Long-term management of nutrients in organic farming - principles and practice

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Implications

Organic farming faces a number of challenges as it moves forward. It has become a part of the global agricultural industry and therefore organic products are traded not just between farms and regions but between countries and continents. Inevitably, large amounts of nutrients are exported from farms as part of this process. These farms can only continue to produce acceptable quantities of quality food if these nutrients are replaced. Soil has a finite capacity to supply crop nutrients unless they are replenished. The solution is perhaps easiest for nitrogen where biological fixation by legumes can be harnessed to provide the engine for crop production. For other major and micronutrients more consideration needs to be given to acceptable sources for organic production; in situ mineral weathering from soil parent materials will only rarely meet crop demand. In addition we need to understand and improve the recycling and management of all nutrients on farm to optimise crop and livestock production and quality while minimising losses.

Background and objectives

The EU Regulation on organic food 834/2007 (EC 2007) sets a legal framework for practices which are considered acceptable within organic production. The regulation also aims to embody the principles of organic production set out by IFOAM (Health, Ecology, Fairness and Care) and states these principles within the regulation. A key concept within organic production is the idea of a balanced system (especially within the Health and Ecology principles) and to a limited extent the regulation addresses this issue by controlling the sources of external nutrients that can be imported to the farm. The regulation is mainly focussed on the farm as this is considered to be the main unit of control. However some wider scale issues are also addressed, e.g. the ability to import organic fodder from within the region. There is a vast body of research on nutrient management in organic farming carried out within Europe over the last 30 years but the majority of it focuses on nitrogen (N) and phosphorus (P) with fewer studies on potassium (K) and very rare consideration of secondary macro (Ca, Mg, S) and the wide range of micro-nutrients. Within this paper we address some of the options and challenges for improving the long-term management of nutrients in organic production with a consideration of both local and global scale issues. This is not a comprehensive review of nutrient management in organic farming but provides the opening for a debate on future issues in nutrient management in organic production.

Discussion

Recently there has been considerable controversy in the scientific literature with regard to quantifying and closing the yield gap between organic and conventional production (Reganold & Dobermann 2012; Seufert et al. 2012; Connor 2013). Increasing yields in

organic farming will require an increase in both the total amounts of macro and micro-nutrients and their availability from acceptable sources. If higher yields are to be achieved sustainably, this requires a concerted approach from agronomists, soil scientists and plant breeders . Farmgate nutrient budgets for organic farms show both positive and negative results for macro and micro-nutrients e.g. Haas et al. 2007; Nesme et al. 2012; Watson et al. 2012. Many budgeting studies show balanced nutrient budgets (values close to zero) for P and K but studies are sometimes published from data collated for only one year. This may mask critical issues in organic production where practices may be planned on a rotational basis e.g. nutrient import in permitted fertilisers. Some crops export much larger quantities of nutrient per kg dry matter than others and this kind of detail can also be lost in budgets calculated for short periods. It is essential that nutrient budgets are estimated over at least one full crop rotation and that this information is used alongside soil analysis to allow useful interpretation whether for farm planning or policy-making.

Nutrient management in organic horticulture is perhaps a special case in relation to both the principles and practice of organic production. Within organic field-based annual cropping systems, the principles of organic farming suggest that use of crop rotation is key to the provision of nutrients to growing crops and that this can be supplemented by acceptable inputs of fertilisers and manures. However in protected cropping, where standards are currently under-developed, the use of crop rotation is more difficult issue as setting aside land for fertility building is generally not economically viable. As a result production in protected cropping systems may be more heavily based on imported nutrients than in field based systems, although total limits on applied N still apply. There is currently no requirement for field-based and protected cropping systems to be linked e.g. in the way that intensive livestock systems (pigs, poultry) are required to have a field-based element when produced organically.

Optimisation of the use of on-farm nutrient sources such as soils, crop residues and farmyard manure where available is critical in any approach to increase yields in organic production. However, in addition to these resources and selection of suitable plant species and varieties, locally available off-farm materials are an important option. While once viewed only as waste for disposal, materials such as food processing, kitchen and garden wastes can represent a valuable source of various nutrients (as well as potentially toxic elements). However, use of such soil amendments in organic farming requires these materials to be approved for use in organic farming and to be analysed prior to application so that they can be used appropriately with a rotational nutrient management plan, as well as in line with environmental legislation to protect agricultural land and the food chain (European Community and national regulations e.g. EC, 1986). Manures, composts and other organic materials as well as imported feed may contain both macro and micro nutrients which need careful scrutiny in the long-term. For example, high levels of copper have been found in manures due to contamination with waste from footbaths using copper salts (e.g. Jokela et al. 2010) and Zn from metal equipment or building materials in animal housing in also increased in manures (Öborn et al. 2005). Waste materials, and thus nutrients, from processing and/or consumption of organic products are not generally returned to organic farming systems potentially resulting in nutrient depletion of soils.

There are ongoing debates about whether the food system in Northern Europe can continue to rely on global transport of food; hence there has been an increased interest in relocalisation of the food system (Peters et al., 2008). Changing diets have been a

major driving force in the spatial decoupling of consumption and production. This is not only the demand for "exotic" products which cannot be produced locally and year-round consumption of seasonal goods but also the changing patterns of meat consumption. The EU imports the equivalent of 37 million tonnes of soya bean, accounting for about 15 million hectares of land outside the EU and the largest cause of the EU net 'virtual' land import (von Witzke and Noleppa 2010). This is increasingly pertinent for organic farming which now has substantial global trade and increasing numbers of countries requesting recognition of their organic standards by the EU. As a result of spatial decoupling of food production and consumption, macro and micronutrients are being exported not just from organic farms but from entire regions and replacement nutrient inputs acceptable to the organic standards will have to be found (ideally in the country of production) if soil fertility is to be maintained. There has also been increasing decoupling of crop and livestock production in Europe over the last 40 years and it is interesting to consider whether this has occurred in organic production to the same extent that it has in conventional production. From a point of principle there is an expectation that mixed farming will be more prevalent within organic production, with a degree of reliance on home produced feed and fodder.

The scale at which nutrient management is best considered to answer questions about long-term sustainability of organic farming in relation to nutrients is thus an interesting one. Nesme et al. (2012) question whether the farm is the correct scale to address nutrient balances in organic farming or whether groups of farms or regions are more appropriate. This larger scale would allow exploration of the issues about decoupling of livestock and crop production and also the appropriate uses of local soil amenders or "waste" products. Ultimately, returning human waste to organic farms is one way to help to "close the nutrient loop" although this is not currently allowed within the EU regulations. Issues over the use of globally traded commodities like rock phosphate within organic production continue to be up for debate. It is however very difficult to obtain figures which allow robust independent analysis of the reliance of organic production on the use of particular inputs.

Improving the management of nutrients in organic farming in the long-term will continue to challenge the research community. It undoubtedly will require a range of approaches both on farm and at a wider scale. However, in looking for economically viable solutions to on-farm and off-farm nutrient management challenges, it is essential to hold on firmly to the principles of organic production.

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