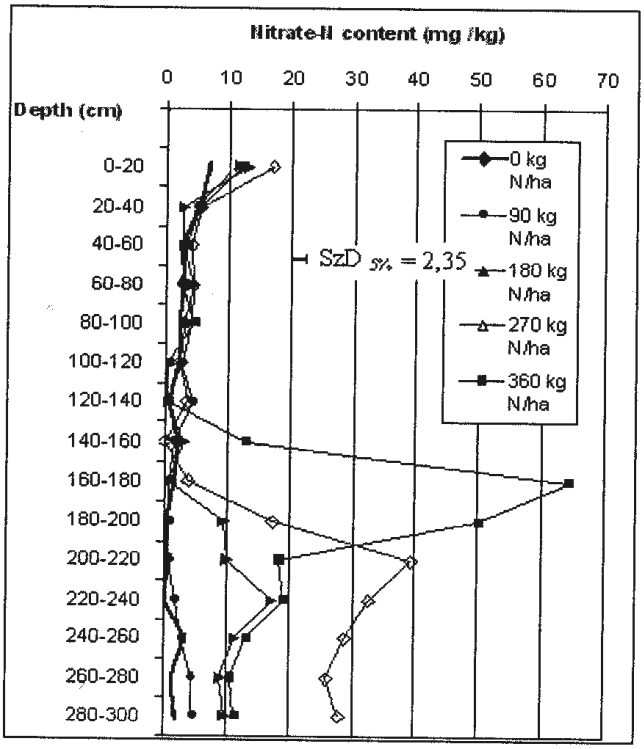

Figure 1. Vertical distribution of nitrate-N in the year 1994

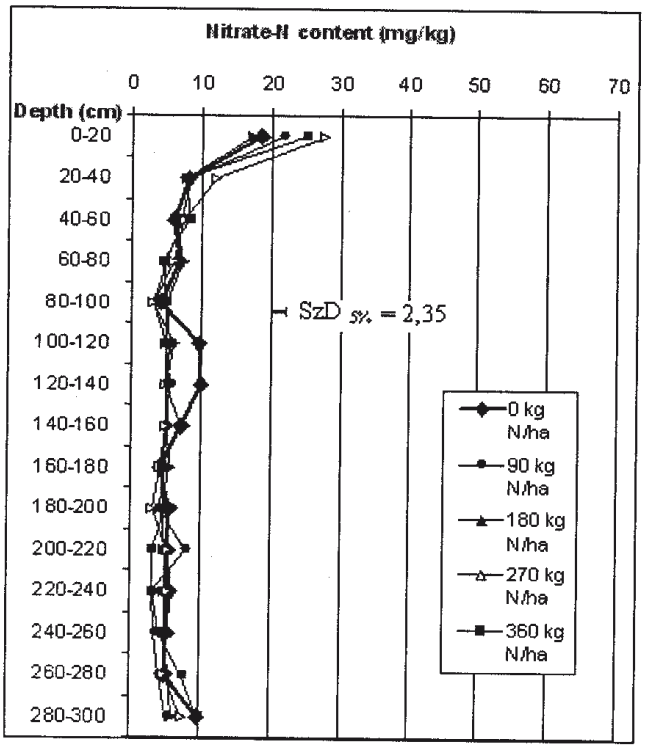

Figure 2. Vertical distribution of nitrate-N in 2003

Differences between the nitrate content of treatments were observable from the statistical analysis.

As it can seen from the *Figure 2.,* in the year 2003 the maximum of nitrate accumulation (18-28 mg/kg) was in the upper soil layer affected by the *Robina pseudo- acacia.* By 2003 the accumulation ceased, the nitrate content showed equable distribution in the 0-3 meters plots for all the treatments. According to the SD5% (2.35), the effects of the former treatments were not measurable.

Average nitrate-N content of the soil is given in *Table 1.* As it can be seen from the results, in the year 2003 the upper soil layer contained 20 mg/kg more nitrate-N than in 1994, affected by the *Robina pseudo- acacia.* While in 1994 103,5 mg/kg nitrate-N was lost for plants – because it was in the 1-3 m soil layer-, until then in 2003 the most part of the accumulated nitrate-N was in the upper soil layer. Results showed, that in 1994 the nitrate-N content of the 0-3 meters soil layer was 129,0 mg/kg and in 2003 it was just 98,0 mg/kg, that means the nitrate-N decreased during the 9 years because the elapsed time and the differences between the 2 years weather. In 1994 the average rainfall was around 520 mm/year, and in 2003 it was just around 480 mm/year.

Table 1. Nitrate-N content of the soil, mg/kg

Depth	0-1 m	1-3 m	0-3 m
1994	25.5	103.5	129.0
2003	45.0	53.0	98.0

Average nitrate-N content (in 0-3 meters soil layer) as effected by nitrogen fertilization can be seen in *Table 2.* In 1994 increasing the dose of former nitrogen fertilization (0, 90, 180, 270, 360 kg N/ha) nitrate content in the soil profile increased (34-284 mg/kg) too. Contrarily, all treatments showed about the 90-105 mg/kg values in 2003. However at 0 and 90 kgN/ha fertilizer rates nitrate-N content increased by the year of 2003 on the field, because the Robina pseudo- acacia .

Table 2. Nitrate-N content (in 0-3 meters soil layer) as effected by former nitrogen fertilization, mg/kg

N fertilizer	0 kg N/ha	90 kg N/ha	180 kg N/ha	270 kg N/ha	360 kg N/ha
1994	34.5	48.0	100.5	181.5	283.5
2003	91.5	94.5	94.5	106.5	103.5

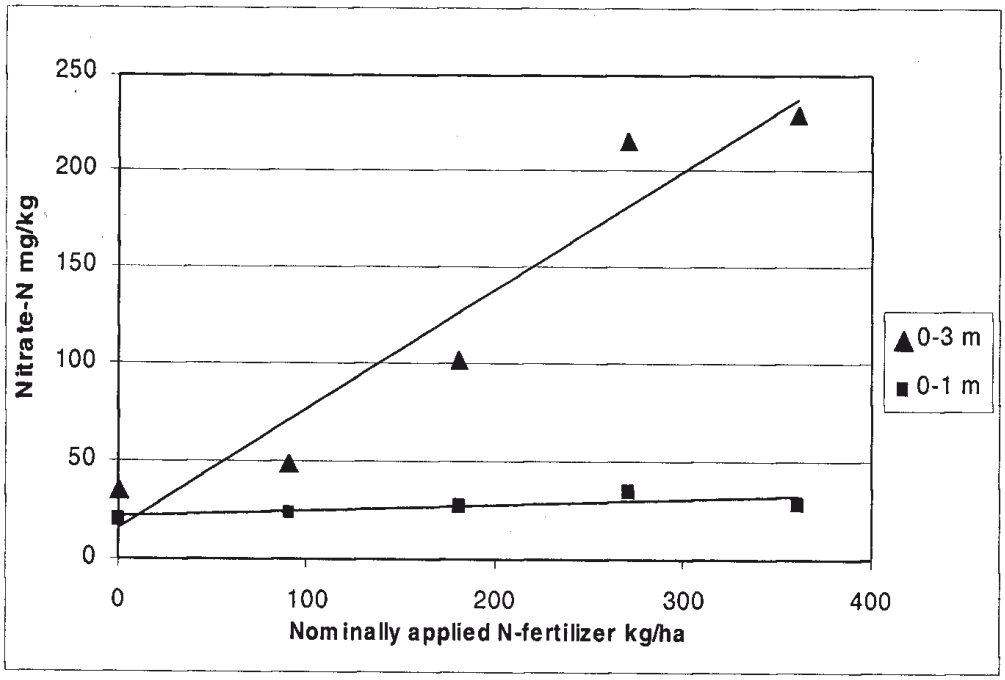

Figure 3. Nominally applied N-fertilizer in connection to nitrate- N content of the soil in the year 1994

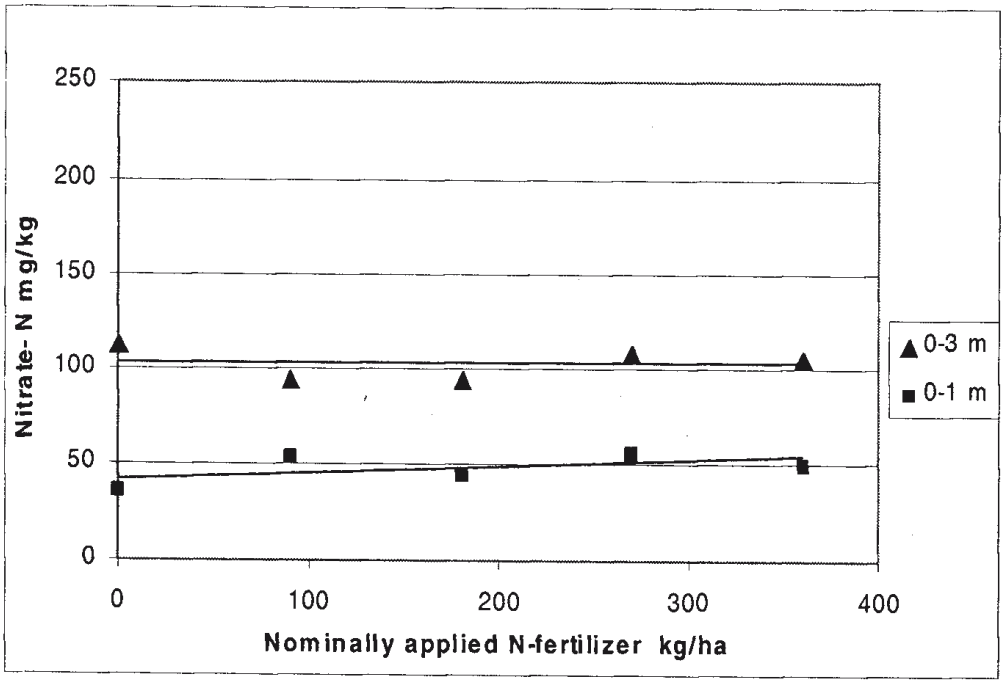

Figure 4. Nominally applied N-fertilizer in connection to nitrate- N content of the soil in the year 2003

Nominally applied N-fertilizer in connection nitrate-N content of the soil can be seen in *Figures 3 and 4* in the years 1994 and 2003. The nitrate-N content of the 0-1 m soil layer was around 20-30 mg/kg for all the former fertilizer treatments, which is in available depths for roots. In case of the 0 and 90 kg/ha N former fertilizer treatments most of the nitrate-N is in the upper soil layer, but for the higher fertilizer rates (180, 270, 360 kg N/ha) only a few mg/kg nitrate-N was in the upper soil layer (0-1 meters), much of the nitrate-N (100-230 mg/kg) is lost for plant uptake, it could moved into groundwater.

As it can be seen from the Figure 4., the nitrate-N was in the upper soil layer and the nitrate-N content of the 0-3 meters soil layer was around 100 mg/kg for all the former fertilizer treatments. It means, that the effects of the former fertilizer treatments are not measurable, in contrast to 1994.

CONCLUSIONS

The most important results of this study, which analysed the nitrate distribution in the 0-3 meters soil layer in the years 1994 and 2003, are the followings.

In the case of the 90 kg N/ha or higher rates of nitrogen fertilization the maximum of nitrate accumulation front (20-65 mg/kg) was at 140-240 centimetres in 1994, the remarkable nitrate-N content was under 2 meters so much of the nitrate-N is lost for plant uptake, it could moved into groundwater.

Results showed that by the year of 2003 the nitrate-N content of the 0-3 meters soil profile decreased, however at 0 and 90 kg N/ha former fertilizer rates nitrate-N content was grown. The maximum of nitrate-N content was in the upper soil layer. The accumulation ceased in the 0-3 meters soil layer, the nitrate content showed equable distribution for all the treatments.

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