Appendix 4
Draft of article for Elm Farm Bulletin

**Optimising P and K management in organic farming systems (aim for two pages of A4)**

For the past three years a research team drawn from Elm Farm Research Centre, IACR-Rothamsted, the Royal Agricultural College, SAC and the University of Reading have been working to improve and integrate the best scientific understanding of phosphorus (P) and potassium (K) cycling in organic farming systems. Our aim was to improve the advisory guidelines currently available for P and K management drawing on the best of published work, where appropriate, and carrying out new investigations, where necessary.

It has been the perception of many conventional farmers and scientists that organic farmers are running down the long-term fertility of soils with regard to P and K, because they do not use the regular maintenance dressings of P and K fertilisers common to conventional agriculture. However, organic standards clearly stress the need of organic farmers to maintain or enhance the long-term fertility of the soil. So for a number of farm systems and crop rotations on organic farms we compiled P and K budgets. The difference between the sum of the inputs and the sum of the outputs gives the farm/rotation nutrient budget. If the inputs and outputs balance, the system can be considered to maintain soil fertility, while a surplus can indicate a potential for loss and a deficit raises questions of sustainability. (*Such an approach can also be taken for N. Watch out for guidelines and reference tables to allow the compilation of N, P and K budgets coming out in the next year as part of the output of further MAFF projects*).

Where P and K budgets were compiled for rotations on organic farms around the UK, both surpluses and deficits are seen for P and K (Table). These differences arise from the contrasting rotations, varied interactions with on-farm livestock and the use of supplementary nutrients, such variation is typically seen in similar studies in Scandinavia, Germany and New Zealand.

Table Simple summary of rotational budgets for P and K around the UK

| Rotation | | Livestock | Supplementary nutrients | P balance kg/ha/year | K balance kg/ha/year |
|---|---|---|---|---|---|
| 1 | Red clover/vetch, potatoes, winter wheat, spring beans, spring wheat | None | + redzlaag | - 2.6 | -38 |
| 2 | 2 year grass-clover, potatoes, onions, spring barley | None | + compost | + 1.9 | -20 |
| 3 | 3 year grass-clover, oats, swedes, oats undersown | Beef/sheep | | -16.2 | -64 |
| 4 | 3 year grass-clover, winter wheat, winter triticale | Beef/sheep | + redzlaag | + 6.3 | -23 |
| 5 | 3 year grass-clover, winter wheat, winter triticale | Dairy | | -10.7 | -37 |
| 6 | 2 year grass-clover (pigs), winter wheat, spring wheat, cereal | Pigs/beef | + redzlaag | + 5.9 | -28 |
| 7 | 3 year grass-clover, fodder beet, spring beans, winter triticale | Dairy | + redzlaag | +33.9 | +13 |
| 8 | 3 year grass-clover, winter wheat, w. oats, w. beans, winter wheat, spring oats/winter triticale | Sheep | + redzlaag | + 5.9 | -36 |
| 9 | Red clover, winter wheat, spring beans, spring cereal | None | | -9.5 | -21 |
| 10 | 2 year grass-clover, winter wheat, spring cereal, pigs on stubble, winter wheat | Pigs/sheep | | +23.1 | +26 |
| 11 | 2 year grass-clover, winter wheat, oats, winter beans, winter wheat, spring barley | Chickens | | +5.9 | 0 |

Where supplementary P was not applied, relatively large P deficits are seen (Rotations 3, 5 and 9). In Rotations 10 and 11 the use of supplementary feed for the non-ruminant livestock may have caused the P surpluses even in the absence of supplementary P. At the farm level, bought –in supplementary feed and bedding materials can represent significant inputs of P and K to the farm. In most cases where supplementary P was applied, any P deficit was cancelled out. The large P surplus in Rotation 7 would be removed if supplementary P fertiliser was withdrawn.

Significant K deficits are common in these rotations. Only Rotation 2 received any supplementary K (in compost). However, calculation of nutrient budgets at the farm gate for mixed organic farming systems did not show any significant K deficits. In rotations with livestock it is crucial to balance removals of K in silage and crops with the returns in manure and slurry. This was achieved in rotation 11, but K surpluses occurred in Rotations 7 and 10 and other livestock rotations showed K deficits. Over time this can lead to the creation of spatial patterns in nutrient enrichment and depletion around the farm, even where the whole farm seems to have a balanced nutrient budget.

These calculated budgets (Table) do not account for any supply of P or K from soil reserves. Nutrient surpluses may lead to the build-up of soil reserves, so long as losses are prevented. Potassium-releasing heavy clay soils can release around 60 kg K $ha^{-1}$ $year^{-1}$, even in soils of lower clay content these mineral can still release significant amounts of K through weathering. However, carboniferous clays do not release much K and local knowledge of the soils is critical in assessing the potential of the soil to support any K deficit.

- Very simple nutrient budgeting can be used to indicate surpluses or deficits of P and K in rotations or at the whole farm level.
- Organic farming systems do not necessarily have either a deficit or a surplus for P and K. The nutrient budget depends on farm management.
- Nutrients exported in produce should be replaced from an acceptable source. However, it is critical that a nutrient budget contains all possible inputs and outputs.
- Imports of supplementary feed and bedding material can represent a substantial input of P and K. These are then used in the system in manures.
- The sustainable release of K from soil minerals by weathering on some soils can correct an apparent K deficit.

Field experiments with supplementary nutrients were carried out on silage leys at Elm Farm, SAC and the Royal Agricultural College. Cores of the same soils were also taken back to the greenhouse for more intensive crop growth studies. The measurement of available K in soil, using ammonium nitrate (UK standard method), related strongly to crop K offtake. The conventional index of soil K does seem to be a useful guide to the likely response of crops to K application in organic farming systems.

Additions of FYM or green waste compost (25 tonnes fresh weight $ha^{-1}$) significantly increased available K in soil. The supplementary K fertilisers were applied at 41.5 kg K $ha^{-1}$ (=50 kg $K_2O$; potassium sulphate, Kali Vinasse, MsL-K) also increased available K. At the same application rate Kali vinasse supplied as much K as potassium sulphate. But at the typical farm application rates used FYM supplied 5 times as much and compost twice as much K in total. Crop K offtake was significantly increased by applications of FYM and Kali vinasse (to a lesser extent) and this effect persisted for at least two seasons after application. These materials also added some N to the system, and while some of the effect measured was due to the supply of K, interactions between nutrients would have also led to the yield differences. MsL-K increased the pool of slowly available K (non-exhangeable) in soil, more than the available pool. It is expected to release K more slowly, but no effects of MsL-K were seen on crop K contents or offtake during these experiments.

Despite the range of P availability in the soils used, measured by Olsen P, there were no effects of any fertiliser treatment on the P content of grass-clover swards or arable crops in the experiments. P offtake was not increased above that of the control soil except occasionally where yields were significantly increased by other factors eg. with FYM addition. P dynamics in soil are the result of the complex interaction of both mineral and organic cycles. The conventional P index measures only the available fractions of the mineral pools. Large amounts of P can be contained within the microbial biomass (c. 150 kg P $ha^{-1}$ at Elm Farm) and in other organic forms in the soil. The P in the microbial biomass seems to increase as the conventional P index decreases. It is also known that the activity of mycorrhizal fungi, which can facilitate P uptake by crops, increases as the conventional P index decreases. The interaction of the mineral and organic P cycles may have enabled even soils with a very low P index to meet the crop P demand in these experiments. The conventional P index does not seem to be a very good guide to the likely response of crops to P application in organic farming systems. At low P index values applications of P in organic forms may therefore be critical to stimulate P dynamics and soil P supply.

On the low P index soils used, available P (Olsen) was increased by the addition of organic materials (FYM and compost at 25 t $ha^{-1}$). Sewage sludge (currently prohibited in organic systems) increased available P in soils very significantly, and if problems with its use (e.g. metal contamination, transmission of disease) could be overcome it would become a useful source of supplementary P.

- Where supplementary nutrients are required, many locally renewable waste products may represent good sources of P and K (e.g. green waste compost, rapemeal) – but acceptability must always be checked with Sector Body
- Organic residues (manures and crop residues) should be treated as a resource. Waste management plans are desirable. Adherence to Codes of Good Practice for storage and application will minimise losses.
- When planning manure applications use the best available information on nutrient contents – get your own analysis or use 'organic' values (*Watch out for the publication of a Guide to Manure Management for Organic Systems in the next year)*
- P and K behave differently in soils and crops. Although they tend to be managed together in conventional agriculture, different factors control their use and availability for crops.
- Manage nutrients in space and time. Make sure nutrient sources are applied in sequence to different areas of farm. Identify crops with high demands.
- Response to supplementary P and K is dependent on the presence of adequate N. Responses more often seen to mixed nutrient sources than to applications of P and K individually.