Research needs for organic agriculture

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*Tutkittua tietoa luomusta*
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Why support organic farming?

• Food quality
• Food security
  1. soil conservation
  2. environment/biodiversity protection
  3. self-sufficiency at farm level
  4. minimum use of non-renewable and scarce resources
     – Energy, minerals (NPK etc), water
     – Imported concentrate feed (soya, maize)
Nafferton Factorial Systems Comparison experiments
Experimental Design

Nafferton Factorial Systems Comparison Trial
Food quality

Pesticide residues

• The frequency of occurrence of pesticide residues is 3 times higher in conventional than organic crops (Smith-Sprangler et al. 2012 Ann Inter Med 157, 348-366)

• Organic food consumption was shown to reduce exposure to organophosphorus pesticides in pre-school children (Curl et al. 2003 Environ Health Perspect 111, 377-382)

➢ 78% of conventional fruit and 31% of conventional vegetables contain detectable pesticide residues

➢ 10% of organic fruit and vegetables also contain detectable pesticide residues
Effect of fertilisation and crop protection on the Cadmium content in potato (average of 4 seasons) (Cooper et al. 2013 J Agric. Food Chem. 59, 4715-4724)
Relative levels of nutritionally desirable antioxidants in fruit and vegetables; a meta-analysis
(Brandt et al. 2011 CRC Crit. Rev Plant Sci. 30, 177-197)

% higher or lower than in conventional

<table>
<thead>
<tr>
<th>Defence compounds</th>
<th>Flavones &amp; Flavonols</th>
<th>Phenolic acids</th>
<th>Total Phenolics</th>
<th>N&amp;S compounds</th>
<th>Carotenes</th>
<th>Vitamin C</th>
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<tbody>
<tr>
<td>n = 189</td>
<td>56</td>
<td>36</td>
<td>29</td>
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<td>32</td>
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Effect of fertilisation and crop protection on the vitamin C content in potato (average of 4 seasons)

Crop protection

- Conventional
- Organic

ns

Fertilisation

- Conventional
- Organic

P<0.001
Effect of fertilisation and crop protection on the glycosinolate content in cabbage (average of 2 seasons)

mg kg\(^{-1}\) fresh weight

Conventional | Organic
---|---
Crop protection

Fertilisation

mg kg\(^{-1}\) fresh weight

Conventional | Organic
---|---

ns

P<0.001
Main cause of lodging - Physiological weakness and fungal infections of the stem base caused by imbalanced N-supply

% of max.

- Red: Crop demand (NPK)
- Blue: Mineral NPK
- Green: Organic matter inputs

S = sowing  M = maturity  FI = Fertility input
Effect of fertilisation and crop protection on the total carotenoid content in lettuce (average of 4 seasons)

μg g⁻¹ fresh weight

Crop protection

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<td>P = 0.028</td>
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Composition differences between organic and conventional milk during the outdoor grazing and winter indoor period


% difference compared to conventional
Proportion of cows receiving antibiotic treatments for mastitis in conventional and organic dairy herds (annual average) (Butler et al. unpublished)
Research needs
Food quality

• Breeding/genotype selection, management and supply-chain organisation based strategies to
  – optimise sensory quality, storability and shelf-life of organic fruit and vegetables (and dairy products?)

• Breeding/genotype selection and management based strategies to optimise
  – protein and phytochemical content and processing quality in organic cereal production
  – micro-nutrient supply to organic crops and livestock (Se, Zn, Cu and Iodine)
Food security

“The ability to provide access to enough food of high quality for humans through sustainable methods of production”

**Sustainability** in this context means without
- negative impacts on the environment,
- reliance on non-renewable resources,
- an erosion of current ethical standards

while ensuring
- fair economic returns to all food chain stakeholders
- flexibility to meet the challenges of global change
“Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist”

Kenneth Boulding, economist
How can we feed 9 Billion people in a sustainable way?
Can yields be further increased?

Exhibit 1
Crop Yields (5-year moving average)
Wheat – France, Germany, United Kingdom; Rice – Japan

7.5 t ha\(^{-1}\)
Total global use of nitrogen, phosphorus and area of irrigated land

Total global pesticide production and global pesticide imports

Nitrogen, population growth and emissions
- Manufacture of N-fertiliser accounts for 10% of agricultural GHG emissions

World population and agricultural surface vs Fertilizer Nitrogen and NO$_x$ emission (UNESCO-SCOPE, 2007)
Organically and conventionally farmed soil (Naff silt loam) losses due to water erosion 1948 to 1985

(Reganold et al. 1987 Nature 330; 370-372)
Diminishing returns of fertiliser applications

Fertiliser use efficiency?

Agricultural intensification over the last 40 years is estimated to have resulted in:

- a 2 fold increase in global food production\(^1\)
- a 5-7 fold increase in mineral NPK use\(^1\)
- resulting in a 2-3 fold reduction in nutrient use efficiency of crop production
- 2-3 times as much NPK is needed to produce a kg of food than 40 years ago
- can we get around the “law of diminishing returns”

\(^1\) Hirel et al. (2007) Journal of Experimental Botany 58: 2369-2387
Energy use – CO$_2$ emissions

Mineral N-Fertiliser

- 1 kg Nitrogen-fertiliser = 36,000kJ = 1 L fuel
- 1 kg nitrogen fertiliser (NH$_3$NO$_3$) results in
  = 2.38 kg CO$_2$ (equivalents of CO$_2$, CH$_4$ and N$_2$O)
- UK Farm level = 100 ha cereals x 200 kg N/ha/annum
  = 20,000 Litre fuel used
  = 47,600 kg CO$_2$ into the atmosphere

- European level = 11 Million t N/annum*
  = 11,000 Million Litre fuel used

  www.fertilizereurope.com
Proven global reserve: 1,333Gb: 45.7 years-consumption of 2009 (BP, 2010)

URR = Ultimate Recoverable Resource (Proven + Provable)
Why will Phosphorus become a bottleneck for productivity?

Phosphorus (P) fertiliser is a mined mineral

- Numerous scientific studies conclude that phosphorus (phosphate rock) reserves-resources will be depleted in the 21st century
  - Pessimistic: in 30-40 years
  - More optimistic: in 70-80 years

- IFDC (International Fertilizer Development Centre) prediction: 300-400 years
  - Based on current consumption
  - P-consumption is likely to increase by >2 fold
Peak Phosphorus Curve


(Source: Piesse and Thirtle, 2009)
Can conventional farming deliver food security?

• **High yields** in conventional systems rely on *mineral NPK fertiliser inputs* and **are not sustainable**
  – Mineral **N-fertiliser** manufacture is estimated to account for 10% of total greenhouse gas emissions from agriculture
  – Mineral **P-deposits** will be depleted in 30-100 (300?) years

• **Without mineral P-inputs** yields in conventional farming will decline by more than 50%

• Currently mineral NPK fertilisers are still too cheap
  – BUT mineral fertiliser prices have increased by more than **8-fold** in the last 10 years
What are the solutions?

The main approaches available are:

1. **More efficient recycling** of NPK via
   - animal and green manures,
   - crop residues, food processing waste
   - communal and domestic organic waste
   - human toilet waste/sewage

2. **Reduction of losses** of fertiliser from soils

3. **Breeding/selection** of more nutrient (especially N and P) efficient crop varieties (EU-NUE crops project)

4. **Reduce meat, egg and dairy production** and consumption
Amount of cereal (corn-equivalents) necessary to produce 1 kg of livestock products
Effect of fertilisation and crop protection on wheat yield (average of 4 seasons) (Bilsborrow et al. 2013 Eur J Agron 51, 71-80)

Grain yield (t ha⁻¹)

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Effect of fertilisation and crop protection on the *cabbage* yield (average of 4 seasons)
Effect of fertilisation and crop protection on the onion yield (average of 4 seasons)

![Graph showing the effect of fertilisation and crop protection on onion yield.](image)
Can organic farming deliver food security?

- **Crop yields** in organic farming systems are lower
  - by up to **40%** in arable crops such as cereals/potato
  - yields in many horticultural crops are only slightly lower

- There is **great potential to increase yields in organic farming** systems by **optimising/increasing organic fertiliser inputs regimes**
  - Evidence from **long term trials in China** suggest that when used **at the same mineral input level**, mineral and organic fertilisers (e.g. manure) will produce **similar yields**

- There is increasing amount of organic waste !!!!!

- **Need to integrate better soil management with innovations in other areas** (e.g. breeding, crop protection, tillage)
Research needs
Food security (=profitability?)

- Development of “precision” organic waste based fertiliser products and fertilisation regimes
  - N:P:K ratios; micronutrient (e.g. Se, Zn, Cu, Iodine) supply
  - Predictable and optimised N&P availability/release pattern
  - Suppressiveness to soil-borne diseases

- Improved protocols for legume cover-, inter- or companion crops;
  - N-retention/fixation, weed control, soil structure

- Improved (a) protocols and genotypes for home grown grain legumes and (b) supply chains for soya
  - Protein feeds for pigs/poultry

- Crop breeding/variety selection for nutrient use efficiency (especially from organic fertiliser inputs)
Research needs
Food security (=profitability?)

- **Crop breeding/selection for robustness and product quality**
  - Competitiveness against weeds
  - Disease resistances for crop pathogens that are also a problem in organic farming (late blight in potato, *Septoria* in cereals, soil borne diseases and nematodes in greenhouse crops)
  - Pest resistance/tolerance in crops

- **Development of crop protection products that are acceptable under organic farming standards**

- **Livestock breeding/selection for robustness, product quality and low environmental impact**
  - Disease (e.g. mastitis) and parasite (GIN) resistance
  - Meat/milk/egg quality/low GHG emissions in outdoor/grazing-based systems
Thank you
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