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Gypsum-based management practices to prevent phosphorus transportation

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Introduction

The phosphorus (P) load on waters caused by field cultivation is one of the most significant environmental problems caused by agriculture. P accumulation into arable soils results from manure use or high P fertilization rates in past decades. In Finland, particularly soil erosion causes significant P load (1-2 kg/ha/a) in spite of considerable decrease (from 30 to 8 kg/ha) in P fertilizer rates from 1990s (SYKE, 2007). Vegetated buffer zones (VBZ) along water courses or constructed wetlands are found to be insufficient to prevent phosphorus losses from fields to waterways. New solutions, tools and products to reduce the P load are required.

Gypsum ($CaSO_4 \cdot 2H_2O$) as soil amendment inhibits P load: Through Calcium ion (Ca^{2+}) it improves soil structural properties like aggregate stability of clay soil which is important for erosion control. Gypsum also controls P leaching by increasing soil electrical conductivity which improves phosphate binding on soil surfaces (Aura *et al.*, 2006), or through Ca-P precipitation (Zhu & Alva, 1994; Favaretto *et al.,* 2006) in alkaline soils (Kordlaghari & Rowel, 2006). Alternatively, gypsum in liquid manure reduces ortho-P concentration of the liquid phase. This was observed in laboratory with an additional aeration of the manure (Heinonen-Tanski *et al.*, 2000).

Soluble P in soils and manures can be precipitated by Ca, iron (Fe) or aluminium (Al) compounds. Although Fe and Al flocculate soil particles and bind soluble P to Al- and Fe –phosphates in soil solution or liquid manure, this approach is not sustainable as P in Al- or Fe-precipitates are typically unavailable for field crops (at soil pH >3-4). Our approach was to hold P in soil (root zone) as a part of ecological cycle for continuous use in agriculture. This should be achieved by management practices like Ca-precipitation.

Material and methods

Phosphogypsum ($CaSO_4 \cdot 2H_2O$) from Siilinjärvi plant (Yara, former Kemira GrowHow) were tested in soil incubation-leaching –studies (I), and in liquid pig manure treatment (II) in farm pit.

As soil amendment (I), 0-6 g gypsum was mixed to ½ kg soils of different texture, test-P, and pH. Soils were fertilised by soluble phosphates (10-25 mg per soil column) and thereafter watered weekly to field capacity. After 2-3 months, soils were leached with 300 ml water. Molybdate reactive ortho-P concentrations of runoff were measured with $(NH_4)_6Mo_7O_{24}.4H_2O$. The leaching procedure was repeated up to 10 times in order to measure the cumulative P-leaching through soil columns. Similarly, unfertilized soil columns (½ kg soils) of different soil types at different P-status were also treated with 2 g gypsum and cumulative P-leaching, with EC, was measured followed by monthly oversaturation and leaching with 300 ml deionized water. Meanwhile, columns were watered to field capacity each 2 weeks, to attain drying cycles found under natural conditions. Erodibility was analysed by measuring turbidity of the leached waters.

In the manure treatment (II), a farm test was conducted to precipitate the P of pig slurry in farm pit. Gypsum-MgO –based precipitate was stirred into the liquid pig manure, <0.7%. MgO was used for pH rise which was previously observed to be a necessity for the ortho-P decrease. Additionally, MgO provided a building block into struvite ($MgNH_4$-phosphate) precipitation. According to the pre-studies laboratory, no aeration was then needed. After sedimentation, ortho-P concentration and pH of the upper part (liquid) were recorded. Total P of the liquid and the sediment was analysed after 1 and 2 months. The fraction in which the P level was reduced (upper liquid part) represented 2/3 of the total manure volume. Manure samples were taken from different depths to measure the concentrations for total P and K (H_2SO_4 -HNO_3 -soluble), and for water-soluble P, K, NO_3-and NH_4-N (by photometry TRAACS with Sherwood fl.). Water-soluble P was comparable to ortho-P analysed with $(NH_4)_6Mo_7O_{24}.4H_2O$.

Results and discussion

I. Gypsum as soil amendment

In soil columns, gypsum additions significantly reduced erodibility and ortho-P concentrations in the leaching water. The effect was clear when agronomic soil test-P (extracted with 0.5 M acid ammonium acetate) was 9 mg/l or more. After 500 mm rain simulation (10 watering with 300 ml) gypsum rate 6 g/l reduced the ortho-P load from 3.94 to 1.67 g per leached water, when P-fertilization with $Ca(H_2PO_4)_2\ H_2O$ was 20 mg/l and soil test-P 36 mg/l (Figure 1). Similarly, soil electrical conductivity increased by over 50%. The same phenomenon was recorded for other soil types without P-fertilization (Figure 2). Additionally, gypsum affected particle P as turbidity significantly decreased by 2-g treatment per ½-kg soil (Figure 3). Currently, gypsum is tested under field and catchment conditions.

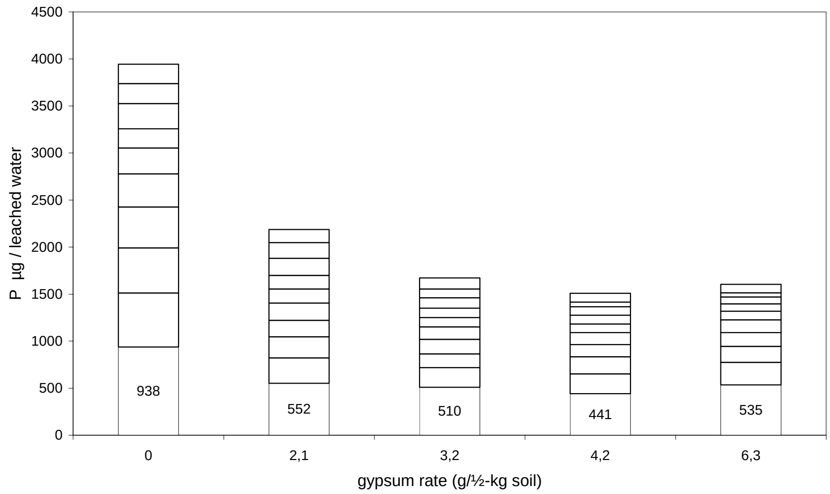

Figure 1. P-leaching from ½ kg soil columns treated with 0-6.3 g gypsum. Numbers represent ortho-P concentration in 1st leaching with 300 ml water. Soil was fertilized with 10 mg P per pot when gypsum was mixed.

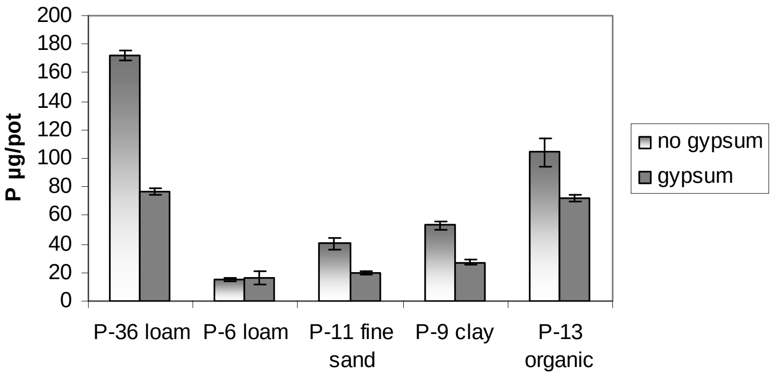

Figure 2. P-leaching from ½ kg soil columns treated with 2 g gypsum or not. Soils originate from fields of different soil type and P-status. Numbers represent soil test-P (mg/l soil, with acid AAc extraction). The bars represent cumulative ortho-P concentrations after 4 leaching procedure by 300 ml water. Columns were not fertilized.

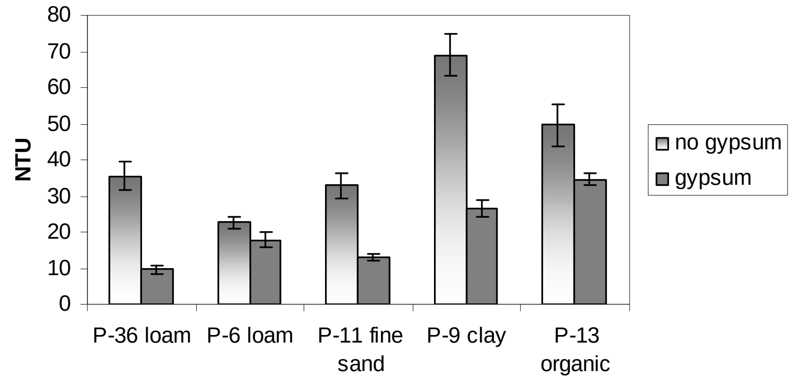

Figure 3. Turbidity of leaching waters from soil columns with and without gypsum. See caption of Figure 2 for more details.

II. Gypsum in manure treatment

In the pig manure test, the gypsum-based precipitate fractionated phosphorus to P-rich sediment and to almost P-free upper part. Upper low-P fraction represented 2/3 of the total manure volume. In this upper part, total P reduced from 1.05 g kg^{-1} to 0.13, ortho-P from 0.73 to 0.02g kg^{-1} (Figure 4). This P-low part of settled liquid manure is applicable on fields with high soil-P as NK-fertiliser, as liquid phase contained total N 2.1 g kg^{-1} (ammonium-N 1.9), and total K 1.7 g kg^{-1}. Lower P-rich part contained 3.1 g kg^{-1} P and 1.3 g ortho-P, respectively. This part could be use as raw material in energy production, or alternatively as P-fertilizer where its use does not induce P leaching or transportation from fields. N-concentration in the "solid phase" (DM 18%) was 3.6 g kg^{-1} (ammonium-N 1.9). K concentration was 2.0 g kg^{-1} in the solid fraction, but water soluble K remain same (1.8) both in liquid and solid fractions. Currently, the method is optimised for cattle slurry.

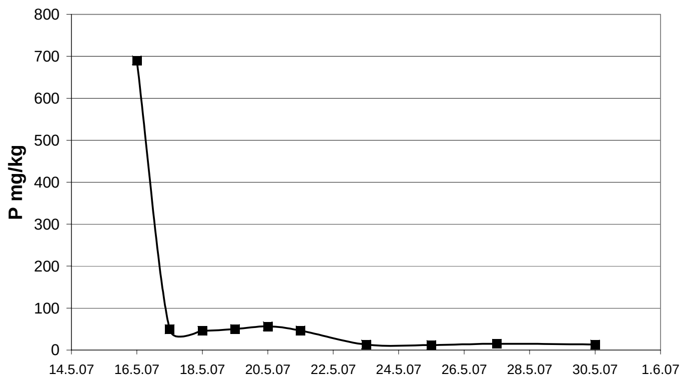

Figure 4. Ortho-P concentration of flowing pig slurry above settled fraction, after gypsum treatment with additives like MgO.

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