Professor G.W. Leeper Memorial Lecture 2007 SUMMARY

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Prelude

First, some background to the Leeper Lecture with a Western Australia flavour. Sir John Winthrop Hackett was a Sub Dean of Trinity College at the University of Melbourne and crucial to the establishment of The University of Western Australia. He was a friend of Alexander Leeper, who was the first Warden of Trinity College, and he named one of his sons Geoffrey Winthrop Leeper after Sir John Winthrop Hackett. Geoffrey Leeper became a Professor at The University of Melbourne where he taught Alan Robson who is now the Hackett Professor of Agriculture and Vice Chancellor of UWA. I heard some of this history from Professor Don Markwell, a recent Warden of Trinity College and now Deputy Vice Chancellor (Education) at UWA, and I first heard about Professor Leeper from Alan Robson at UWA in the early 1970s. Thus, Professor Leeper was part of a long-standing connection between UWA and the University of Melbourne.

Professor Leeper was most particular about the use of the English language, and his writings on this topic included "The Scientist's English" published in the *Australian Journal of Science* in 1941. He stated in this article that "…… every man must have his own style, and some like long words more than others. But the scientific world may be divided into two groups, those who try to find things out and those who endeavour to ascertain them, and we of the first group spend far too much time trying to find our what those of the second group mean." His articles were read widely, including by my husband, as an undergraduate at the University of Sydney under the tuition of Professor Charles Birch.

Organic agriculture: a model for understanding soil fertility

I selected the title of this lecture as a platform for investigating the concept of soil fertility. Organic agriculture has a strong dependence on soil biological fertility, a component of soil fertility easily overlooked by modern agricultural management practices. There is a unique opportunity to use organic agriculture as a model for exploring the relative roles of soil chemical and biological processes in food production.

In Western Australia in the 1980s, the solution to serious nutrient pollution of the Peel Inlet-Harvey Estuary was the construction of the Dawesville Cut to flush nutrients in these waterways into the Indian Ocean. Education programs for nutrient use efficiency were put in place in the surrounding agricultural areas. More recent concerns about nutrient

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pollution in the Swan River may be linked to loss of nutrients from both urban and agricultural sources. In 2006, the Western Australian Minister for the Environment proposed a ban on the use of soluble phosphate fertilisers on the Swan Coastal Plain by 2011. Legislation to restrict the use of soluble phosphorus in this region was foreshadowed.

The Fertiliser Industry Federation of Australia (FIFA) has already addressed issues related to use of fertilisers by introducing the FERTCARE program (http://www.fifa.asn.au/default.asp?V_DOC_ID=1071). This program seeks to increase awareness of the need to minimise detrimental impacts of fertilisers to ensure sustainable farming and fertiliser industries. The FERTCARE program is designed for everyone in the fertiliser industry, including those producing, transporting, selling, storing and spreading fertilisers. Modules are also available for advisers who make recommendations on fertiliser use.

There are excellent examples of information for avoiding nutrient loss from agricultural land (e.g. the Farm Nutrient Loss Index - User Manual in Victoria). Information is also available for protecting waterways and marine environments from damage caused by excessive nutrient and soil loss (e.g. the Land Use Impact Model (LUIM)). Protocols within these publications describe practices for avoiding loss of soil fertility which can cause off-farm problems. However, most agricultural soils are managed to increase chemical fertility without particular attention being paid to soil biological fertility. It is also possible for some biological components of soil fertility to be overridden by addition of soluble fertiliser (N and P). In contrast, organic farming systems depend more on soil biological fertility than do other forms of agriculture.

The organic agriculture model is based on well-defined certification processes (see websites for the Organic Federation of Australia (OFA) http://www.ofa.org.au). Organic certifiers maintain standards of practice which they regulate. Certification covers allowable forms of nutrients, and although nutrients must be added to replace those lost in produce, the higher reliance on soil biological fertility leads to greater emphasis on cycling of nutrients from organic matter and management of soil carbon through inputs (e.g. compost and manure), use of green manures, retention of stubble etc. A new Australian Standard is being developed for organic production and AQIS approval is required for Australian organic exports.

How can soil biological processes be maximised to support appropriate levels of biological fertility? Options include: use of green manures; rotations with legumes; use of less intensive cropping; use of mineral ground rock fertilisers; and dependence on residual (chemical) fertilisers. Does this mean a focus on soil biological fertility would lead to a yield penalty? Organic practices may not maintain current levels of chemical fertility in some soils and climatic zones (especially for phosphorus) and they are not immune to nutrient loss. However, the purpose of focusing on organic systems as a model for understanding soil fertility is (i) to consider the extent to which soil biological processes might contribute to soil fertility in all farming systems, and (ii) to consider whether or not full benefits of these processes are captured.

Interactions among organisms in soil are complex, but collectively, they are primarily involved in converting organic materials into plant-available nutrients. There is a wide range of soil tests which can be used to identify the level of activity of soil organisms, including assessment of carbon-based fractions, microbial biomass (carbon) measurements, characterization of groups of organisms (e.g. mites and earthworms, or bacteria such as rhizobia or nitrifying bacteria). Organisms can be assessed in terms of soil biodiversity (e.g. at the DNA-level) or in terms of their activity (e.g. enzyme activity). Other assessments include the presence of mycorrhizal fungi in roots or the relative abundance of fungi and bacteria (e.g. ratios of fungal to bacterial biomass). Different soil tests are relevant at various scales (e.g. at the soil pore, soil profile, paddock, whole farm or catchment scale).

Differentiation between chemical and biological fertility is not straight-forward. Some biological processes influence components of soil chemical fertility (e.g. soil pH and transformations of nutrients). Therefore, measurement of components of soil biological fertility is complex and has to be considered in the context. Simple soil tests may not explain the whole 'chemical fertility story'. For example, some chemical transformations can be biologically mediated, but slow mineralisation of nutrients may not be detected as an increase in nutrients in soil if plants remove them as soon as they are released. Slow release - rapid uptake of nutrients by plants may be interpreted as low chemical fertility, but this may not be an accurate interpretation for organic systems.

Both nationally and internationally (see websites of the OFA http://www.ofa.org.au/ and IFOAM http://www.ecoweb.dk/ifoam/), there is considerable information about nutrients permitted for use in organic farming systems. A common source of some nutrients for organic farming systems is relatively insoluble forms of rock and their slow dissolution can be mediated by both microbial and chemical processes. Recent studies have shown how different communities of microorganisms may be associated with particular minerals (e.g. Gleeson et al. 2005, Microbial Ecology 50, 360–35), but the importance of specific microorganisms in dissolution of rock minerals used by organic producers is not yet understood.

Soil is a fractal habitat for countless forms of organisms. The physical characteristics of soil determines its capacity to protect organic matter and maintain water films that are essential for microbial activity. With shifts in use of tillage and types of organic matter as a means of managing soil fertility, the relative abundance of organisms changes, as does their activity. Overall, the challenge is to avoid management practices that reduce background levels of soil carbon. Organic farming systems depend on biological processes which mineralise organic matter, leading to loss of soil carbon. Therefore, retention of adequate levels of carbon in soil needs to be associated with constraints on microbial activity. This may be achieved by modifying the soil habitat, such as through addition of clay to sandy soils, or by adding other substances that alter the soil habitat, protect organic matter and retard its mineralisation. The practicality of these options depends on the farming system.

How much carbon (as organic matter) can a soil retain? Soil physical, chemical and biological factors are all involved in retention of carbon in soil. The addition and subsequent loss of carbon from soil is analogous to a see-saw. Generally, mineralisation of recently added soil organic matter occurs rapidly and most is lost quickly. Soil management therefore requires management of soil organisms. The soil carbon see-saw needs to favour retention of organic matter to a greater extent in organic systems but, as mentioned above, this could result in a greater loss of carbon associated with higher levels of microbial activity unless the organic matter is protected to some extent.

Carbon has never been recognized as being so important as it is today. Is it possible to maintain a higher level of carbon in soil? In organic farming systems, a focus on carbon has always been considered essential, but other factors such as increased water use efficiency, reduced loss of nutrients and energy, and minimising erosion are potentially important side-effects. Although such benefits are relevant in all agricultural systems, the absence of a fall-back position (e.g. use of soluble fertilisers) in organic systems, forces use of practices that depend on soil biological fertility. Thus, organic agriculture is a model for understanding soil fertility because it recognises the interdependence among the components of soil fertility.

There is potential to balance soil biological fertility with chemical and physical fertility through soil management practices that simultaneously (i) conserve soil carbon (i.e. increase the amount of nitrogen supplied in organic form) and (ii) manage mycorrhizas (i.e. reduce dependence on use of soluble phosphorus). To take this a step further, if phosphorus is managed first (based on a biological process such as colonization of roots by mycorrhizal fungi where applicable), this would effectively dictate nitrogen requirements (based on P:N for the plant species). This model (depending on water availability) constrains nitrogen use according to phosphorus supply. The alternative of constraining phosphorus use according to nitrogen supply has no detectable upper limit based on factors related to soil biological fertility, and is more likely to result in excessive use of nitrogen.

This investigation of organic agriculture as a model for questioning the relative roles of soil chemical and biological processes in food production justifies a closer look at the role of soil biological fertility in all farming systems. Furthermore, farming systems that manage phosphorus effectively using an understanding of soil biological processes are more likely to require environmentally-appropriate nitrogen inputs than are systems for which management of nitrogen fertiliser is the primary focus.