New Approaches to Phosphorus Regulation and Management

Cornish, P.S.[1] and Oberson, A[2]

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Abstract

Phosphorus (P) conservation and the environmental, ecological and economic issues related to over-use and under-use of P on organic farms are addressed. Re-examination of Certification Standards is recommended to ensure the conservation and efficient use of P through adaptation of organic management to local conditions, ecology, culture and scale. Changes that will conserve P and minimise environmental risk are identified, along with the necessary research to make this possible.

Introduction

P export from organic farms is not an issue where soil is fertile, P export is low, and crop and livestock production are balanced by high internal recycling of nutrients, as in mixed farms of the Swiss Midlands (Maeder *et al.* 2002) - few farms can even aspire to this ideal. For others, P is a non-renewable input which is mostly derived directly, or indirectly, from declining stocks of rock phosphate (RP). Paradoxically, available soil-P is declining on some farms/regions causing economic and ecological concern, whilst increasing in others to the point of ecological concern. Here we overview the literature on P in organic farms and make a case-study of Australia to (i) explore whether the cornerstone values of organic production are being maintained, (ii) examine the case for changes in the Certification Standards, and (iii) identify research priorities.

The stocks and flows of P

Soil P dynamics are outlined by Smeck (1985) **-** the '*soil solution'* contains small amounts of dissolved organic and inorganic P. A greater proportion of the total P is chemically *sorbed* in soil or held in readily mineralisable organic forms. Sorbed P replaces plant uptake from the soil solution. In naturally fertile or over-fertilized soils the stock of sorbed P is large: in parts of Europe and North America good crops have been grown without P-fertiliser for decades by depleting sorbed P. Most soil P is in *sparingly soluble* minerals or inaccessible organic matter. Newly added dissolved P is sorbed within hours/days of application or being mineralized, and is eventually 'fixed' into slowly available forms – in Australian studies only 10-20% of applied P is used by plants in the year of application (Bolland and Gilkes 1998, Bünemann *et al.* 2005). Biological changes under organic management may increase access to less available forms of P (Jakobsen *et al*. 2005), plants may be selected for improved access to less-available P (Harvey 2008), and organically-grown plants may access more subsoil P than conventional crops (Cornish 2008). These processes only delay the requirement for P to be replaced by fertiliser or manure (Cornish 2008). If not, the plant-available fraction of P will be exhausted. All ecosystems need to replace the P removed.

Most P absorbed by agricultural plants passes to humans, directly or via animal products. Animal waste is mostly returned to soil, but human waste has in the past mostly returned to surface water in sewage - a major stock of P denied to organic

[1] University of Western Sydney, Penrith South DC, 1979 Australia, Email p.cornish@uws.edu.au

[2] Institute of Plant Sciences, ETH, Zurich. Email astrid.oberson@ipw.agrl.ethz.ch

farmers. This policy removes humans from the ecosystem, depletes P from terrestrial ecosystems and contributes to nutrient enrichment of surface waters. All farmers ‘trade’ P by importing fertiliser, manure, compost and grain, and selling products. As a result of the global and regional P-trade, parts of Western Europe and North America have greatly elevated P concentrations in soil, including any organic farms with a positive farm P balance (Stockdale and Watson, 2002; Oberson and Frossard 2005). Elsewhere, concern is generally for declining soil P and productivity (Cornish, 2008). If no P is applied, the soil stock of P is depleted, which may be *desirable* if it reduces environmental risk, or *undesirable* if P deficiency reduces the protective cover of vegetation over erosion-prone soils and when it forces farmers into low profitability or food insecurity.

Environmental threat from excess nutrient use

Intensive agriculture in Europe is regulated to reduce the environmental risk from N or P inputs significantly exceeding outputs. It may take years for a positive P balance to increase risk over a farm, but localised areas can be at risk earlier. Risks emerge quickly in soil with low P sorption capacity. The issue is complex when manure is used for fertiliser. It is impossible to regulate the use of manure to manage both N and P together. Where manure is the main source of N for crops, more P is applied than necessary (Wells *et al*. 2002), increasing environmental risks. Separating animal and crop enterprises amplifies the problem, yet stockless grain farms and intensive animal enterprises may both be certified. Both face significant issues: ecologically responsible disposal of animal waste; or for farmers who depend on imported manure for N, reduced need for manure achieved ultimately by including more legumes in rotations.

Environmental threat from insufficient phosphorus fertiliser use

Soil P may be low, as with subsistence farmers in parts of Africa (Oberson, unpublished) and India (Cornish, unpublished), and in developed economies such as Australia (National Land and Water Audit, 2001). P export without replacement further lowers concentrations of available P, reduces N-fixation by legumes, and cuts plant productivity. P is transferred from grazed to cropped areas and from there to humans either directly in grain or in meat from animals fed on the grain. In poor rural communities nutrient transfer to near the homestead impoverishes grazed land and increases grazing pressure and land degradation, whether organic or not.

Fertilizer use, phosphorus deficiency, and economic viability

Manure is not always available to organic farmers. In lesser-developed countries manure is in short supply if it is used for fuel, and although individual land holdings may be small, animals range over ‘common’ areas so manure collection is not feasible (Bationo *et al*. 2007). Manure collection is also not possible in some developed regions with low-moderate rainfall as in Australia where crops are produced on large mixed farms. In Europe and North America stockless farms have limited access to manure although most of them have enjoyed sufficiently high fertility to raise crops organically without P-fertiliser. However, P concentrations are falling, questioning the sustainability of this practice. Conventional soil testing may not provide answers. Failure to use fertiliser in each of these situations has serious economic consequences. The major fertilisers used in organic farming are based on reactive phosphate rock (RPR) which requires acid soil and sufficient rainfall to be effective. This excludes much of the world where available soil P is low and fertiliser is needed, including southern Australia where RPR is ineffective in organic crops (Dann *et al*. 1996). This, combined with poor supplies of manure or compost, makes soil P management very difficult for a large grain-producing area. The farmers have tried many P fertilizers, yet productivity is low (Cornish 2008). Their over-optimistic use of fertiliser is uneconomic, inefficient and not in accord with basic principles of organic farming. Yet animal and cropping enterprises are integrated and much of the grain is retained on-farm, thus recycling nutrients in strict conformity with organic principles. **The Standards** do not accommodate the economic imperative to lift productivity from impoverished soil in which allowable forms of P are ineffective or unavailable. This is not a healthy ecosystem, and nor is it sustainable, even if good organic practice is otherwise observed. Soluble P added to soil with *high P sorption capacity* and *low solution P* is rapidly incorporated into bio-geochemical cycling. The soluble P feeds the soil, which in turn feeds the plant. Adding soluble P when necessary to maintain soil health seems, to us, to adhere to the organic maxim: “feed the soil, not the plant”.

It is important for organic farming to maintain the principles of minimising imports by maximising opportunities for recycling; maximising efficiency of resource use; and supporting plants through the soil ecosystem. It is also important that the soil ecosystem itself be ‘fed’. Our present knowledge and fertilizer options leave some important situations, exemplified in the foregoing overview and Australian studies, where soluble P remains the only option for feeding P to the soil ecosystem in a way that it can support economic levels of plant production.

Nutrient deficiency reduces water-use efficiency

In water-limited environments, water is the most precious resource after land, and yet nutrient deficiency often sets an upper limit to yield. Farmers have *some* control over nutrients but *little* control over water. With low nutrient inputs, stable production is achieved, but at the cost of a low level of productivity. Production in natural ecosystems in such environments varies inter-annually in response to varying rainfall. Stable but low level yields are not a sign of sustainability.

Organic Certification Standards

Farming systems evolve in a more complex socio-economic environment than when Standards for organic production were first conceived. For example, it could not have been anticipated that changing ‘culture’ and scales of production would lead to the stockless or intensive animal farms now accommodated within the Standards, without ensuring that subsequent problems of nutrient enrichment or depletion are managed. Organic principles embrace the idea of “adaptation of organic management to local conditions, ecology, culture and scale”, but there are many examples of failure to adapt or develop systems that (i) adequately conserve or recycle P, (ii) reflect the unavailability of organic-P sources despite sound organic practice, (iii) reflect gross differences in soils between regions and (iv) differences in the capacity of soils to retain P against environmental losses. The application of Organic Standards has focused on details, whilst in some ways blurring the fundamental aims.

We recommend overhauling the Standards to reassert the core values and objectives of organic farming. Greater sophistication in their interpretation and application is needed, informed by science, to match the heterogeneity in farming systems, regions, soils and cultures. *Accumulation and decline in P must both be addressed, including an allowance for soluble P where it is the only option for feeding P to the soil ecosystem.* Here, the same flexibility is needed that in Europe allows (i) soluble potassium as K_2SO_4 to be used and (ii) accommodates both stockless farms and intensive livestock farms, against all ecological principles. Greater attention is needed in the Standards to nutrient recycling, plus monitoring and evaluation of trends in soil P and the balance of P at the farm gate.

Research and extension

Priorities are to quantify P cycling processes and develop suitable soil tests for organic farms; to improve plant access to reserves of soil P where they are high; to develop strategies for farmers to manage the transition from P sufficiency to deficiency; and to improve the availability of RP. Cultural change should allow the unsustainable blanket ban on human waste to be reconsidered and foster research to make it safe. Other ways to recycle nutrients need to be identified and promoted along with opportunities to reduce P inputs where they are needlessly high. Farmers should also be alerted to the potential costs of over depleting soil P. Fertility management products, and techniques involving paid services (e.g. the 'Albrecht' system) need proper evaluation.

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