Phosphorus nutrition in organic vegetable production

Gunasekhar Nachimuthu
MSc(Ag) TNAU

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School of Environmental and Rural Science
University of New England
Armidale
New South Wales
Australia

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Declaration

I certify that the substance of this thesis has not already been submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

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Abstract

While the economic prospects for organic food and fibre products in the Australian and overseas markets are promising, Australian organic growers face several production constraints. Most of the investigations in Australian broad-acre (extensive arable) organic farming systems indicate a decline in soil available P over time, raising questions about the long term sustainability of organic farming in Australia. However, the sparse literature on vegetable production in NSW has indicated an excess of extractable P due to the use of manures and compost to meet N demand. With this in view, field and glasshouse investigations were carried out with the following objectives:

1. to assess the nutrient status (especially extractable soil P) of organic and conventional vegetable farms in a range of contrasting soil types and climatic conditions, to test the general validity of previous findings concerning organic vegetable production.

2. to examine the plant based P management techniques such as choice of cultivars and crop rotation using legumes to overcome P limitations in low fertility soil in order to develop effective phosphorus management strategies for vegetable growing during conversion to organic production

The first objective was examined by testing the hypothesis that the soil fertility status of organic vegetable farms was lower than adjacent conventional farms at three different vegetable growing regions in eastern Australia. Soil samples were collected from paired organic and conventional farms in each location in February 2005 and 2006. Soil chemical properties (pH, electrical conductivity, total nitrogen (N), resin P, KCl-40 sulfur, nitrate-N and ammonium-N) and microbial biomass carbon were similar between organic and conventional vegetable farms, consistent with earlier studies into organic vegetable production in Australia. Soil extractable P pools were medium to high across farm types (average Colwell P >100 mg kg^{-1}), possibly due to the use of organic inputs to meet N requirement, e.g. composts, green manure and bulky manure, amongst these organic vegetable growers in a wide range of soil and climatic conditions. Soil biological and chemical properties were strongly influenced by crop management practices and soil type, rather than the type of farming system. Crop management in vegetable production in eastern Australia (whether organic or conventional) should also measure soil nutrient status to avoid over-fertilisation and possible off-farm environmental effects. There is also a need to find a suitable nutrient source that supplies both N and P at an optimum rate for crop growth.

While high input vegetable production systems indicate no limitation in soil extractable P or may face the risk of P accumulation, in inherently low-P soils such as those in Australia, changes in nutrient status during conversion to organic vegetable production would

depend, to a large extent, on management strategies employed and type of inputs used. One such strategy explored as part of the second objective in this thesis is genotype x environment interaction in vegetables. As P nutrition is the focus of this thesis, a minor investigation into the impact of P source on locally grown corn cultivars was conducted to measure the effect of P fertiliser (no fertiliser, (control), rock phosphate (RP), poultry manure (PM) or single superphosphate (SP)) on the growth of four organically certified sweet corn (*Zea mays* L.) cultivars (Balinese, Golden Bantam, Hawaiian and Jolly Roger) and one conventional cultivar (Hybrid 424 (Hybrid)). Phosphorus use efficiencies of applied SP were six to eight times and one to two times higher than RP and PM respectively. Organic cultivar responses relative to the Hybrid were similar in P acquisition under deficient and sufficient P levels. This experiment did not support the hypothesis that the organic cultivars investigated were better adapted for P acquisition in low P status soils. There were only marginal differences between cultivars compared with the more pronounced differences between P sources, highlighting the importance of exploring an alternate P source in organic production.

A number of published reports have indicated successful N management using leguminous cover crops and have suggested that potential exists to use leguminous cover crops to improve P cycling and availability also. A series of experiments were conducted to evaluate the potential of two winter legumes (faba beans (FB) and field peas (FP)) as part of a green manure rotation or as a harvested crop, on the P nutrition of subsequent crops. Phosphorus accumulation by FB and FP at the pod initiation and harvest stages was similar, with maximum P input of both legumes occurring after pod initiation; however this needs further verification under field conditions. The legumes accumulated 5-13 % of the applied P (50 kg P ha^{-1} as SP), potentially supplying only 2.5 to 6.5 kg P ha^{-1} to subsequent crops. Field peas acquired similar P from PM and SP, but neither was effective in mobilising P from RP in either the acidic or alkaline soils used.

A dual labelling isotope study conducted to determine the relative contribution of ^{33}P labelled FB and FP residues, and ^{32}P labelled inorganic fertiliser to the P nutrition of subsequent corn also indicated FB and FP residues alone, or in combination with fertilisers, contributed up to 10% and 5% of the total P uptake by corn respectively, compared to a maximum of 54% by inorganic fertilisers. Soil solution analysis suggested that some of the P released from the residues remained in an organic form for the entire period of crop growth. The results suggest that incorporation of legume residues with P concentration higher than those observed under field conditions may still not lead to an immediate net P release to subsequent crops. This study concluded that these legumes cannot be recommended as the sole P source during conversion to organic production, but may provide supplemental P after the harvest of their economic produce along with additional P input

While the findings our field survey confirmed the previous findings that the use of manures and compost to manage N may lead to P accumulation in vegetable farms, the glasshouse studies indicate serious implications for P cycling on organic farms of Australia where native soils are inherently low in P and suggest alternative sources of P should be integrated along with legume residues to overcome the P limitation in organic production especially in low fertility Australian farms.

A longitudinal investigation over several years of similar management on the same farms could lead to better understanding of long-term temporal changes in soil nutrient status in these intensive vegetable production systems. Once this is understood, then the research could focus on developing or identifying better organically approved P sources, designed to meet the immediate nutrient requirement of crops in low input organic systems, provided the incapability of adequate P supply using plant based P management strategies such as choice of cultivars and crop rotation.

Publications arising from this thesis

Journals

Nachimuthu, G, King, K, Kristiansen, P, Lockwood, P and Guppy, C. 2007. Comparison of methods for measuring soil microbial activity using cotton strips and a respirometer. *Journal of Microbiological Methods*. 69(2): 322-329.

Nachimuthu, G, Kristiansen, P, Lockwood, P, Guppy, C and King, K. 2007. Comparison of soil chemical and microbial properties in organic and conventional vegetable farms in eastern Australia. Paper submitted to *Agriculture, Ecosystem and Environment* and currently under revision.

Nachimuthu, G, Kristiansen, P, Guppy, C and Lockwood, P. 2007. Short term phosphorus fertiliser source utilisation by sweet corn (*Zea mays* L.) under organic production. Paper to be submitted to *Agronomy Journal*.

Nachimuthu, G, Guppy, C, Kristiansen, P and Lockwood, P. 2007. Evaluation of the potential of two legumes to enhance P nutrition in a following crop under organic production in Australia. Paper to be submitted to *Agronomy Journal*.

Nachimuthu, G, Guppy, C, Kristiansen, P and Lockwood, P. 2007. Isotopic tracing of phosphorus from legume residues and fertilisers to subsequent corn in legume-corn rotation using dual labelling technique. Paper submitted to *Plant and Soil*.

Conference Proceedings

Nachimuthu, G, Kristiansen, P, Lockwood, P and Guppy, C. 2007b. Soil phosphorus status in organic and conventional vegetable farms in Southeast Queensland, Australia. In: *3rd QLIF Congress, Hohenheim, Germany, March 20-23, 2007*. pp. 40-43

Nachimuthu, G, Kristiansen, P, Lockwood, P and Guppy, C. 2005. A Comparison of soil properties under organic and conventional farming in Australia. In: *Proceedings of the First Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR), 21 - 23 September 2005*, Adelaide, South Australia. pp. 40-43

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