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Phosphorus (P) balances and P availability in a field trial comparing organic and conventional farming systems since 35 years

Klaus Jarosch (1), Astrid Oberson (2), Frossard Emmanuel (2), Lucie Gunst (3), David Dubois (3), Paul Mäder (4), and Jochen Mayer (3)

(1) University Bern, Institute of Geography, Bern, Switzerland (klaus.jarosch@giub.unibe.ch), (2) ETH Zurich, Institute of Agricultural Sciences, Zurich, Switzerland, (3) Agroscope Reckenholz, Zurich, Switzerland, (4) FiBL, Reserach Institute of Organic Agriculture, Frick, Switzerland

Background: The adequate supply with phosphorus (P) is crucial to maintain constant yields in all cropping systems. It remains yet unclear whether P in organic farming systems may become a limiting factor for plant nutrition in the long term.

Material and Methods: The DOK long-term field trial was established in 1978 to compare different farming systems. The trial consists of two organic (biodynamic (DYN), bioorganic (ORG)) and two conventional treatments (using farmyard manure plus mineral fertilizer (KON) and mineral fertilizer only (MIN, established in 1985)). In a control treatment (NON) no fertilizer is applied. The fertilization for the organic treatments DYN and ORG is defined on manure production of 1.4 livestock units (since 1992), while before that 1.2 livestock units were used as reference. Fertilization on the conventional treatments KON and MIN is defined by Swiss fertilization guidelines. Treatments DYN, ORG and KON are maintained at full fertilization level (2) as well as halved fertilization level (1) while treatment MIN is only maintained at fertilization level 2. All treatments are maintained with the same crop rotation with a period of 7 years.

An annual P-balance was calculated, based on the input factors 1) fertilization, 2) seeds and 3) deposition and the output factors 4) removal with crop yields and 5) leaching. The factors fertilization and removal with crop yields were based on documentation since trial establishment. Factor seeds was estimated based on documented quantity of used seeds per treatment and factors deposition and leaching were estimated by values available in literature.

Additionally, P availability was determined via isotopic exchange kinetics (IEK) experiments after each crop rotation period (7 years). The IEK experiments allow to estimate the rate of P exchange from soil into soil solution and thus to estimate plant P availability over a cropping period.

Results and Conclusions: Main influencing parameters of the P-balance were the factors fertilization and the removal with cropping products. Other inputs (deposition, seeds) and outputs (leaching) were of minor importance for the outcome of the balance for all treatments. For the treatments KON2 and M we observed a slightly positive P-balance of 3 and 6 kg ha^{-1} $year^{-1}$, respectively. All other treatments showed a negative P-balance, even in the systems with high fertilization levels (DYN2 and ORG2). The deficit in the P-balance was even more pronounced in the farming systems with reduced fertilizer application rates DYN1, ORG1 and KON1 (-11 to -13 kg ha^{-1} $year^{-1}$). The unfertilized control (NON) showed the highest deficit with -19 kg ha^{-1} $year^{-1}$. The calculated P-balance suggests that the full fertilization level in treatments DYN2 and ORG2 is not sufficient to mitigate the entire P removal. This deficit is even more pronounced on treatments with less fertilization. In the long term, this fertilization practice may lead to P limitation, especially in the organic treatments.

Phosphorus availability determined by IEK in the top soil (0-20 cm) declined with time in all treatments. This decline may currently already limit crop yield in some farming systems, yet, a redistribution of P from deeper soil layers seems to mitigate this limitation. Additionally, the relatively high P-status in the soil prior to initiation of the DOK trial may currently still buffer against P-limitation for plants.

The results of this study will be discussed in regard to sustainable P use in different farming systems.