How much phosphorus do our agrosystems really needs?

Emmanuel Frossard, Astrid Oberson, F Liebisch, Sokrat Sinaj, Alain Mollier

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Keynote Abstract:

How much phosphorus do our agrosystems really need?

Frossard, E.[1], Oberson, A.[1], Liebisch, F.[2], Sinaj, S.[3], Mollier A.[4]

[1] *Plant Nutrition, Institute of Agricultural Sciences, ETH Zurich, Switzerland*

[2] *Crop Science, Institute of Agricultural Sciences, ETH Zurich, Switzerland*

[3] *Plant Nutrition, Agroscope, Changins, Switzerland*

[4] *Interactions Sol Plante Atmosphère, INRA, Bordeaux, France*

emmanuel.frossard@usys.ethz.ch

Phosphorus (P) fertilizers (either mineral or organic) are rarely applied in appropriate amounts to crops and grasslands. Excessive P inputs can be due to the presence of high animal density leading to slurry and/or manure inputs in excess to plant needs, or to fertilization practices including a margin of security to ensure that crops will not suffer from P deficiency. In other cases, especially in Sub Saharan Africa, the lack of financial resources of subsistence farmers leads to situations where P inputs are either very low or inexistent, resulting in the exhaustion of soil P resources. These practices have to be modified as they lead to water quality degradation in the case of excessive P inputs, to low yields and food insecurity when soil P resources are exhausted and no P is added, and as the use efficiency of natural resources must increase. This presentation reviews approaches that have been or could be taken from the farm to the field levels to adjust P inputs for an optimal plant production. The first approach that will be presented is the "needs/inputs" budget measured at farm level. This accounts for the total estimated needs of crops and grasslands and the total inputs by mineral and organic fertilizers. This approach has been implemented in Switzerland in the 1990s as part of the direct payment scheme and resulted in a significant decrease of P inputs in agrosystems without decreasing plant productivity. However, this approach is based on estimated plant needs and inputs for manure derived from references values, it does not consider soil P availability and it does not consider the field level. An approach that can be used at the field level is the soil system P budget. It takes into account the P exported by crops/grasslands, the P added by fertilizers and the P losses from the soil profile. This approach allows seeing whether the system studied is in balance for P, and how inputs are used for agricultural production even at rotation level. But it does not take into account soil P availability and it does not inform on the plant P nutritional status. Soil analyses have been used for decades to predict the needs of P fertilizers for plant biomass production. A popular way to study this relationship is to carry out long-term field experiments with varying doses of P and to compare the soil P status estimated by a given chemical extraction to crop yields. This type of approach allowed the establishment of fertilizers inputs recommendations as a function of plant type and soil extractable P and other soil properties. However these recommendations are derived from estimated plant needs, ignoring the variability of plant nutritional composition, and from relatively few long term field experiments as these are extremely expensive to maintain. Furthermore, as the currently used soil chemical extractions only provide a rough estimation of soil P

availability, progress still needs to be done for a more mechanistic estimation of soil P availability that can be implemented in the practice. A further possibility is to include a diagnostic on plant nutritional status in the fertilization strategy. This is relevant as biomass production is a function of N uptake which itself controls P uptake. The phosphate nutrition index (PNI) can be used as a diagnostic tool to estimate whether a plant has a sufficient level of P compared to its N concentration. Plant biomass production, grasses PNI, and soil P extractability have been measured in different types of grasslands. These data allowed estimating the amount of soil extractable P needed to reach a sufficient P nutritional status and biomass production in these grasslands. The limit for the implementation of this approach is to have rapid and reliable measurements of plant biomass and N and P concentrations in plants. Furthermore, this approach does not quantify the amount of P to be added to the plant stand, it only states whether the plant P status is sufficient or not. Whereas remote sensing approaches provide reliable estimations of biomass, leaf surface and N concentration in plants, measurement of P concentration in plant tissue is much more difficult because only indirect spectral features are related to P status of a plant (for example anthocyanin contents). A generic tool allowing estimating P needs and fertilization for different type of crops, growing in different climates and soils and submitted to different management practices, is still needed. Mechanistic models taking into account both the soil and the plant can help to achieve this. The FUSSIM-P-maize model is an example of this approach. It is composed of three modules: one that calculates P needs based on the plant growth as allowed by climatic conditions, one that calculates soil P availability based on the diffusion of P from the soil phase of the soil to the solution, and one that calculates the uptake of P by the root system from the soil solution. If sufficient P is available, the plant will reach maximal growth. But if soil available P is limited then P uptake will be limited, this will reduce carbon fixation, modify C allocation in the plant, affect root growth and morphology and this will decrease P uptake on the long term. The principles of the model are applicable for other plants species (*Festuca, Pinus*). The model needs to be tested in the presence of multiple stresses (N or water limitation, soil compaction) and other agricultural plants. It has the potential to quantify the effect of “rhizospheric processes” on P uptake, which will probably become more significant as soil available P will decrease. And it can be used to predict the critical level of soil available P under which plant biomass production could be negatively affected.