Nutrient Exclusivity in Organic Farming—Does It Offer Advantages?

By H. Kirchmann and M.H. Ryan

The following aims are associated with organic farming: to produce healthier foods, to be environmentally friendly, and to be more sustainable. Organic principles are applied in the belief that they are the best way to achieve these aims. However, a critical analysis of organic fertilization practices does not support this belief.

Fertilization within organic farming is designed to maintain soil fertility, but not to directly feed plants. Nutrients are applied in organic or low solubility inorganic forms in the belief that plants will obtain balanced nutrition through the actions of soil microbes. The exclusion of synthetic fertilizers in organic farming has been motivated by various arguments: lower crop quality, faster humus-breakdown, and a non-synchronized supply to crops. Furthermore, philosophical views about life are a basic fundament for organic principles (Kirchmann 1994).

What yields are achieved on organic farms and what area of land is required to sustain these yields?

A number of long-term field trials in Europe reveal that crop yields are on average 20% lower in organic systems that combine crops with animals and 33 to 45% lower in organic systems with crops alone, compared to their conventional counterparts (**Table 1**). Studies of farms under long-term organic management in Australia reveal yields of individual crops as substantially lower than on conventional neighboring farms (**Table 1**). Lower yields reflect either a lower fertilizer input and/or a lower uptake efficiency of nutrients from fertilizers.

The low yields on organic farms mean that to produce the same amount of food as conventional farms, more land is needed. For instance, to sustain food production in Europe, widespread adoption of organic farming without animals would require an increase in land area of 64%, assuming crop production is reduced by 39%, and adoption of organic systems with animals would require an increase in land area of 25%. If conventional farming is widely replaced by organic farming, clearing of wildlife habitats and conversion of natural and semi-natural ecosystems into agricultural land is unavoidable in systems that did not originally produce a food surplus. Thus, biodiversity will be reduced. But the main concern is that lower yields would increase the size of the world hunger map.

Can an enhanced soil biological community improve availability of plant nutrients in organic systems?

It is often assumed that the soil biological community will be enhanced in response to organic management, developing a greater capacity to supply plants with nutrients from organic and poorly soluble inorganic sources. One component of the soil biological community that occur consistently more abundantly on organic farms are arbuscular mycorrhizal fungi, as soluble phosphorus (P) fertilizers suppress their occurrence on conventional farms (Ryan et al., 2000). Arbuscular mycorrhizal fungi are best known for their ability to enhance host plant uptake of P and other nutrients. However, studies of organic crops and pastures in southern

Table 1. Mean yields and N inputs from long-term farming system experiments in Europe and from paired commercial farms under long-term organic and conventional management in Australia.

Experiment and farming system	Yield, t/ha Organic	Yield, t/ha Con.	Yield decrease, %	N input, kg/ha/yr Organic	N input, kg/ha/yr Con.	Reference
Norway: Apelsvoll-site (8 years)						
Crops plus animals				121	227	Korsaeth and Eltun , 2000
Barley, oats, wheat	3.7	5.0	26			Eltun et al., 2002
Three-year forage crop	8.3	10.7	22			
Green fodder	7.1	7.6	7			
Switzerland: DOK-trials (24 years)						
Crops plus animals				105	138	Spiess et al., 1993
Winter wheat	4.1	4.5	10			Besson et al., 1999
Three-year forage crop	11.5	14.0	18			Mäder et al., 2002
Potato	30.0	48.0	38			
Sweden: Skåne-trials (12 years)						
Crops only				59	130	Ivarson and Gunnarsson, 2001
Winter wheat	3.7	6.3	41			
Potato	21.4	38.0	44			
Crops plus animals				110	185	
Winter wheat	4.1	6.4	36			
Two-year forage crop	6.6	9.3	29			
Australia: New South Wales (30 years; One pair of farms)						
Crops plus animals				0	17[3]	Ryan et al., 2004
Wheat[1]	2.9	5.5	48			
Australia: Victoria (17 years; 10 pairs of farms)						
Animals only				0	17[3]	Small and McDonald, 1993
Milk , L/ha/year[2]	6740	9060	26			

[1] Organic wheat was fertilized with 18 kg P/ha/year as rock phosphate and conventional wheat with 16 kg P/ha/year as diammonium phosphate (average grain yields over 3 years from a farm pair where one farm had been under organic management for 30 years).

[2] Conventional pastures received 27 kg P/ha/year as soluble synthetic fertilizers, while biodynamic pastures received no P (average milk yields over 3 years from 10 paired farms where one farm in each pair had been under biodynamic management for an average of 17 years).

[3] N directly applied in fertilizer (N inputs from legumes not calculated).

Australia show that high colonization does not overcome the serious P-deficiency experienced in these systems (Ryan et al., 2000; Ryan and Angus, 2003). Indeed, as the fungi obtain all carbon (C) requirements from the host plant, if the fungi supply no return nutritional benefits they may act as a parasite on crops, reducing crop yield potential (Ryan et al., in press). The generalization that organic practices automatically stimulate an enlarged soil biological community, and that this can partly substitute for inorganic fertilizers, is inaccurate (Ryan and Ash, 1999).

Lower mean N input in organic farming—does it result in less nitrate leaching?

A comprehensive literature review showed that the average leaching of nitrate (NO_3) over a crop rotation was somewhat lower per unit area from organic systems than conventional systems (Kirchmann and Bergström, 2001). However, a correct comparison of leaching between systems also requires yields to be considered and this was not accomplished due to differences in the sequence and type of crops grown, differences in the input intensity

Table 2. Partial N budget in organic and conventional long-term trials in Sweden.

Experiment and farming system	Organic Input	Organic Offtake	Organic Leaching	Conventional Input	Conventional Offtake	Conventional Leaching	Reference
	- - - - - - - kg N/ha/yr - - - - - - -			- - - - - - - kg N/ha/yr - - - - - - -			
Halland-site							
Crops only	66	30	43	99	79	29	Torstensson et al., 2005
Crops plus animals	120	105	35	113	71	26	
Västergötland-site							
Crops only	105	42	20	113	85	3	Torstensson, 2003a Lindén et al., 1993
Mean	**97**	**59**	**33**	**108**	**78**	**19**	

of nitrogen (N) and a general lack of yield data (Kirchmann and Bergström, 2001). In a series of Swedish long-term field lysimeter trials that commenced in the early 1990s, similar crop rotations in the organic and conventional system were maintained, except in years when green manure was grown. Furthermore, mean N input in the organic systems was close to that of conventional systems (**Table 2**). In these studies, on both a sandy and a clay soil, organic systems had greater nutrient leaching and greater release of N and P to drainage water both per hectare and per unit of harvested N. These experiments indicate that if differences between comparative studies caused by different crop rotations and N input intensity are largely eliminated, leaching of N from organic systems is not lower per unit area.

It appears that the asynchrony of crop N demand and N release from manures compared to inorganic synthetic fertilizers is the major cause for the higher leaching losses from organic systems, as more manure N remains in the soil after application and is mineralized at times when there is no crop demand (Bergström and Kirchmann, 1999; 2004).

Is nutrient cycling enhanced by organic farming?

There is no doubt that the sustainability of most agricultural systems could be improved through an increased emphasis on recycling and greater return of nutrients in municipal wastes and off-farm products. However, losses via the food cycle would not be reduced through widespread adoption of organic farming as current regulations within the organic movement do not allow use of urban wastes due to concerns about contamination with metals and organic pollutants. To improve recycling of nutrients and reduce the risk of contamination with pollutants, new recovery technologies to extract nutrients out of wastewater and biogas residues and other municipal wastes are currently being developed. However, as the new nutrient recovery technologies will produce easily soluble, inorganic products, only conventional farmers may be able to use these products and thereby improve nutrient cycling.

To maintain soil fertility, organic farmers may purchase approved organic fertilizers. In Europe, these fertilizers generally originate from conventional production. In fact, in Sweden there is an increasing trend in organic farming to apply nutrients of off-farm origin via approved organic fertilizers such as meat meal, bone meal, poultry manure, and wastes derived from food industries (Swedish Control Organization for Alternative Crop production). This is an indirect transfer of nutrients originating from conventional production and creates a reliance on production systems fertilized with inorganic fertilizers. A regulation by the European Union (EU) will prohibit the use of conventionally grown fodder in organic animal production after August 2005. On the other hand, there are practically no restrictions on the use of organic fertilizers, such as animal manures, derived from conventional farms and on by-products from food processing industries (meat meal, blood meal, bone meal, residues from fish industries, canning industries etc). Thus, organic farmers can continue to rely on the import of nutrients from conventional production through purchase of organic manures. This approach obviously would not be sustainable if a large proportion of farms convert to organic production.

Several peer-reviewed papers conclude that organic farming is superior to conventional agriculture.

How stringent are comparisons?

There is a tendency when presenting results from comparative studies of organic and conventional farms to assume that any differences occurring between systems are a consequence of the management factors that are inherently dissimilar, namely the exclusion of pesticides and readily soluble inorganic fertilizers on organic farms. Thus, it is assumed that the results are generally representative of organic and conventional systems. However, differences may be caused by management practices that are potentially open to manipulation in a similar manner in each system and/or may vary greatly within one or both.

The following factors should be considered when evaluating comparative studies of systems:

1) The soil fertility status at the start of an experiment will determine the productivity of the system. In fertile soils, initially, smaller yield differences will be detected and both fertilizer and energy efficiency will be in favor of low-input systems.
2) The choice of crops in rotation will determine N leaching. Crops affect N leaching from agricultural soils in several ways: the longevity of the crop, rooting depth, the amount of crop residues and their mineralization potential and the degree of soil tillage.
3) The amount of imported (purchased) nutrients and organic matter need to be equal. To set aside boundary conditions between systems is not scientific proof for the superiority of one system over the other.

Conclusion

When critical scientific analysis is applied to organic farming, the dogma of superiority of organic farming fails. Despite their aim of being more sustainable, organic principles do not provide a better long-term outcome in the search for sufficient food production than conventional ones. We advocate a flexible approach where farming systems are designed to meet specific environmental, economic, and social goals, unencumbered by unscientific, dogmatic constraints (Kirchmann and Thorvaldsson, 2000).

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References: Due to space limitations, the reference list is not printed in the original issue. The reference list is available as a PDF file (with the article) at the website: >**www.ppi-ppic.org**<.

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