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Editors Toomas Tamm and Liisa Pietola

Liisa Pietola: University of Helsinki, Department of Applied Chemistry and Microbiology P.O. Box 27, FIN-00014 Helsinki, FINLAND

Present address: Kemira GrowHow Oyj, Research Centre, P.O. Box 2,
FIN-02271 Espoo, FINLAND

Toomas Tamm: Estonian University of Life Scienses, Department of Water Management. Kreutzwald Str 5, EE51014 Tartu, ESTONIA.

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Water discharge and nutrient leaching from organic mixed crop rotation

Pentti Seuri and Miia Kuisma

MTT Agrifood Research Finland, Huttulantie1,FIN-51900 Juva, Finland
E-mail: pentti.seuri@mtt.fi, miia.kuisma@mtt.fi

Abstract

Water discharge and nutrient leaching studies were conducted in an experimental field under organic farming practice for 20 years. The water discharge measurements cover five years out of a six-year crop rotation. The water discharge for the whole year was 1520 m^3 ha^{-1} (=152 mm). More than 2/3 of the total discharge occurred in April-May. The total precipitation for the whole year was 680 mm.

The total amount of N in the drainage runoff was 11.5 kg ha^{-1} and the flow-weighted average content 7.5 mg l^{-1}. The total amount of P in the drainage runoff was 48 g ha^{-1} and the flow-weighted average content 0.031 mg l^{-1}. 85% of the total P was dissolved reactive phosphorus (DRP).

Some preliminary correlation between N leaching and N management was observed, i.e. higher N concentrations in drainage water were found on green fallow after autumn ploughing compared to first-year grass or spring cereal. Variation in the P concentration of the drainage water between the plots seems to be correlated to soil P status rather than P management.

1. Introduction

Organic production may reduce nutrient leaching because of the low external inputs of nutrients and high internal recirculation. There is, however, a risk of high losses from organic fertilizers, e.g. farmyard manure and legume biomass. Crop rotation plays a key role in nutrient management and to form a complete picture of nutrient leaching it is necessary to follow the entire crop rotation each year. Turtola et al. (2005) reported results from a similar type of crop rotation compared to this paper. However, they had only one single year of crop rotation presented each of the years.

Water discharge and nutrient leaching is difficult or costly to measure accurately because of the various flows of water in the soil-plant system. The main flows of water are surface runoff, drainage runoff, ground water runoff and evapotranspiration. Specially designed lysimeters, where all other flows except evapotranspiration can be measured, can very seldom cover field-scale areas and the soil in designed lysimeters is extremely difficult to set undisturbed. On the other hand, if the water discharge is measured only from the field, there are some serious difficulties in controlling all the flows on the field. However, the processes in the soil are undisturbed.

2. Material and methods

Water discharge and nutrient leaching studies were conducted in an experimental field under organic farming practice for 20 years. The experimental field is located on a moraine soil in Juva, eastern Finland. The soil profile was undisturbed since subsurface drainage in 1989. The six-year crop rotation (5.9 ha) consists of spring cereal with undersown grass seeds (1st year), two-year grassland (2nd and 3rd), winter cereal (4th), green manure (5th) and spring cereal (6th). The water discharge measurements cover five years out of the six-year crop rotation each year (in 2005, the 6th year plot was missing) and the area covers 4.9 ha.

Approximately 30 t ha^{-1} cattle sludge was spread every year with a few exceptions on the first-year plot, which equals about 0.3 LU ha^{-1} for the whole crop rotation per year. The harvested grain yields as net yields amounted to a long-run average of about 2000 kg DM ha^{-1} and the grass yields to about 6000 kg DM ha^{-1}. In 2005 the 4th year plot (winter wheat) was ploughed in spring because of poor overwintering, plot received some cattle sludge and oats was sown.

The water discharge from the whole measurement field from the drainpipes was measured automatically (v-notch with electronic pressure sensor) and flow-weighted water samples were taken manually, 42 samples throughout the year. The water samples were stored frozen and analysed at the laboratory of the North-Karelia Regional Environment Centre in July 2005 and January 2006. The samples were analysed for both total and soluble nitrogen and phosphorus fractions, total solids, pH and conductivity. In January and from 30 June to 5 October the measuring equipment did not work properly and the water discharge was estimated by manual measurements during those periods. For more details about measurement fields, see Schneider et al. (2005).

In addition, water discharge was measured manually from each of the individual plots on 9 November, and water samples were taken manually three times from each of the individual plots between 9 November and 18 November. Three samples were also taken from surface runoff in spring and four in autumn.

Soil test results by Finnish soil testing procedures are available from the experimental field since 1989. The latest tests date back to 2004 (AAAc-EDTA procedure, Lakanen and Erviö 1971). The results are not presented in this paper.

3. Results and discussion

The subsurface drainage discharge for the whole year was 1520 m^3 ha^{-1} (=152 mm) (Figure 1). More than 2/3 of the total discharge occurred in April-May. Precipitation for the whole year totalled 680 mm. The autumn was extremely dry (36 mm in September and 43 mm in October) with hardly any discharge. Difference of the drainage discharge between plots was measured only once (manual measuring). The discharge was relatively even between the plots, except for one plot (Figure 3).

Nitrogen

The total amount of leached nitrogen (N) in the drainage runoff was 11.5 kg ha^{-1} (Figure 1) and the flow-weighted average content 7.5 mg l^{-1} (Figure 2). Nitrate-N was the major component of the total N (no data presented), varying from 1.8 mg l^{-1} to 9.9 mg l^{-1}. The content of ammonium-N was less than 10 µg l^{-1} most of the year. Somewhat higher values (40 µg l^{-1}) were measured in winter and some peak values (270 µg l^{-1}) at the very beginning of April. The nitrite-N content was less than 1 µg l^{-1} throughout the year, except for the somewhat higher values (4–6 µg l^{-1}) observed during winter. There was no clear difference in total N content between the drainage runoff and the surface runoff after the snow had melted.

Three water samples from each of the individual plots after ploughing in autumn indicated a clear difference in total N content between the plots (Figure 3). The fourth- and fifth-year plots were ploughed at the beginning of October. The total N content on the fifth-year plot (green manure) was double (10 mg l^{-1}) the second-year (grass I) and the fourth-year plots. The first-year (spring wheat + undersown grass) and the third-year (grass II, winter wheat was sown on 26 August) plots were between these extremes.

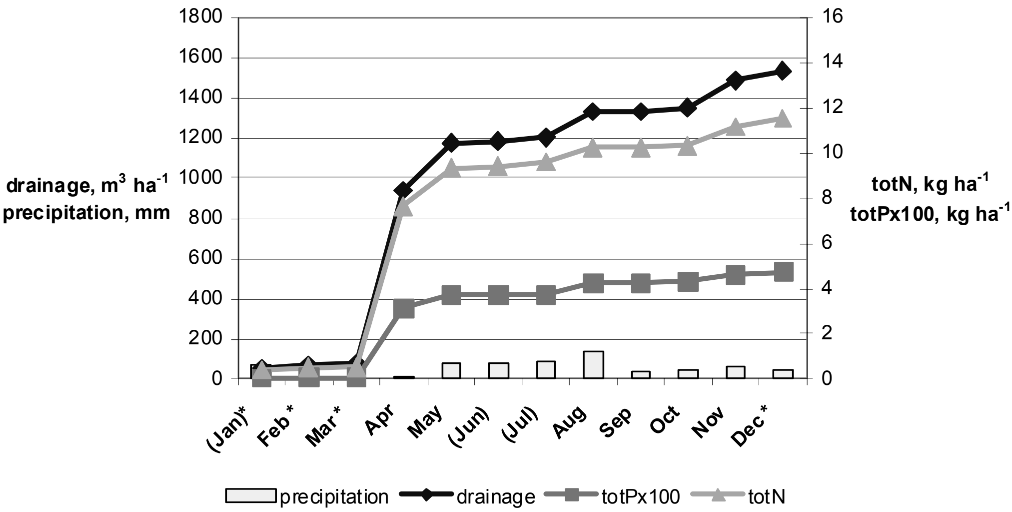

Figure 1. Subsurface drainage water (m^3 ha^{-1}), precipitation (mm) and total nitrogen (totN kg ha^{-1}) and total phosphorus (totPx100 kg ha^{-1}) leaching by subsurface drainage water in 2005.

( ) = data estimated, * = snow as water

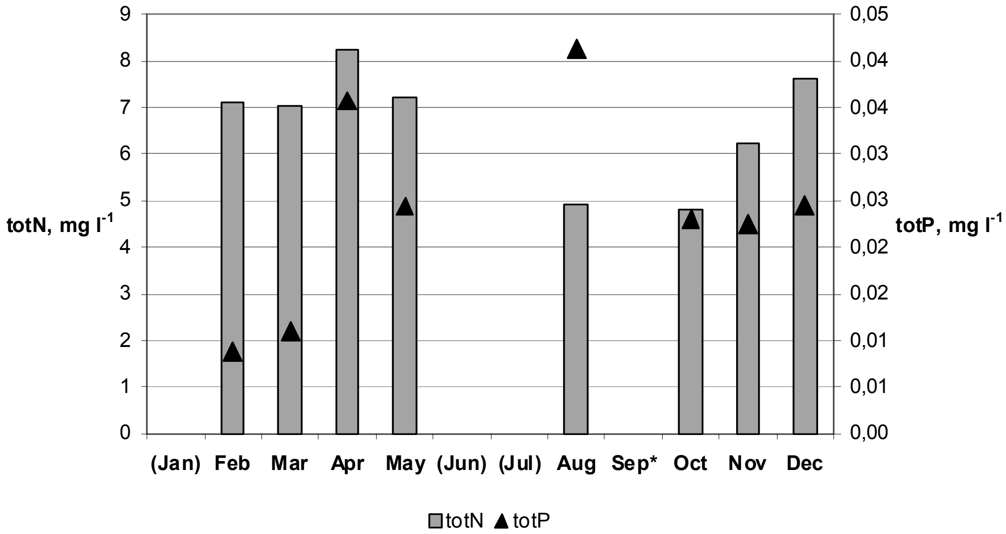

Figure 2. Flow-weighted average total nitrogen (totN mg l-1) and total phosphorus (totP mg l-1) concentrations in subsurface drainage water in 2005.

( ) = no data, * = no drainage water

Phosphorus

The total amount of leached phosphorus (P) in the drainage runoff was 48 g ha^{-1} (Figure 1) and the flow-weighted average content 0.031 mg l^{-1} (Figure 2). 85% of the total P was dissolved reactive phosphorus (DRP). There was a period of one week in early April (snow melted mainly during this week) with peak values (0.11 mg l-1) of total P. The lowest total P contents were in winter and late spring. The soil P status varied from 8 to 30 mg l^{-1}, i.e. the soil P status was slightly higher than the Finnish average (15.9 mg l^{-1}, Mäntylahti 2002). The total P content was higher in the surface runoff than in the drainage runoff at the beginning of April, but otherwise it was vice versa.

There was great variation between the three samples from individual plots after ploughing (Figure 3). On the first- and fifth-year plots the total P content tended to be the lowest and it correlated with the lowest soil P status (8–10 mg l^{-1}). Between the other plots there was no clear difference in the P content of the water samples; soil P status was 24–30 mg l^{-1}.

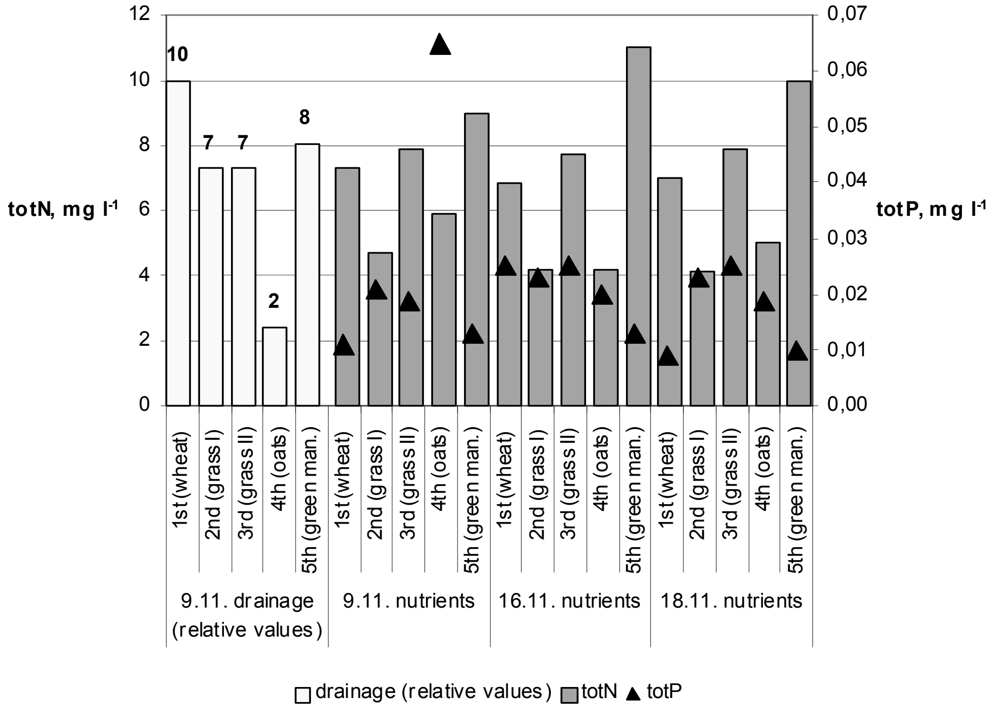

Figure 3. Total nitrogen (totN mg l^{-1}) and total phosphorus (totP mg l^{-1}) concentrations in subsurface drainage water on different plots of the crop rotation and relative values of subsurface drainage in 2005.

There are very few results from organic agriculture in comparable conditions for reference. Turtola et al. (2005) found slightly lower total nitrogen leaching from a similar type of crop rotation. However, the drainage runoff was very low in one experiment on sandy soil (Toholampi) and the yield was very low in another experiment on heavy clay soil (Jokioinen). In this study, the correlation between water discharge and N leaching was very strong (Figure 1).

The P concentration in the drainage water was extremely low in the Toholampi experiment by Turtola et al. (2005) because of a special soil type with active ferrous and aluminium-rich subsoil, which bound phosphorus chemically. This resulted in very minor total leached P in the drainage water. However, the total leached P in the surface runoff was as high as 400 g ha^{-1} average over seven years.

4. Conclusions

This was the very first year of measuring discharge and nutrient leaching from the experimental field. After some technical problems the field itself worked fine. The drainage discharge was relatively even between the plots, except for one plot. However, more plot-specific observations are needed. It is necessary to measure and analyse also the surface runoff to form the whole picture concerning the total nutrient flows. The water discharge reacted immediately to heavy rain, indicating the high filtration capacity of the coarse moraine. This is very helpful for finding the correlation between water discharge and N leaching.

The high initial P status of the soil offers an ideal opportunity to follow changes in the P status of the soil. There is a common tendency in organic farming to a declining soil P status in the long run because of a negative P balance in the soil. The initial variation between the plots in soil P status also offers an opportunity to investigate the role of soil P status in P leaching.

References

Lakanen, E. and Erviö, R.1971. A comparison of eight extractants for the determination of plant available micronutrients in soils. Acta Agr. Fenn. 123:223–232.

Mäntylahti, V. 2002. Peltojen ravinnetilan kehitys 50 vuoden aikana. In: Uusitalo, R. and Salo, R. (eds.), Tutkittu maa – turvalliset elintarvikkeet. Viljavuustutkimuksen 50 vuotta – juhlaseminaari, Jokioinen, 24.9.2002. Maa- ja elintarviketalous 13, 61 p. (In Finnish) http://www.mtt.fi/met/pdf/met13.pdf

Schneider, Th., Kuisma, M. and Seuri, P. 2005. Nitrogen and phosphorus leakage in ecological recycling agriculture. pp. 60–70. In: Granstedt, A., Thomsson, O. and Schneider, Th. (eds.). Environmental Impacts of Eco-Local Food Systems – final report from BERAS work package 2. Ekologiskt lantbruk 46. http://www.cul.slu.se/information/publik/ekolantbruk46.pdf

Turtola, E., Lemola, R., Esala, M., Joki-Tokola, E., Hakkola, H. & Lehto, E. 2005. Ravinnekuormitus vesiin. pp. 4–29 (Abstract in English). In: Turtola et al. Ympäristökuormitus luonnonmukaisessa viljelyssä – tutkimusvuosien 1997 – 2004 loppuraportti. Maa- ja elintarviketalouden tutkimuskeskus, 69 p. Jokioinen 31.3.2005. (In Finnish)