CALCIUM CHLORIDE (0.01M) EXTRACTABLE PHOSPHORUS IN THE TREATMENTS OF WESTSIK'S CROP ROTATION EXPERIMENT

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Abstract.
Phosphorus is an essential nutrient, which is commonly applied to agricultural fields to increase crop yields. The accumulation of phosphorus in soils has become a major concern which represents a potential risk for contamination of surface and ground water. The main processes for phosphorus losses from agricultural fields in Nyírség region are deflation, surface runoff and subsurface leaching, the amount and processes behind these losses are still unknown. Phosphorus accumulations were studied in the Westsik's crop rotation experiment to evaluate how the treatments affect phosphorus content of cultivated and dipper 40-60 soil layer. Organic and inorganic phosphorus in 0.01 M calcium chloride ($CaCl_2$) extracts were studied in the potato field of Westsik's crop rotation experiment. Organic phosphorus proved to be an important part of total phosphorus in soil solution of the crop rotation experiment, which models various possible methods of nutrient management (fallow, straw, farmyard and green manure). The role of this fraction as a phosphorus source for crops, its transfer from soil to plant and potential risk for contamination of surface and ground water is still unclear.

Keywords: calcium chloride ($CaCl_2$) extracts, organic and inorganic phosphorus

INTRODUCTION

Many unfertilised soil in Hungary are low in phosphorus, and this can have adverse effects on plant and animal health as phosphorus with nitrogen controls primary productivity in most natural ecosystems. The increased used P fertilisers in the 20th Century resulted in a dramatic increase in plant and animal production and health (Johnston and Poulton, 1993). The presence of excess phosphorus in soil increases the risk of leaching process, which could results soil degradation and accelerates the eutrophication in aquatic ecosystems. The increased mobility of soil colloids in the presence of high amount of phosphorus is reported to be connected with higher dispersion and instability of soil particles. Tarafdar and Jungk (1987) found increased phosphatase activity in the vicinity of roots coinciding with a decrease of organic phosphorus and an increase of inorganic phosphorus concentration in barley field. Concentration of organic and inorganic phosphorus in calcium chloride extracts was 7.8 and 1.8 mol/dm^3. When soil microbial biomass was destroyed by autoclaving, organic phosphorus concentration increased to 64.8 mol/dm^3 whereas the inorganic phosphorus was hardly changed. Inoculation of the autoclaved soil with non-sterile soil and incubation for 5 days decreased the organic phosphorus concentration to 27.9 mol/dm^3 but did not change inorganic. The greatest reduction of organic phosphorus concentration occurred in fresh extracts of the autoclaved soil. Inorganic phosphorus was depleted to traces in all extracts. Organic phosphorus was hydrolyzed by isolated acid and alkaline phosphatases and they concluded that organic phosphorus in soil solution is a heterogeneous pool and originating from microbial biomass.

The contribution of soil organic phosphorus to plants nutrition been studied in relation to phosphorus mineralization and organic matter turnover (Hedley et al., 1982; Sharpley, 1985). But soil organic phosphorus compounds might also be directly hydrolyzed through phosphatase activity at the root surface and increased phosphatase activity in the rhizosphere. However, it is still not clear if phosphorus is mobilized from soil organic phosphorus compounds through the activity of root phosphatase. Soil phosphorus concentration has been used as an indicator of potential loss. Sharpley, (1996), McDowell and Sharpley (2001) Maguire and Sims, (2002), proved correlation between yield losses and soil phosphorus levels. In environmental studies, phosphorus desorption is usually measured with procedures that simulate phosphorus transfer into solution such as calcium chloride extractable phosphorus Houba et al., (1991), Houba and Novozamsky (1998).

MATERIAL AND METHODS

The crop rotation experiment established by Vilmos Westsik in 1929 offers an excellent possibility to study phosphorus accumulation and loss in many respects. The experiment consist of 15 treatments, makes it possible to study sustainability of agricultural production under different applications of green, straw and farmyard manure treatments, to study the ecological impact as well as economic aspects of different production methods. One of the main practical objects of the Westsik's crop rotation experiment was to measure the long-term effects of different organic manure and inorganic fertilisers on rye and potato production Westsik, (1964).

Table 1:

Treatments of the Westsik's crop rotation experiment

	Organic Manure t/ha	Crop I. ($N/P_2O_5/K_2O$) kg/ha	Crop 2. ($N/P_2O_5/K_2O$) kg/ha	Crop 3. ($N/P_2O_5/K_2O$) kg/ha
F-1	Manure	Fallow= (0/0/0)	Rye (0/0/0)	Potato (0/0/0)
F-2	Green	Lupine= (0/63/56)	Rye (0/34/28)	Potato (36/0/0)
F-3	Root	Lupine= (0/63/56)	Rye (0/34/28)	Potato (36/0/0)
F-4	Mulch (3,48 t/ha)	Rye+ (54/31/28)	Potato (36/31/28)	Rye (0/0/0)
F-5	Straw (11.3 t/ha)	Rye+ (54/31/28)	Potato (36/31/28)	Rye (0/0/0)
F-6	Straw (11.3 t/ha)	Rye+ (54/31/28)	Potato (36/31/28)	Rye (0/0/0)
F-7	Straw (11.3 t/ha)	Rye+ (0/0/0)	Potato (0/0/0)	Rye (0/0/0)
F-8	Green	Lupine= (0/31/0)	Rye+ (36/31/28)	Potato (0/31/28)
F-9	Forage	Lupine= (0/31/28)	Rye (36/31/28)	Potato (36/0/0)
F-10	Farmyard (26.1 t/ha)	+Forage (0/0/0)	Rye (0/0/0)	Potato (0/0/0)
F-11	Farmyard (26.1 t/ha)	+Forage (0/63/56)	Rye (0/31/28)	Potato (36/0/0)
F-12	Green SC	Rye+ (0/63/56)	Rye (0/31/28)	Potato (36/0/0)
F-13	Green SC	Rye+ (36/31/28)	Potato (0/31/28)	Rye (36/31/28)
F-14	Green SC	Rye+ (36/31/28)	Potato (0/31/28)	Rye (36/31/28)
F-15	Green SC	Rye+ (0/0/0)	Potato (0/0/0)	Rye (0/0/0)

Crop 4 in F-8 treatment is rye with NPK=36/0/0 kg/ha

The treatments of the Westsik's crop rotation experiment were intended to increase soil fertility using different organic matter amendments, as the original purpose was to evaluate the cumulative effects of organic matters on light sandy soil with a long history of arable cropping. The F-1 received no fertilisers and organic material except the rye and potato roots and straw incorporated into the soil. The F-2 represents green manure treatment, where lupine was grown as a main crop and incorporated into the soil 4-5 weeks after flowering. The phosphorus and potassium fertilisers in this treatment were applied the previous autumn, before the lupine was sown. The represents lupine root manure treatment, where lupine was grown for grain and the total organic material, except for the grain, was incorporated into the soil. Blocks F-4 - F-7 represent straw manure treatments. In the F-4 block, rye straw was applied as mulch. In blocks F-6 and F-7, straw manure was fermented without nitrogen, and in block F-6, with nitrogen addition. The straw manure was incorporated into the soil 4-6 weeks before the sowing of rye. F-8 is the only block with 4 main crops, where lupine grew twice in 4 years; once as a main crop produced for grain and once as a second crop produced after rye and before potato, for green manure. In the F-9 block, lupine was grown as a forage crop and harvested 2-3 weeks after flowering. F-10 and F-11 represent farmyard manure treatments. In F-12, lupine is grown after a green forage crop and sown in May. This block is also evaluated with farmyard manure treatments to measure the comparative effects of the two treatments. F-13, F-14 and F-15 treatments represent green manure treatments, where lupine is grown as a second crop after rye and before potato. The F-15 block received no fertilisers. The difference between blocks F-13 and F-14 can be found in the time of the incorporation of green manure. The phosphorus content was determined by extraction in 0,01M $CaCl_2$ Houba, Novozamsky (1998); Houba, Temminghoff (1999), Jászberényi (1993): Jászberényi, Loch, (1995).

RESULTS AND DISCUSSIONS

The total phosphorus content of the soil in Westsik's crop rotation ranges from 0.03 to 0.10 %, which corresponds to a phosphorus stock of 1.5-3.0 t/ha in the ploughed soil layer. The amount of ammonium lactate (AL) extractable phosphorus is between the values of 30-210 mg/kg depending on the treatments. Traditionally, AL-extractable phosphorus has been used by soil testing laboratories to describe the amount of phosphorus in soil available for crop uptake and to determine the probability of crop response to added phosphorus, and thereby fertilizer phosphorus requirements. Bio available phosphorus is often used to describe phosphorus in soil or sediment that is available for uptake by algae or macrophytes in surface waters (Beauchemin and Simard (2000). Occasionally, bio available phosphorus is used to describe the availability of soil phosphorus to plants. There are also a large number of soil phosphorus extraction methods that have been designed to account for various soil types and mechanisms controlling the chemistry of soil phosphorus. For example, numerous soil extractants are available for acid soils, where Al and Fe dominate phosphorus chemistry, and basic or calcareous soils, where Ca dominates soil phosphorus reactions.

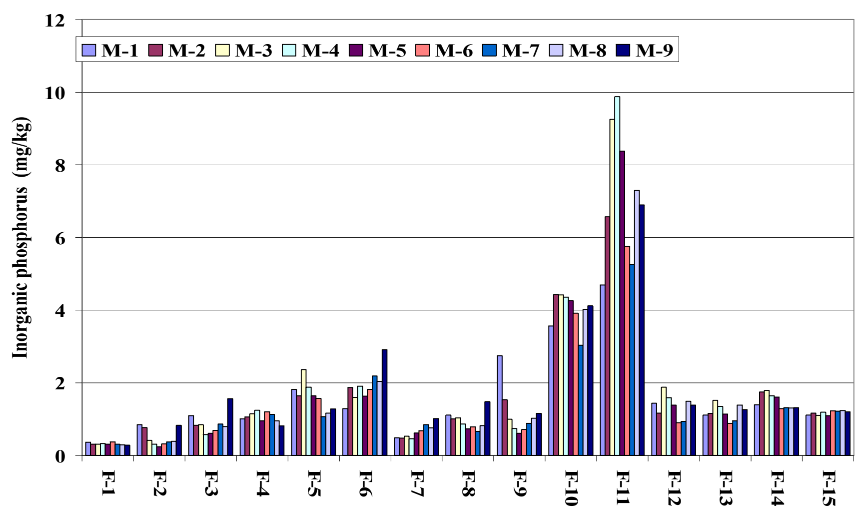

Figure 1: 0.01 M ($CaCl_2$) extracted inorganic phosphorus in treatments of Westsik's crop rotation experiment (mg/kg4444)

The treatments of the Westsik's crop rotation experiment are marked by poor phosphorus supply. F probe approved significant difference between the two dunes, with regard to total phosphorus content. On the first dune, the total phosphorus content at the depth of 0-60 cm was 0.074, 0.066 and 0.067 % on the second dune. It was 0.136, 0.133 and 0.134 %, when samples were taken on the side along the Érpatak, on the top of the dune, and on the Eastern side, separately Lazányi (2003). Among the treatments, the total phosphorus content of crop rotations F-1, F-2 and F-3 was 0.06 %. With crop rotation F-4, the total phosphorus content was 0.07 %, while with F-5, it was 0.10 %. The total phosphorus content of the soil of the second dune ranged from 0.10 % to 0.16 %. With crop rotations F-11 and F-14, the total phosphorus content of the soil was 0.16 %, while with crop rotation F-15, the phosphorus content was 0.10 % Lazányi (2003). In present study the 0.01 M ($CaCl_2$) extracted inorganic phosphorus was highest in F-10 and F-11 in treatments of Westsik's crop rotation experiment, which received farmyard manure (26.1 t/ha/3 years) since 1929 (Figure 1). Increased inorganic phosphorus in 0.01 M soil extracts must be connected with physical, chemical and biological property of soil.

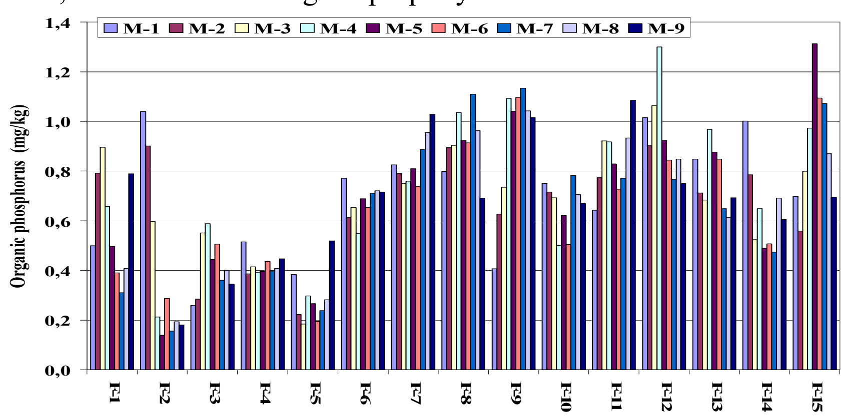

Figure 2: 0.01 M ($CaCl_2$) extracted organic phosphorus in treatments of Westsik's crop rotation experiment (mg/kg)

In previous study, AL extractable phosphorus content was the lowest in control crop rotations F-15, F-7 F-1, while it was high in crop rotations F-10 and F-11, using farmyard manure Lazányi (2003). AL-extractable phosphorus content of the crop rotation F-1, F-2 and F-3 was lower than 100 mg/kg, while F-11 was outstanding, many times higher than the similar value of control treatments. On the second dune, crop rotation F-15 had the lowest phosphate content of 2.7 mg/100 g soil. In present study, 0.01 M ($CaCl_2$) extracted organic phosphorus was nearly uniform in treatments of

Westsik's crop rotation experiment except for F-2, F-3, F-4 and F-5 treatments (Figure 2).

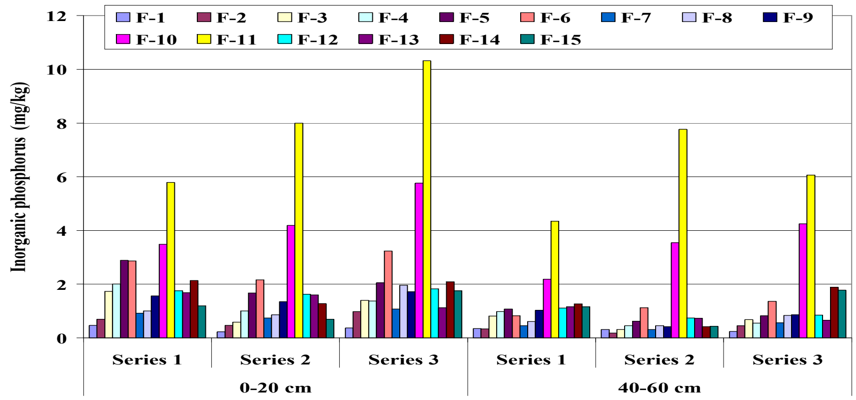

Figure 3: 0.01 M ($CaCl_2$) extracted inorganic phosphorus in the series of Westsik's crop rotation experiment at 0-20 and 40-60 cm (mg/kg)

The availability of phosphorus and the potential for adverse environmental effects should also be studied in the Westsik's crop rotation experiment, in which organic matter and inorganic phosphate have been applied since 1929, on sandy soils with light texture. The experiment makes it possible to study the phosphorus balance of different treatments. When the amount of phosphorus applied to the soil exceeds the amount removed by a crop, there is a positive phosphorus balance and phosphorus will accumulate in the soil, except when it is lost. 0.01 M ($CaCl_2$) extracted inorganic phosphorus was nearly uniform at 0-20 and 40-60 cm (Figure 3). Series in Figure 3 and 4 represent potato, grown in Westsik's crop rotation experiment for 3 subsequent years.

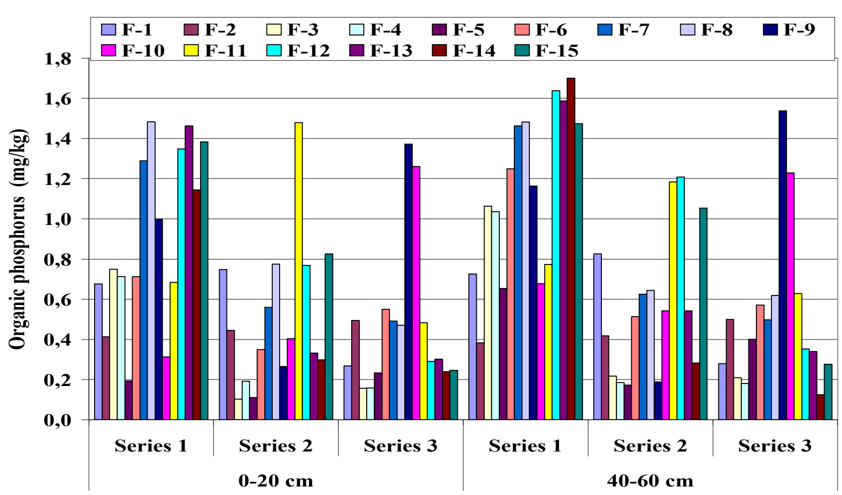

Figure 4: 0.01 M ($CaCl_2$) extracted organic phosphorus in the series of Westsik's crop rotation experiment at 0-20 and 40-60 cm (mg/kg)

The crops took up the highest amount of phosphorus in crop rotations F-8, F-11, F-12. The amount of phosphorus absorbed by the plants varied from 17.1 kg/hectare/2 crops (crop rotation F-1) to 82.1 kg/hectare/3 crops (F-11). The amount of phosphorus taken up by the crops in the crop rotation experiment was determined as the product of the actual yields and the amount of phosphorus drawn up by unit of main product and related by-products. Accordingly, the lowest phosphorus uptake could be measured in crop rotations F-1, F-15 and F-7, where phosphorus supplement was provided exclusively through natural resources. Phosphorus balance of Westsik's crop rotation experiment was in equilibrium or even positive, except in the control plots. The greatest phosphorus surplus could be found in crop rotation F-11, where regular fertilisation was performed, in addition to the farmyard manure treatments, in every third year. Considerable phosphorus surplus can also be found in F-2 and F-3 treatments, where lupine root and green manure were applied. Phosphorus surplus can be demonstrated in the F-10 and F-11 farmyard manure treatments, but it has resulted no increase in 0.01 M ($CaCl_2$) extracted organic phosphorus content (Figure 4).

DISCUSSIONS

Diffuse losses of phosphorus from agricultural territory are a major component of surface water pollution in many part of the World (Osztoics et al. (2007). Water Quality survey in Ireland indicate that agriculture can be a significant source of P loss to water, perhaps of the order of 50 percent of the total (EPA, 1991- 1994). When soils were low in phosphorus in their natural state the loss to water is generally was in the order of 0.1 to 0.2 kg P per ha per year or less including water erosion and deflation. The quantities lost from fertilised agricultural land is generally still very small (1 kg P /ha/year) from an economic viewpoint but increases plant (both algae and higher plants) production in rivers and lakes where phosphorus is usually the limiting nutrient. Eutrophication has adverse effects on water quality in terms of fish and other organisms that live in water, on the amenity value of water and on the suitability of the water for drinking or industrial use, unless it receives prior treatment. In Ireland, over 90 percent of agricultural land is devoted to grassland. Fertiliser and animal manures are added to the soil surface each year, and most of it tends to accumulate in the soil surface, which can easily become saturated with P. Water can run over or infiltrate through this P-enriched surface soil and carry significant amounts of P with it. In Nyírség region farmyard manure application increased 0.01 M ($CaCl_2$) extracted inorganic phosphorus content, but do not resulted evident changes in 0.01 M ($CaCl_2$) extracted organic phosphorus. Organic component in each series of crop rotation was higher at 40-60 cm sampling level (Figure 5).

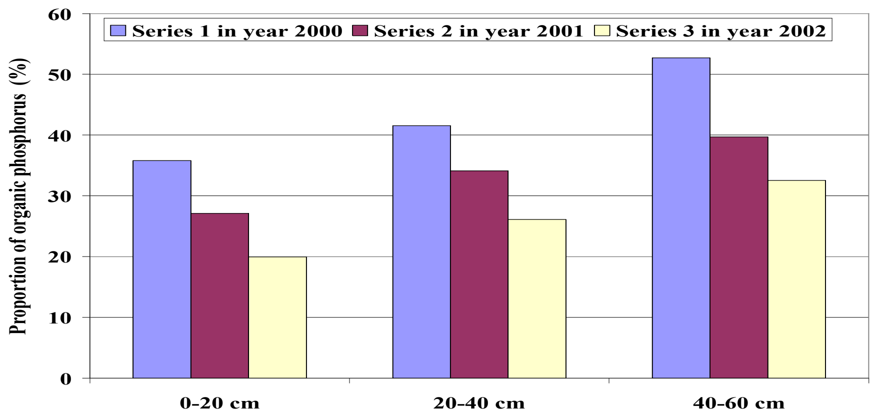

Figure 5: Proportion of 0.01 M ($CaCl_2$) extracted organic phosphorus in the Westsik's crop rotation experiment (%)

The ultimate goal of soil testing is to provide the user with a recommendation as to the likelihood that the application of nutrients in fertilizers or manures will provide a profitable increase in crop response. Recommendations based on soil testing results are developed using crop response data that have been obtained within region with similar soils, cropping systems, and climatic conditions. It is important to submit samples to a laboratory that is familiar with the crops to be grown and the soils and management practices that will be used. Decades of farmyard manure application to F-10 and F-11 treatment have resulted in substantially increased soil inorganic P concentration measured in 0.01 M ($CaCl_2$) extract. This elevated soil P generally does not cause agronomic problems, but it might contributes to the high P concentration found in some surface waters in Nyírség region. Current fertilization practices can be improved if organic and inorganic forms of nitrogen and phosphorous measured in 0.01 M ($CaCl_2$) extract are taken into consideration. Continued application of high dosage of farmyard manure increases the potential for loss of phosphorus to the environment, but growers can minimize P loss to the environment by eliminating or impounding tail water, and by growing winter cover crops to minimize winter runoff and deflation. These practices are especially important in Nyírség region particularly if those fields were slopes generating runoff and deflation can also increase the problem of nutrient loss. On the other hand, increased inorganic phosphorous was measured in F-10 and F-11 treatments of Westsik's crop rotation experiment, which received 26.1 t/ha/3 years farmyard manure since 1929. This is much higher then the country average.

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