THE EFFECT OF FERTILIZATION AND IRRIGATION ON THE CHANGE OF NO_3-N DETERMINED IN 0.01 M $CACL_2$ OF THE SOIL PROFILE

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Abstract

*We investigated the effect of treatments on N fractions determined in 0.01 M $CaCl_2$, in a crop rotation, irrigation (not irrigated, irrigated: 2*50 mm) and fertilization (N: 0, 120, 240 kg ha^{-1}, P_2O_5: 0, 90, 180 kg ha^{-1}, K_2O: 0, 90, 180 kg ha^{-1}) experiment, in the 20. year of the long-term experiment, on maize monoculture. The experiment was set up on lowland pseudomyceliar Chernozem soil. We measured the $CaCl_2$-NO_3-N content of the 200 cm deep soil profile, by the method of HOUBA et al. (1990).*

Our statements are concluded as follows:

– The effect of treatments is traceable by the NO_3-N fraction determined in $CaCl_2$. N fertilization increased significantly the amount of NO_3-N.

– According to the average yields and soil examinations the 240 kg ha^{-1} N dose hasn't been utilized. NO_3-N content of the soil profile is indicative of the N-accumulation.

– The distribution of NO_3-N in the soil profile indicates well the different leaching of irrigated and not irrigated plots. On not irrigated plots the accumulation depth of nitrate-N occurred in 200 cm deep soil layer. The NO_3-N content of irrigated plots is less than the half of the NO_3-N content of not irrigated plots, and presumably the maximum nitrate-N accumulation is in deeper layers.

– Our results are in accordance with earlier experiences in Hungary.

Key words: 0.01 M $CaCl_2$, nitrate leaching, nitrate profile

INTRODUCTION

Nitrogen fertilization has favorable and unfavorable effects. It increases the yield and improves the quality of crops and fodder, therefore the dominance of nitrogen fertilization is also characteristic in Hungary. The overdose and one-sidedness of nitrogen fertilization has numerous dangers. Among nitrogen fertilizers ammonium salts and urea acidify the soil. Among the harmful environmental influences of nitrogen overdose the increase of soil solution nitrate concentration involves great danger, as it can be easily leached. Leaching causes the pollution of drinking water reserve, and sickness of human bodies through the food chain.

The previous section point to the fact the accurate determination of nitrogen doses is essential for the adequate quantity and quality of yield and the environmental tolerance agricultural cultivation.

According to BALLENGER and MADOS (1944) under natural circumstances the soil nitrogen content depends on the quantity of easily mineralizable organic bonded nitrogen and on the degree of the organic bonded nitrogen reserve transformation.

The Hungarian Plant Nutrition Recommendation System determines the nitrogen supply according to the before mentioned principles based on humus content considering production site categories and texture (BUZAS and FEKETE, 1979).

SARKADI (1975) estimates the soil nitrogen supply ability based on total nitrogen content as

Nitrogen supply ability = N*f*300(kg/ha)
(where f depends on soil texture and soil type, these factors determine the nitrification relations)

Potential nitrogen supply ability can be characterized by microbiological/incubation methods. A number of incubation methods are known. In Hungary the method of Várallyay (VÁRALLYAY, 1950) is spread. As incubation methods demand a lot of time they are not suitable for serial tests, and therefore they are not used in practice. In stead of them direct determination of inorganic nitrogen forms (NO_3-N, NH_4-N) is spread applying KCl or other salt solutions as extractants.

In abroad N_{min} method of WEHRMANN and SCHARPF (1979) is used to measure the NO^{3-} and NH^{4+} content of soil are determined within 1 m depth, in autumn and in spring. The recommendation method was adapted for Hungarian circumstances by PÁLMAI et al. (1998). It is important that the date of sampling is to be near to fertilization, as the quantity of mineral nitrogen forms is less constant than humus featuring the reserves.

Nitrate leaching was studied in many long term experiments. The NO_3-N distribution in a 6 m deep calcareous chernozem soil profile was investigated in the 12., 17., 22. and 28. years of an NPK fertilization long –term experiment in Nagyhörcsög set by MTA-TAKI (KÁDÁR et al., 1987; NÉMETH et al., 1988; KÁDÁR és NÉMETH, 1993; NÉMETH és KÁDÁR, 1999; KÁDÁR és NÉMETH, 2004). They pointed out that in the first three investigations date 40-60% of nitrogen excess can be detected as NO_3-N in 0-6 m layer, which was introduced by fertilizer and was not uptaken by plant. In case of 300 kg ha^{-1} treatment the maximum of nitrate accumulation was in 2 m depth in the 12. year of the experiment, then in the 17. year the first maximum was above 1 m, and the second was about 3 m. In the last investigation date significant part of the NO_3-N reserves leached under 6 meter. This movement is equivalent of 20-40 cm/year velocity due to their calculations.

IZSÁKI and IVÁNYI (2002) studied NO_3-N distribution in the 4., 8. and 11. year of a long term experiment set on chernozem-meadow soil in Szarvas. In case of the largest treatment (240 kg ha-1) the leaching was significant even in the 4. year. In the 8. year the maximum of nitrate leaching was found in 140-180 cm depth, independent from the N supply level. To the 11. year of the experiment nitrate leached into deeper layers.

To characterize the various nitrogen forms 0.01 M $CaCl_2$ extractant is also suitable.

The advantages of this method are the followings (LOCH, 2006):

- dilute salt solution has moderate solving and ion exchanging effect,
- Ca content of the extractant is near to the soil solution concentration,
- the extracted solution can be easily filtered,
- several nutrient element is well measurable (N, P, K and certain microelements),
- beyond inorganic ions that directly available for plants, easily soluble and oxidizable organic N, P, S forms are also measurable in the extractant.

In a number of long term experiment were found a close correlation between nitrogen fractions in 0.01M calcium chloride and the yield, and the N fractions indicated well the effect of fertilization. (JÁSZBERÉNYI et al., 1994; LAZÁNYI et al., 2002; NAGY és JÁSZBERÉNYI, 2002; NAGY et al., 2002; LOCH et al., 2005)

MATERIAL AND METHODS

A long-term fertilization experiment was established on Látókép Experimental Station of the Centre of Agricultural Sciences, University of Debrecen, in 1984, by Ruzsányi László. The aim was to study the effect of crop rotation, irrigation (not irrigated, irrigated: 2*50 mm) and fertilization. The plots were set up, with 3 nitrogen (0, 120 and 240 kg

N/ha/year), 3 phosphorus (0, 90 and 180 kg P_2O_5/ha/year) and 3 potassium fertilizer rates (0, 90 and 180 kg K_2O/ha/year) in four repeats.

The experimental site is located in the north-eastern part of the Great Hungarian Plain. The soil of the experimental site was a lowland pseudomyceliar Chernozem. The climate is subhumid temperate continental, with a mean annual precipitation of 566 mm. The average level of groundwater table is around 6-8 m. The depth of humus layer is 70-80 cm, and the humus content is 2.5-3.0 %. The pH_{KCl} of the topsoil is 5.5-6.5. The total nitrogen content of soil is 0.12-0.18%.

Soil samples were collected, on the 20. year of the long-term experiment, representatively under corn monoculture plots in 29 of June, 22 of July, 7 of September and 4 of October, 2004. Samples were taken from every 20 cm interval of the 200 cm deep soil profile. We determined the NO_3-N content of soil in 0.01 M $CaCl_2$ extractant (HOUBA et al., 1990).

All statistical analyses were performed with SPSS (version 13). Differences were examined by Welch's t-tests, assuming unequal variances between groups. If a significant difference between groups was detected, post hoc Tamhane's t tests ($P < 0.05$), assuming a non-normal distribution and unequal variances, were performed.

RESULTS AND DISCUSSION

Effect of the date of sampling on the NO_3-N content of soil profile of all N treatments

The average nitrate content of soils on each date of sampling, on irrigated and not irrigated soils are shown in *Table 1.* However the nitrate content fluctuated as a function of time there was not significant difference between average nitrate values. Presumably it means that the N-uptake of maize did not change the nitrate concentration of soil solution, due to the soil nutrient buffer capacity, as we calculated with the average nitrate values of the different dates of sampling on our further studies.

There was a decided difference between the mean NO_3-N content of irrigated and non irrigated conditions. Presumably the cause of lower nitrate content of irrigated plots is the nitrate leaching, the greater N uptake by plants, and the different circumstances of nitrification and denitrification.

Table 1.

The average NO_3-N content (mg kg^{-1}) of the 200 cm deep soil profile of all N treatments as a function of the date of sampling, and irrigation

Time	Not irrigated	Irrigated	All samples
June 29.	14.43	8.12	11.27
July 22.	14.78	5.05	9.91
September 7.	15.65	4.12	9.89
October 4.	13.95	6.42	10.18

Effect of N fertilization on the NO_3-N content of soil profiles

The mean nitrate values as a function of N fertilization, and irrigation can be seen in *Table 2.* Fertilization had significant effect (at $p < 0.05$) on NO_3-N determined in 0.01 M $CaCl_2$ solution. That means that 0.01 M $CaCl_2$ solution indicates well the impact of N fertilization.

The increased N doses caused major differences between mean nitrate values of irrigated and non irrigated soils. While on control N treatment there was no difference between the two mean nitrate values, on the 120 kg ha^{-1} N treatment the average NO_3-N content of non irrigated plots was about 4 times higher than that of irrigated plots, and on the 240 kg ha^{-1} N treatment this proportion was 2. The higher nitrate concentration and irrigation caused more intensive nitrate leaching.

Table 2.

NO_3-N content (mg kg^{-1}) of the 200 cm deep soil profile in each treatment

Irrigation	N treatment			All treatment
	0 kg ha^{-1}	120 kg ha^{-1}	240 kg ha^{-1}	
Not irrigated (n=480)	1.66	8.84	33.60	44.10
Irrigated (n=480)	1.44	2.16	14.18	17.78
All samples (n=960)	1.55	5.50	23.89	30.94

NO_3-N profile of irrigated and non irrigated soils

The nitrate-N profile curves of irrigated and non irrigated soils on the 20. year of the long-term experiment are shown in *Figure 1*. The distribution of NO_3-N in the soil profile is dependent on N fertilizer doses. The NO_3-N profile curves of control plots are vertically equaled on irrigated and non irrigated soils as well.

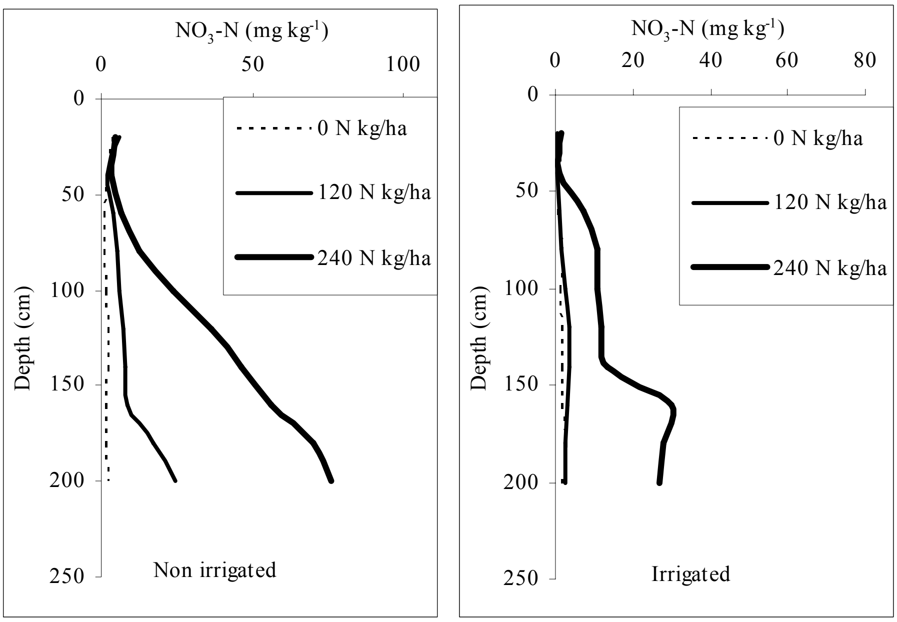

Fig 1. NO_3-N profile curves of irrigated and non irrigated plots on the 20. year of the long-term experiment

The profile curves of fertilized and non irrigated plots have a characteristic maximum. The accumulation depth of nitrate-N occurred in 200 cm deep soil layer.

The average nitrate-N content of samples from every 20 cm interval of soil profile on 120 and 240 kg ha^{-1} N treatments and its proportion are represented in *Table 3*.

Table 3.

Quantities ($mg \cdot kg^{-1}$) of average NO_3-N content of samples from every 20 cm interval of the soil profile of fertilized and non irrigated plots

Depth (cm)	N treatment		Difference between NO_3^- content of 240 and 120 kg ha^{-1} N treatments
	120 kg ha^{-1}	240 kg ha^{-1}	
	NO_3-N (mg kg^{-1})		
20	6.16	4.65	-1.51
40	2.30	3.14	0.84
60	3.67	6.64	2.97
80	5.22	12.70	7.48
100	6.10	23.81	17.71
120	6.97	36.22	29.25
140	7.73	46.37	38.64
160	8.77	56.56	47.79
180	17.11	69.92	52.81
200	24.33	76.05	51.72

The difference of the nitrate content of two treatments is dependent on the depth. In the 0-40 cm soil layer the nitrate content is similar, than the difference increased as a function of depth. It means that there was notable nitrate accumulation in the 240 kg ha^{-1} N treatment. There was significant difference between the NO_3-N content of topsoil and that of deeper layers on plots that were treated with 240 kg ha^{-1} N.

The nitrate-N profile curve of irrigated plots is vertically equalled relatively (Figure 1). However on the 240 kg ha^{-1} N treatment it has a slight maximum at the depth of 150-200 cm, the nitrate accumulation layer cannot be observed. Presumably the nitrate leached to the deeper layers.

The average nitrate-N content of samples from every 20 cm interval of the soil profile on N fertilized plots are shown in *Table 4.* The differences increased as well by the depth. On 200 cm depth, the mean NO_3-Ncontent of 240 kg ha^{-1} N treatment is nearly 10 times higher than that of 120 kg ha^{-1} N treatment. The high differences in the nitrate profiles resulted as an effect of several years of fertilization and irrigation.

There was significant difference between the $CaCl_2$-NO_3^- content of topsoil and that of deeper layers on each treatment.

Table 4.

Quantities ($mg \cdot kg^{-1}$) and proportion of average nitrate-N content of samples from every 20 cm interval of the soil profile of irrigated plots

Depth	N treatment		Difference between NO_3^- content of 240 and 120 kg ha^{-1} N treatments
	120 kg ha^{-1}	240 kg ha^{-1}	
	NO_3^-N (mg kg^{-1})		
20	0.63	1.68	1.05
40	0.31	1.01	0.70
60	0.80	7.07	6.27
80	1.58	10.98	9.40
100	2.41	10.89	8.48
120	3.68	11.81	8.13
140	3.68	13.55	9.87
160	3.22	30.13	26.91
180	2.53	27.67	25.14
200	2.74	26.99	24.25

Our previous statements proved that there was a nitrogen overdose in 240 kg ha^{-1} N treatment, and this effected high nitrate leaching.

Relation between NO_3-N content of soil and yield of maize on irrigated and not irrigated plots

The NO_3-N content of 200 cm deep soil profile on irrigated and not irrigated plots, the yield of maize and the surplus yield are shown on *Figure 2.*

We calculated the total NO_3-N content (kg ha^{-1}) of 200 cm deep soil layer on irrigated and non irrigated soils. As it is represented, the NO_3-N content of the highest N treatment is 4-6 times higher than that of 120 kg ha^{-1} N treatment. It is in accordance with the average yields, because the highest N dose didn't effected notable surplus yield. The surplus N accumulated in the soil, and leached to the deeper layers.

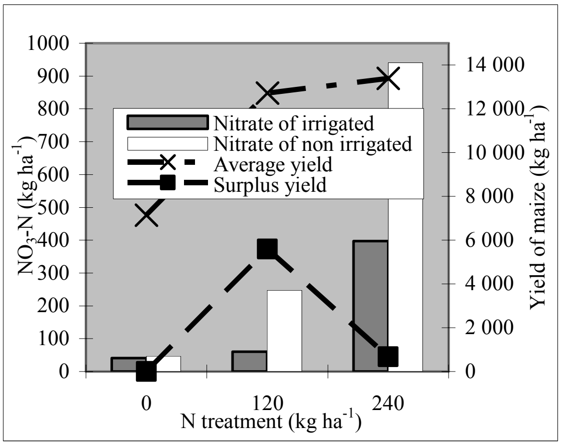

Fig. 2. The NO_3-N content of 200 cm deep soil profile on irrigated and not irrigated plots, the yield of maize and the surplus yield

CONCLUSION

Our results proved that the NO_3-N fraction of 0.01 M $CaCl_2$ solution indicates well the impact of long term N fertilization and irrigation, and we could explain the yield of maize change by the amount of NO_3-N fraction.

The 240 kg ha^{-1} N dose caused nitrate accumulation in the soil according to our examinations. The average yields confirmed that as well, because the highest N dose didn't effected notable surplus yield, so this remained in the soil.

The nitrate leaching is traceable by the NO_3-N fraction of 0.01 M $CaCl_2$. We can establish that, the 240 kg ha^{-1} N dose effected large nitrate leaching, especially in irrigated conditions. Our statements are in accordance with the experiences of other long term experimental researches.

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