3rd QLIF Congress, Hohenheim, Germany, March 20-23, 2007
Archived at http://orgprints.org/view/projects/int_conf_qlif2007.html

Phosphorus Management on 'Extensive' Organic Farms with Infertile Soils

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Key words: phosphorus, Australia, soil fertility, grain, grazing

Abstract

Two case-study farms with negative P balances maintained acceptable productivity without fertilisers, apparently by 'mining' 'available' P reserves in surface and subsoil. The question for these organic farms is 'how long before fertiliser is needed?' With six farms on lower-fertility, weakly acidic to alkaline soils and modest rainfall (380-580 mm/yr), low productivity was related to P deficiency despite positive P balances from using allowable fertilisers. Useful supplies of compost or manure were unavailable. Until effective allowable fertilisers or microbial inoculants have been developed, there is a case for using soluble forms of P fertiliser on soils where soil-solution P is low and soil P-sorption is high, so that additions of soluble P 'feed the soil, not the plant'.

Introduction

Australian agriculture has traditionally been 'low input-low output' because of the variable (risky) climate, generally infertile soils, and relative costs of land and labour (Freebairn *et al.* 2006). Low inputs have led to declining fertility in areas that were once fertile. Hydrologic imbalance has led to rising water-tables and dryland salinity in some areas, so higher water use from productive crops and pastures is needed to correct any imbalance. Organic agriculture is set against this background of inherently low or depleted soil fertility and a need for systems with increased water-use, at least on the 20 M ha used for extensive crop or mixed-farms producing grain, meat and wool. Productivity is important as there is no financial incentive to convert to organics. Soils are often low in organic matter but manures and composts are scarce, leading Penfold (2000) to conclude that problems with P constrain the adoption of organic farming on extensive grain farms. This paper tests Penfold's conclusion through farm case studies and literature, and explores broader questions of sustainablility.

Materials and methods

The case studies were grain-wool-meat producing farms from a range of soil types and agro-climatic regions. Biodynamic dairies were included (from Burkett *et al.* 2006) to contrast intensive animal-based systems. Intensive horticulture was excluded as it uses high organic inputs (Wells *et al.* 2002). Conceptually, if outputs exceed inputs over the longer-term, then to maintain production soil P must ultimately be accessed from a) presently unavailable or 'slowly available' sources, b) available but inaccessible sources like subsoil or c) transfer from other parts of the farm that need less P. Thus questions were: are the farms in P balance? If not, is productivity being sustained? If yes, but the P budget is negative, where is P coming from? If P is added, but production is low or declining, why? Eight farmers were selected with a history of organic farming and respect in the industry. Two others were well-known low input wool and grain farms where wheat is cropped into permanent *Medicago sativa* or

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native grass pasture with low inputs of superphosphate, on 10-20% of the farm area which is rotated annually. Data were used to estimate farm-scale P budgets, the intensity of production (crops/time, animals/area), areas of crop/pasture, yields, potential for movement of P around farms, farmer's perceptions of productivity and constraints from P, and attempts to deal with any perceived 'constraint'. Other data were typical rotations, sales (or retention) of grain and animals in different classes (dairy, beef, sheep for wool or meat etc.). P removal calculations used published P concentrations (Anon. 2000).

Results and discussion

The farms were moderately large for their respective areas/industries and had been organic for long periods (Table 1). All farmers said they managed P within the context of general soil fertility and whole-farm management, not as a single-issue.

Case Study farms with a negative P balance. Of the 7 *organic* farms (excluding the 5 biodynamic dairies and the non-organic mixed farm), only 2 farms had a negative P balance (Farms 1 and 7). These were the dairy (-4.84 kg/ha/yr) and one mixed farm (-3.76 kg/ha/yr), both on fertile soils. These farmers were not concerned about P.

Table 1. Description of Case Study Farms and their P balance

Farm number/ main enterprises	Years organic	Soil group	Annual rainfall (mm)	Farm area (ha)	Farm P balance (kg/ha/yr)	Farmer sees P as 'problem'
1 grain/graze	37	Vertisol	660	890	-3.76	Yes
2 grain/graze	44	Aridisol	381	1093	0.69	Yes
3 grain/graze	28	Unknown	475	506	7.15	Suspected
4 grain/graze	20	Aridisol	375	180	5.23	Yes
5 grain/graze	8	Alfisol	580	580	1.81	Yes
6 grain/graze	15	Aridisol	500	441	0.73	Yes
7 dairy/crop	16	Mollisol	900	214	-4.84	No
8 graze/grain	Low input	Sodisol	400	2100	0.28	No
9 graze/grain	Low input	Sodisol	550	1500	-0.15	No
Biodynamic dairies*	various	various	various	various	-7.10	Unknown

*Burkett *et al*. 2006. The 5 biodynamic farms were paired with conventional farms for the study. The P balance here ignores losses in runoff and precipitation in soil, included by Burkett *et al*.

Biodynamic dairies: negative P balance. The 5 biodynamic dairies were in large negative P balance. Data of Burkett *et al.* (2006) showed that Olsen-extractable soil P concentrations in the surface (0-10 cm) were much lower than in the conventional farms with which they were paired, that subsoil P was accessed, and that pasture had lower P%. Production was lower in the biodynamic dairies (milk/cow, cows /ha).

Positive P balance of 'mixed' farms. Five of the 6 organic grain and grazing farms were in positive P balance (0.69 to 7.15 kg P/ha/yr), three substantially so. All of these farmers were concerned about P, citing visual evidence, falling productivity and low soil P tests. One (4) had just ceased farming organically after 20 years, citing low productivity due to P deficiency and no allowable fertiliser giving useful responses.

Extensive mixed farming is the main land-use in arable Australia, an area >20 M ha. Farms 2 to 6 cover the main soils, so it is a concern that such difficulty is experienced managing P on these organic farms. None used much organic P (manure, compost) due to very short local supply. With declining productivity and other evidence of P deficiency, they are hardly 'sustainable', despite inputs of P. The fundamental problem is low availability of rock phosphates due to low rainfall or insufficiently low pH (Sale *et al.* 1997). Managing P is an intractable problem on these extensive organic farms, confirming Penfold (2000). The dairy farms may have currently enjoyed acceptable productivity and profitability, but depletion of soil P is inevitable. They cannot be sustainable in the long term. Only farms 8 and 9 can be regarded as sustainable in this regard. These low input farms are mainly grazing, with small P exports in wool and lambs balanced by inputs of soluble-P to small areas of crop that are rotated.

How do the organic farms cope with P? Farms in negative balance 'mine' 'available' P that may not be accessed on conventional farms, including subsoil P. The case study dairy also set modest production targets and added value by integrating production with processing and marketing. The mixed farm on vertisol soil (1) relied on mining of once-high soil-P reserves, much as conventional farms in the area (Dalal 1997), but average wheat yields of 2.5 t/ha are low compared to the estimated potential of 4.2 t/ha (Table 2), pointing to depleted fertility. The farmer confirmed this, citing low soil-P concentrations. Profitability was maintained by integrating operations with a local cattle sale yard (cattle fattening) and a second farm. Only the grain was sold as organic. *The question for these farms is 'how long will the available sources of P last'*.

Farmers with extensive 'mixed' farms on lower fertility soils had evaluated many inputs, particularly reactive phosphate rock (RPR), guano and microbial inoculants. All of these farmers lacked confidence in these products, yet such was the problem that enough P-fertiliser was used to give a substantial P imbalance in three cases. Low yields (Table 2) suggest all but one of these farms has reason to be concerned about productivity. (This did not necessarily mean lower profitability.) A major issue for mixed farmers is the ineffectiveness of insoluble P sources and poor supplies of alternative organic sources. *For these farmers, the urgent need is for allowable fertilisers which work and are cost-effective*. These farmers coped by a) using P-fertiliser (ineffectively), b) using relatively low cropping intensities and/or c) retaining a significant proportion of the grain produced on-farm for stockfeed (Table 2). Long pasture phases allow 'unavailable' P from mineral sources to enter 'available' pools and may mobilise P from subsoil to surface through deep-rooted perennials (Farm 8,9). Export of animal products results in lower losses of P than in grain. These systems are atypical of the region. Farm economics dictate the ratio of crop/pasture (animals). Farms locked into a low ratio will suffer economic disadvantage at times.

Table 2. Details of 5 mixed enterprises, all using approved P fertilisers

Farm number	2	3	4	5	6
Cropping intensity	0.2	0.5	0.5	0.13	0.25
Grain/hay retained on-farm	>50%	<10%	>80%	~50%	>30%
Product exported Major (*minor*)	Meat, grain *wool*	Wool, grain	Meat, Wool *wheat flour*	Meat, wool *eggs, grain*	Meat, wool *grain*
Average wheat yield (t/ha)	<1.0	3.0	1.2**	2.0	1.2
Est. rainfall-limited wheat yield (t/ha)*	2.8	3.2	2.5	4.3	4.6

*Estimates based on methods in French and Schultz (1984), Cornish and Murray (1989)

** Ceased organic production 2005 due to low yields caused by P deficiency

What can farmers on relatively infertile soils do? Biofertilisers' or soil inoculants may help plants access P that is normally unavailable, but performance is variable and yield responses are mostly small (Jakobsen *et al.* 2005). Conventional farmers who wish to use less fertiliser on high-P soils may accept this, but for most organic farms this is not an option. Studies of mycorrhizae on organic farms have not shown enhanced P nutrition or access to less available sources of P (Ryan (2000 and *pers. comm*.). Early work with RPR/S mixtures showed increased P uptake and biomass of fodder mixtures (Evans *et al*. 2006). An unproven variation on an old approach is inoculation and composting RPR with C-rich material e.g. molasses. According to Evans (*pers. comm*.) this avoids early competition for substrates in the rhizosphere and soil and gives control over the supply of C and the P-solubilising organisms(s).

Conclusions

On organic farms that don't replace P, the question is 'when will fertiliser be needed?' On extensive, mixed farms with infertile soils that are weakly acid to alkaline and receive modest rainfall, P fertilisers are ineffective. Here, there is a need for cost-effective fertilisers. Composted RPR and S-amended RPR hold more promise than microbial inoculants in the future. The case studies confirm earlier reports that managing P is a major problem for many organic farmers, particularly grain growers (Penfold (2000), impeding wider conversion to organic systems.

Given the current lack of effective fertiliser options, there is a case for using soluble inorganic P sources where it can be shown that the soil solution concentrations of P are low and P sorption capacity is high, such that any added soluble P will be rapidly sorbed and find its way to plants only via slow desorption into the soil solution. This is consistent with the organic principle of 'feeding the soil, not the plant'.

Acknowledgements

The Rural Industries Research and Development Corporation, sponsored a workshop with the case study farmers and scientists. My thanks go to these many colleagues.

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