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Phosphorus management in organic farming

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Organic Farming acts on sites with different P fertilisation history
Primarily crop production in organic farming aims to optimise use of soil-borne phosphorus (P) and of fertiliser P applied. Several long-term experiments have shown only slightly lower crop yields after decades of omitted P fertilisation compared to P-fertilised plots (Gransee and Merbach 2000) showing that P mobilisation from the solid phase of the soil can cover crop demands especially when yield levels are lower compared to mainstream agriculture. Soil P-reserves are dependent on specific site conditions and former fertiliser inputs. For Germany a tremendous additive surplus of P input with fertilisers and feedstuff imports in agriculture is calculated on the basis of statistical data. For the time between 1950-2000 additive P input exceeded P removal of crops by about 800 kg/ha P in the new and 1400 kg/ha P in the old German federal states (Köster and Nieder 2004). Also in other regions of the world decades of P fertilisation higher than crop removal have increased soil P levels. At the same time, 30 % of the worldwide agricultural area has negative P-balances (McDonald et al. 2011). It is estimated that 40 % of worldwide crops are affected by P deficiencies (Vance 2001).

Organic farming is currently benefiting from the history of P over-fertilisation. Nevertheless, with negative long-term budgets organic farming will increasingly depend on P amendments in the future (Loes and Oegaard 2001). The questions are then: when will organic farms run into a definite deficit resulting in yield losses and what measures and strategies can be used to replenish the plant available P pool in soils?

P budgets of organic farming systems are often negative
Due to fodder imports and manure management, organic livestock farms are normally described as having balanced or even positive P budgets (Berry et al. 2003) although their P export via milk products and bones of slaughtered animals is higher when compared with arable organic farms. Livestock systems benefit from the intensification of nutrient cycling with animal keeping indicated by feed crop production, nutrient transfer from grassland and use of manures. But if they are using 100% organic feed from farm-own production and have no other P imports they will reduce their P reserves by product export in the long-run. In closed arable organic farming systems specialised on cash crops a nutrient transfer between fields via biogas-manure could be introduced, but generally lower capacities exist to increase the on-farm nutrient cycle. Organic vegetable production often relies on high amounts of nitrogen and P imported by organic manures or green waste composts. These organic inputs can generate surplus P in soils.

Generally, soils under long-term organic farming have lower available P contents than those under conventional agricultural use (Oehl et al. 2002). This does not necessarily mean that yields are limited due to lack of P. Soils under organic and conventional farming mostly differ in inorganic P fractions but seldom in organic fractions except microbial P, which is often higher under organic than conventional farming conditions (Oehl et al. 2001). Extensive analyses of recent P fertilisation trials showed the limited possibility to predict P supply to crops by soil analysis values. It was shown that even if nutrient contents in the top soil classified by CAL and DL method are 'very low' (A) or 'low' (B) there is only little probability to increase yields by additional P fertilisation (Kuchenbuch and Buczko 2011). Thus, P mining in soils with low available P contents indicated by negative P budgets might be tolerable even in the medium or long-term, especially when the lower yield expectations of organic farming are considered.

Soil tests on P for organic farming
A deeper interpretation and active P management is only possible when the availability of P soil reserves can be described. The role of organic and inorganic P and/or microbial parameters for P supply in organic plant production has to be defined and quantified by suitable soil tests. The common fertiliser recommendations in organic farming indicates that the soil test level "low" (B) is sufficient for the typical low yield expectations. Up to now, no systematic relation of P from organic

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Cycling of nutrients and P by mulch of clover grass. *© Hans Marten Paulsen*

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fractions in the soil to P nutrition of crops has been found. However, in organic farming this source is claimed to be of utmost importance in supporting the aim of basing organic production on nourishing plants primarily through the soil ecosystem.

It is assumed that methods of soil analysis used in the past have under-estimated the available P resources in central European soils. Also special soil tests for organic farming have been developed (Haneklaus et al. 2005), but the usability of these methods for organic agricultural practice has not been described and verified.

Organic farming systems are usually predominantly N-limited and the crop P needs for yield level under

Mixed cropping of P-efficient white lupin with safflower. *© Hans Marten Paulsen*

organic growth conditions are not well defined. Furthermore, the available threshold values used to describe P supply in plant tissue are derived from systems fertilised with sufficient mineral N and might not be adequate for lower yield levels. It is obvious that a real P budget management is not possible without further information on these basic parameters.

Mobilising soil P reserves by biological measures

Using suitable root systems and adapted crop rotations

Root geometry, root-length density and active root surface area, increased by mycorrhiza in certain species, are important factors influencing the ability of plants to unlock nutrients from the solid phase of the soil. The enhancement of active root surface to assure an intensive P exploration of plants in soil should be an inevitable goal of agricultural production.

P management in organic farming should entail a composition of crop plants displaying different root systems and capacities for P up-take. For example white lupin and buckwheat are described as having an efficient P uptake and different spe-cies can access different soil P reser-ves (Mat Hassan 2010). Also other dicots displaying taproot systems combined with intensive rhizosphere activity – like lucerne or pea – can be introduced into organic crop rota-tions to strengthen organic P flow. When grown in mixed cropping, P efficient crops can directly enhance the P nutrition of the cropping part-ner. On the other hand, effective P uptake by these plants might also limit P that is available for the fol-lowing crops. Also the cultivation, mulching and redistribution of more common cover crops like grass clover may enhance biological P cycling on farm. The nutrient (and P) value and nutrient relations of the plant tissue can be influenced by crop type and plant age.

Enhancing soil microbial activity

Soil microbes colonise the rhizosphere, enhanced by root exudates. P mobi-lisation from insoluble inorganic and organic soil reserves takes place by soil acidification or exudation of phosphatases by plants and micro-bes. Mycorrhiza and their activity increase with increasing depletion of P soil reserves. But microbes and plants are also competing for the orthophosphate available in the soil solution. Thus, the net balance of available P from these biological processes is difficult to quantify. It depends on several environmental conditions as well as substrate attri-butes, e.g. the C:P ratio of organic materials (Oberson et al. 2010).

Organic inputs can stimulate soil microbial activity and soil P mobili-sation. But since the factors driving microbial P release are not completely understood the prediction of plant available P coming from soil microbes is difficult to quantify.

Organic farming relies on this bio-logical P mobilisation and targeted P fertilisation is often neglected, without knowing the real potential of these processes for an efficient nutrient management. Due to the sometimes high, but in the short-term

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Roots and worms in the subsoil. *© Hans Marten Paulsen*

insoluble, reserves available in soil as well as the relatively low export of P by sold products, this theory is attractive but may mine soil P in the long-term and finally result in P deficiencies. Nevertheless, processes of P-mobilisation hold promise for increasing the use efficiency of P added with mineral or organic sources (Simpson et al. 2011).

P acquisition from the subsoil
Compared with the topsoil, spatial accessibility of the less mobile P in the subsoil is generally lower. But especially under high organic fertiliser supply crop roots can translocate high amounts of organic P downwards by the roots. The proportion of P in the deeper layers is considered to range from 25 to 70 % of the total amount of P in the soil profile. In the subsoil, roots have been reported to grow predominantly in macropores either formed by physical processes such as swelling and shrinking, or biogenically (old root channels and earthworm borrows). The area around biopores, the so-called drilosphere, is considered as a preferred site for nutrient acquisition in the subsoil. Thus, crop-species that can enhance earthworm population should be preferred in organic agriculture. Earthworm excreta are characterised by higher biological activity and higher content of microbial P and alkaline phosphatase activity. Thus, roots growing in earthworm biopores meet higher P contents in the tapestries of the walls coated with worm cast (Pankhurst et al. 2002).

P delivery from the subsoil is enhanced when P content in the topsoil is low, as demonstrated by long-term field trials (Oehl 2002; Wechsung and Pagel 1993). Already before topsoils were extensively fertilised with P, it was shown by means of 32P tracer methods that the subsoil substantially contributed to plant P nutrition. In a degraded prairie soil it was shown, that continuous alfalfa growth can restore lost P reserves by P mobilisation from stable soil reserves (Daroub et al. 2001).

What we should know
The role of a dense plant rooting system in increasing P uptake by physical measures is undoubted. Also the importance of chemical and biological interactions in the root zone is known. But the potential for an increase in biological P mobilisation through management is not quantified and it is still unclear to what extent plants, and soil and root microbes can mobilise the P reserves and feed them into the active soil-plant farm P cycle (Guppy et al. 2009). So these biological measures to enhance P mobilisation are far from confirmed knowledge which can be used in management advice. Due to the complex factors determining P mobility in soil, each component of the P cycle in organic farms should be analysed to decide on the necessity and the right place for P imports. Of genuine importance for organic systems might be the role of P for rhizobial N fixation with legumes (Römer and Lehne 2004). In any case, a hidden depletion of available P in soils under long-term organic management by use of P sources with low availability in the soil/plant P circle should be avoided.

Suitable fertilisers must be discussed
After estimating possible capacities of biological P mobilisation and available P in soils, suitable P fertilisers and fertilising strategies that can be applied in organic farms to correct P imbalances have to be identified.

Use of P fertilisers – especially rock phosphate, which is widely used in organic farming – is potentially linked to soil contamination with Cadmium as well as Uranium (Kratz and Schnug 2005). Furthermore, the use of rock phosphate is often inadequate because most P enters the P budget in more or less insoluble form. When the soil pH is higher than 6, P mobilisation from this source is doubtful and unforeseeable (Arcand and Schneider 2006). Attempts to increase P availability of rock phosphate by mixtures with slurry, manure or compost, or to increase initial P mobilisation by application to plants with high P efficiency improved P usage only little and under controlled conditions. Also, the frequently discussed use of rock powders – e.g. of basaltic or volcanic origin – as fertiliser in organic farming is ineffective, due to low nutrient (and also P) contents and low plant availability. Special developed rock phosphate or bone meal fertilisers generating acid phases to dissolve P have not yet been introduced in practice and are currently not accepted by EU regulation. At least in special cases, the use of soluble P fertilisers such as superphosphate should be allowed.

The recycling of P containing residues from industry and households should also be reintroduced in organic farming under consideration of closed nutrient cycles and under strict limitation of possible pollutants in the sources, e.g. in sewage sludge and composts (Rahmann et al. 2009). Ethical aspects concerning the use of conventional sources and residues from animal production with low animal welfare standards must also be discussed. Therefore farm collaborations that are shifting plant nutrients, among these also P, by livestock and biogas manure from conventional to organic systems should be prepared to face public debates on the consistency of nutrient cycling in organic farming.

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Introduction

Dear Reader,

EcoRegion is an important project that supports the realisation of sustainable development approaches in the whole Baltic Sea Region and contributes to making it a sustainable and prosperous place.

In recent years, progress has been made to advance sustainable development in the Baltic Sea Region. These efforts are now supported by the EcoRegion project, which seeks to turn this area into the world's first EcoRegion, where economical growth goes hand in hand with environmental integrity and social justice.

The project is based on the unique multi-stakeholder network of Baltic 21, which was created for the realisation of the Agenda 21 for the Baltic Sea Region. By way of eight sectoral platforms, Baltic 21 members carry out joint actions and cross-sectoral activities to pursue Sustainable Development in the Baltic Sea Region and the implementation of the Council of the Baltic Sea States Strategy on Sustainable Development 2010–2015. Furthermore the project is aligned with the Aalborg Commitments, through which regional governments voluntarily commit to defining clear targets and implementing concrete actions for Sustainable Development.

Through the EcoRegion project, ten model regions prepare strategic sustainability plans and implement a selected set of concrete measures designed to reach these Sustainable Development targets. This process is supported by a capacity building programme on Integrated Sustainability Management Systems. Numerous workshops foster the inter-regional, cross-sectoral and sectoral-regional dialogue and understanding on Sustainable Development within the Baltic Sea Region. In addition, public materials, including a good practices database, provide information on how to foster Sustainable Development on a regional level.

One of the publications produced by the project is the series EcoRegion Perspectives. It presents policies, projects and practices for the sustainable development of the Baltic Sea Region from various perspectives such as tourism, spatial planning and climate change.

We hope this periodical will give readers an insight into the diversity and potential of innovation and education for sustainable development, and trust that you will find it both interesting and informative.

Dörte Ratzmann,
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

EcoRegion Project Lead Partner