10.7251/AGSY1203368B
UDK 631.416.5:631.84

THE EFFECT OF NITROGEN FERTILIZATION ON NITRATE LEACHING UNDER POTATO PRODUCTION

Aleksandra BENSA*, Vedran RUBINIC, Zdravka SEVER-STRUKIL

Faculty of Agriculture, University Zagreb, Croatia
(Corresponding author: abensa@agr.hr)

Abstract

The aim of this study was to determine the effect of different fertilization by nitrogen on nitrate leaching from the soil during potato production. The study was conducted in Belica, north-west region of Croatia, in the period 2009-2010 on Fluvisol. Fied trial was designed as a completely randomized block design with four levels of nitrogen fertilization (50, 100, 150, 200 kg N/ha), with three replications. Water samples were taken monthly by lysimeters during the growing period of potato and soil samples three times a year. Nitrates in soil and water were determined spectrophotometrically, using a complex yellow phenolsulphonic acid (USDA- SCC-NSCS, 1992). Increase in applied fertilizer rates (50–200 kg N/ha) led to an expected increase in the nitrate concentration in the arable soil layer (0.04–9.51 mg NO_3^-/100 g soil) with significantly highest concentrations on variant fertilized with 200 kg N/ha. Nitrate concentrations in percolating water varied in wide range, 4.1–283.5 mg NO_3^-/l, in dependance of nitrogen fertilization, precipitation, soil moisture regime and stage of growth of potato. Increased nitrogen fertilization of potato was accompanied by an increase in nitrogen leaching (1.1 to 13.9+kg NO_3-N/ha) as well as increase in yields of fresh mass of potato tubers from 8.2 to 37.7 t/ha.

Key words: *nitrogen fertilization, nitrate leaching, potato*

Introduction

Intensive production of potato implies fertilization as an unavoidable measure for high and stable yields, which in turn may lead to contamination of the agroecosystem and its contact ecosystems, primarily water. While N provides large responses in crop yield and is an extremely valuable nutrient, it is the major nutrient of concern in water pollution, Davies (2000). Nitrate leaching is mainly affected by fertilization (quantitiy and type of fertilizer, time of application), precipitation, soil properties and crops consumption of nitrogen. The following research objectives have been defined: a) to determine impact of different nitrogen fertilization of potato on dynamics of nitrate concentrations in arable soil layer and percolating water during growing period of potato, b) to calculate quantitiy of leached nitrate nitrogen from rhizosphere soil layer and c) to determine yields of potato under increasing nitrogen rates.

Material and methods

Investigation was performed in 2009 and 2010 growing seasons of potato, in Belica, north-west region of Croatia. Stationary field trial was laid up on Fluvisols, according to completely randomized block design, which involved four levels of nitrogen fertilization (50, 100, 150 i 200 kg N/ha), with three replications. In both year of investigation, basic fertilization was conducted by same quantitiy of fertilizers on whole area, 300 kg/ha NPK 7:20:30 + 61 kg/ha UREA in 2009 and 333 kg/ha NPK 15:15:15 in 2010. Differences

between fertilization treatment were achieved by top-dressing (0, 185, 370 and 555 kg of KAN/ha). Soil sampling was conducted before planting potatoes, 60 days after planting and in harvest. Tensiometric lysimeters for collecting percolating water were installed at 60 cm below the soil surface. Water samples were extracted monthly during growing seasons of potato, April-September. Soil content of nitrate nitrogen was determined spectrophotometrically, with the aid of the yellow colour complex by phenoldisulphonic acid, *(USDA-SCS-NSCS, 1992*), and nitrate nitrogen in water by the standard APHA method (1992). Total fresh tuber yield was determined in harvest. Analytical data were statistically analyzed using analysis of variance. According to the data of agrometeorological station Čakovec, annual rainfall in 2009. amounted 663,3 mm, which is significantly below the long time average for period 1971-2000. (843,1 mm), and in 2010, 837,2 mm.

Results and discussion

Nitrates in soil

Average nitrate concentrations in arable layer of soil varied in range 1.59 - 9.25 mg NO_3^-/100 g of soil during growing season of potato in 2009, and 0.04 - 9.51 mg NO_3^-/100 g of soil in 2010. The first soil sampling showed no statistically significant differences in nitrate concentrations, in both year of investigation, suggesting uniformity of experimental plots at planting potatoes. Increasing nitrogen fertilization had a significant effect on the increase of nitrate concentrations in the arable layer of soil, in June 2009, from 2.98 mg NO_3^-/100 g of soil to 9.25 mg NO_3^-/100 g of soil. In September 2009 (potato harvest) significantly higher nitrate concentrations were found only in soil of variant fertilized with a total of 200 kg N/ha compared to other variants, indicating a greater potential for leaching in autumn.

Significantly lower nitrate concentrations were found in soil of variants ferilized with 50 and 100 kg N/ha compared to other variants, during June and September in 2010. In soil of variant fertilized with 200 kg N/ha significantly higher nitrate concentrations compared with variant ferilized with 150 kg N/ha were found only in June, while in September those differences were not statistically significant, Table1.

Table 1. Average nitrate concentrations in arable layer of soil due to the nitrogen fertilization

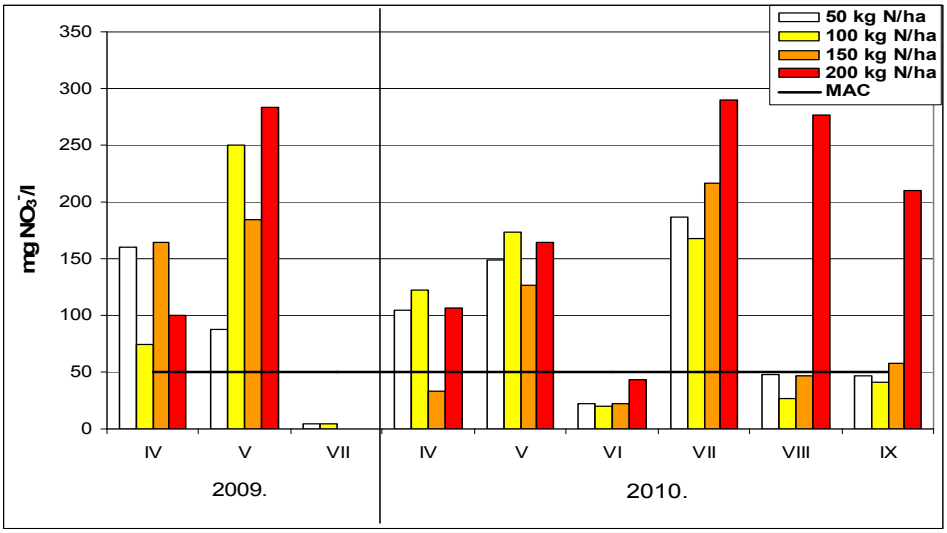
	mg NO_3^-/100g of soil					
Fertilization treatment, kg N/ha	2009.			2010.		
	14.04.	19.06.	18.09.	23.04.	04.06.	14.09.
50	2.17	2.98	0.49	0.05	6.41	0.04
100	1.59	4.38.	0.92	0.04	6.44	0.12
150	1.91	7.01	0.90	0.04	7.09	0.92
200	2.75	9.25	4.63	0.06	9.51	1.09
LSD p=5%	-	0.83	0.52	-	0,64	0,28
p=1%	-	1.26	0,98	-	1,07	0,69

Nitrates in water

Nitrate concentrations in percolating water during 2009 varied in a very wide range (4.1–283.5 mg NO_3^-/l), due to nitrogen fertilization, amount of percolating water, and consumption of nitrate by plants. In April 2009, nitrate concentrations in percolating water exceeded maximum allowed concentrations (MAC), as a result of nitrogen fertilization with

50 kg N/ha on all experimental plots and minimal consumption of nitrates by small potato plants. Increased top-dressing by nitrogen from 50 to 150 kg N/ha led to an increase in nitrate concentrations in percolating water from 184.1 to 283.5 mg NO_3^-/l, while percolating water on variant without top-dressing contained significantly lower nitrate conencentrations, 88.1 mg NO_3^-/l, in May. There was no water percolation in June, as well as in August and September. In July 2009, percolating water was recorded only on variants fertilized with 50 and 100 kg N/ha, containing minimal nitrate concentrations 4.1-4.4 mg NO_3^-/l.

During growing season of potato in 2010, nitrate concentrations in percolating water ranged from 19.9 to 277.1 mg NO_3^-/l. The most pronounced differences of nitrate concentrations in percolating water between variant fertilized with 200 kg N/ha and other fertilization treatment were recorded in August and September. Percolating water of variant fertilized with 200 kg N/ha contained 277.1 mg NO_3^-/l in August, and 209.8 mg NO_3^-/ in September, which significantly exceeding MAC, while nitrate concentrations in percolating water of other variants were significantly lower, in range 26.9-47.5 mg NO_3^-/l in August and 40.7-57.6 mg NO_3^-/l in September, below MAC, Graph 1.



Graph 1. Dynamics of nitrate concentrations in percolating water, 2009–2010

Similar variations of nitrate concentrations in percolating water, in a very wide range (4.4 – 288.1 mg NO_3^-/l) during growing season of potato, was determined by study of Milburn et al (1990). Slightly lower nitrate concentrations in percolating water, 22.1-110.8 mg NO_3^-/l, was reported by Vos et al (2004). Their research was conducted on sandy soils under potato production, including extraction of percolating water at depth of 80 cm below soil surface. Jalali (2005) also found pronounced dynamics of nitrate concentrations in percolating water under potato production, 3-252 mg NO_3^-/l, due to nitrogen fertilization and soil water regime.

Nitrate leaching

Annual nitrate leaching from soil in dry 2009 ranged 1.1 kg NO_3-N/ha (variant fertilized with 50 kg N/ha) to 1.9 kg NO_3-N/ha (variant fertilized with 200 kg N/ha). Maximum monthly nitrate leaching was registered in April, on all fertilization treatmens, in range 0.54–1.30 kg NO_3-N/ha, Table 2.

Table 2. Monthly and annual nitrate leaching in 2009

Fertilization kg N/ha	kg NO_3-N/ha			
	IV	V	VII	Annual
50	0.83	0.22	0.07	1.10
100	0.54	0.73	0.09	1.29
150	1.30	0.46	-	1.76
200	0.92	0.96	-	1.88

Annual nitrate leaching in 2010 ranged from 7.5 to 13.9 kg NO_3-N/ha. Maximum monthly amount of nitrate nitrogen (4.83 kg NO_3-N/ha) was leached by percolating water in overly wet August 2010 (192 mm of precipitation), Table 3.

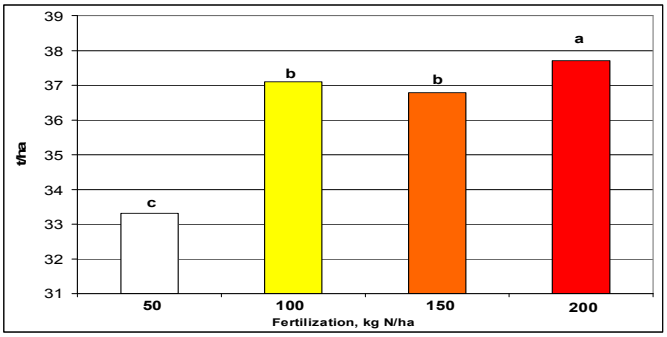
Table 3. Monthly and annual nitrate leaching in 2010

Fertilization kg N/ha	kg NO_3-N/ha						
	IV	V	VI	VII	VIII	IX	Annual
50	0.99	1.58	0.47	0.55	2.20	2.14	7.92
100	1.62	1.88	0.64	0.34	1.20	1.82	7.50
150	0.49	2.23	0.46	0.78	2.13	2.61	8.71
200	1.25	2.55	0.85	0.59	4.83	3,82	13.9

Above mentioned quantities of leached nitrate nitrogen are lower compared to reasearch of Zvomuya et al (2003). They determined nitrate leaching in range 5-33 kg NO_3-N/ha, on sandy loam soil under potato production, including fertilization with 140 to 280 kg N/ha. Linear increase of leached nitrate nitrogen was also proved by Errebhi et al (1988), on loamy sand soil under potato production, with increasing fertilization 45, 90, 135 and 270 kg N/ha.

Potato yields

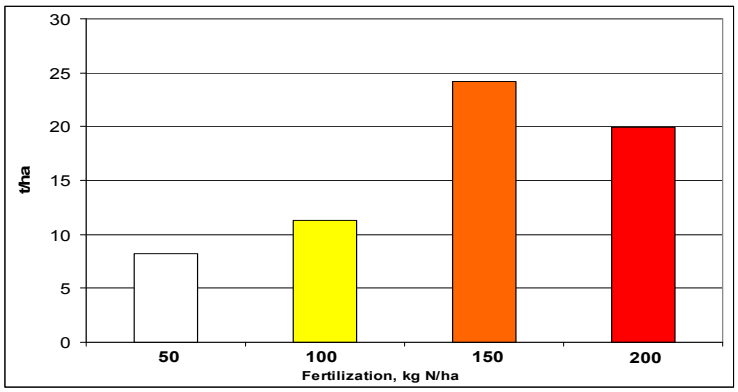
Statistical analysis showed significant differences in the yields of fresh mass of potato tuber in 2009 with respect to nitrogen fertilization. Average yields ranged from 33.3 to 37.7 t/ha. Significantly lower yield of fresh mass of potato tuber was determined on variant without top-dressing (fertilization with 50 kg N/ha) compared to other fertilization treatments. Significantly the highest yield was determined on variant fertilized with 200 kg N/ha, while differences between variants fertilized with 100 and 150 kg N/ha were not significant, Graph 2.



Graph 2. The yields of fresh mass of potato tuber in 2009

Increasing nitrogen fertilizaton from 50 to 200 kg N/ha had no significant influence on potato yields, which varied from 8.2 to 24.2 t/ha in 2010. Due to the extremely rainy August

and September, and consequently several days of stagnation of water on soil surface, especially on one part of experimental plots, lower potato yields than expected were achieved, Graph 3.



Graph 3. The yields of fresh mass of potato tuber in 2010

Conclusion

Significantly higher nitrate concentrations in arable layer of soil were determined on variant fertilized with 200 kg N/ha compared to others variants (fertilization 50-150 kg N/ha). Nitrate concentrations in percolating water varied in a very wide range (4.1–283.5 mg NO_3^-/l), due to applied nitrogen fertilization, amount of percolating water and consumption of nitrate by plants, occassionaly surplasing maximum allowed concentrations (50 mg NO_3^-/l). Potato fertilization with 50 to 200 kg N/ha increased annual nitrate leaching by percolating water, from 1.1 to 1.9 kg NO_3-N/ha in dry 2009, and from 7.5-13.9 kg NO_3-N/ha in wet 2010. Yields of fresh mass of potato tuber rose significantly from 33.3 to 37.7 t/ha in 2009. In 2010, lower potato yields were achieved (8.2.-24.2 t/ha) due to stagnation of water on soil surface and increased nitrogen fertilization had no influence on it.

References

APHA-AWWA-WPCF (1992). Standard Methods for the Examination of Water and Wastewater. Metals (300), 156-157. Washington, DC 20005.

Davies D. (2000) The nitrate issue in England and Wales, Soil Use Management, Vol. 16, p 142-144

Errebhi M., Rosen C., Satish C, Birong E. (1988) Potato Yield Response and Nitrate leaching as Influenced by Nitrogen Management, Agronomy Journal Vol.90, No. 1, p 10-15

Jalali M. (2005) Nitrates leaching from agricultural land in Hamadan, western Iran, Agriculture, Ecosystems & Environment, Vol.110, No 3-4, p 210-218

Milburn P., Richards J.E., Gartley C., Pollock T., O. Neill H i Bailey H. (1990) Nitrate Leaching from Systematically Tiled Potato Fields in New Brunswick, Canada, Journal of Environmental Quality, Vol. 19, No 3, p 448-454

Pravilnik o zdravstvenoj ispravnosti vode za piće (2004). Narodne novine 182/04

Zvomuya F., Rosen C., Russelle M., Gupta S. (2003) Nitrate Leaching and Nitrogen Recovery Following Application of Polyolefin-Coated Urea to Potato, Journal of Environmental Quality, Vol. 32, No 2 p 480-489

Wadell J. T., Gupta S.C., Moncrief J.F., Rosen C.J., Steele D.D. (2000) Irrigation and Nitrogen Management Impacts on Nitrate Leaching under Potato, Journal of Environmental Quality, Vol.29, No.1, p 251-261