QualityLowInputFood

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Improving the sustainability of crop production in Europe; the need to focus on organic matter recycling and nutrient use efficiency

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Contents

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- What limits crop yields – NOW
  - example wheat
- What will limit crop yield in the FUTURE
  - availability, environmental impact and cost N-fertiliser
  - availability and cost of P (and other mined) mineral fertilisers
- Decline in Nutrient Use Efficiency (NUE) in crop production
- What are the solutions?

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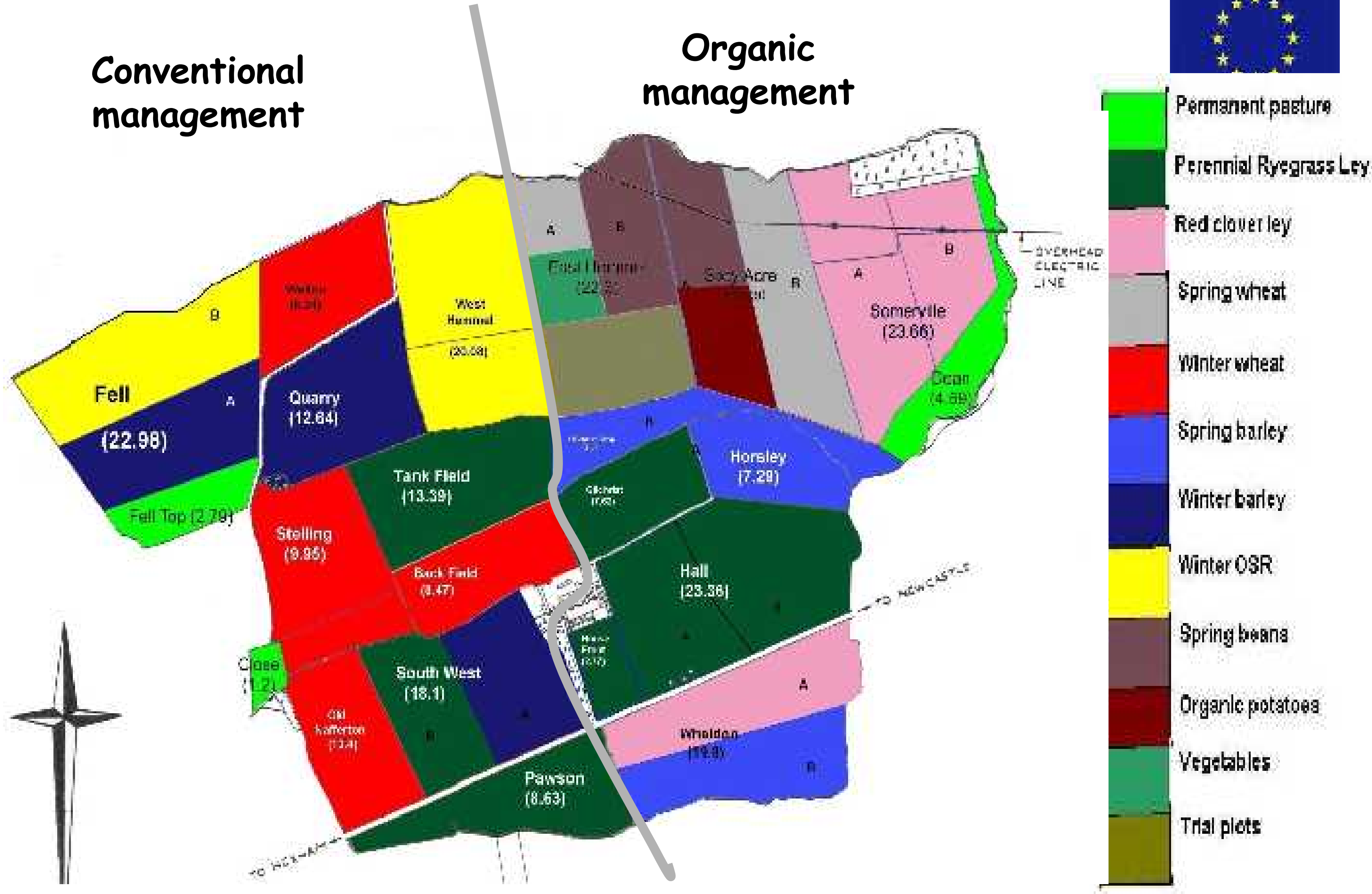
Nafferton Farm
- 360 ha Estate
- cereals, oilseed
- dairy, beef, lamb

Conventional management

Organic management



Fertilisation regime - wheat

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Conventionel

1st Wheat

Nitram (NH_4NO_3)

- March 50 kg ha^{-1}
- April 130kg ha^{-1}
- No P&K Dünger

2nd Wheat

Nitram (NH_4NO_3)

- March 80 kg ha^{-1}
- April 130 kg ha^{-1}

Superphosphat +KCL

(0:20:30) 64 kg P ha^{-1}

96 kg K ha^{-1}

Organic

1st Wheat

- No Fertiliser

2nd Wheat

Experiment 1&2:

No Fertiliser

Experiment 3&4:

composted cow manure

(equiv. 210 kg N ha^{-1})

Crop protection regimes

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Conventionel

Weed control

- Isoproturan 3 l/ha
- mecoprop-P 1 l/ha)
- Pendimethalin 1.5 l/ha)

Disease control

- Epoxiconazole 0.5l/ha,
  chlorothalonil 1 l/ha
  chlormequat (CCC) 2.3l/ha
  fenpropimorph 0.2 l/ha
- Epoxiconazole 0.5 l/ha
  chlorothalonil 1l/ha,
  fenpropidin 0.25 l/ha,
  trifloxystrobin 0.25 l/ha

Organic

Weed control

- 1-2 mechanical (Einbock)

Disease control

- No treatment

Nafferton factorial production systems comparison trial – experimental design

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- Rotation design (4)
  - Non-divers (2): 2 years grass/clover 6 years cereals, 1 year potato/ vegetables
  - Diversified (2): 3 years grass/clover, 2 years cereals 2 years potato/vegetables, 1 year faba beans)
- Crop protection (2)
  - Conventional (pesticides used to farm assured standards)
  - Organic (according to soil association standards)
- Fertilisation (2)
  - Conventional (pesticides used to farm assured standards)
  - Organic (composted manure inputs only)
- Replicate blocks (4)
- Replicate experiments (4)

Total area: 6 ha

Effect of fertilisation and crop protection on wheat yield (Malacca – short straw variety)

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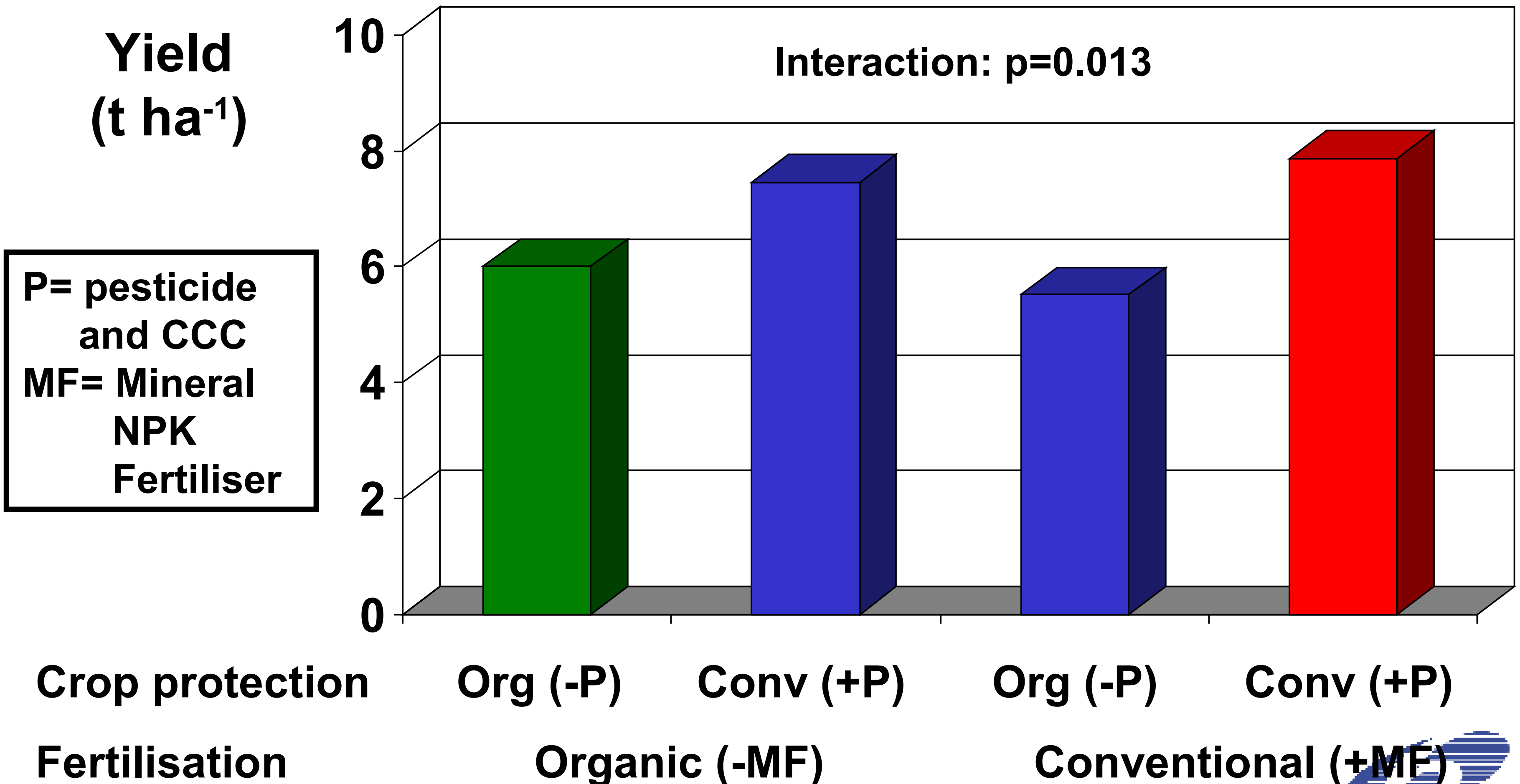
Adding mineral fertilisers to crops protected by pesticides increases yield, while adding mineral fertilisers to non-pesticide treated crops decreases yield



Wheat – Interaction CP x FM

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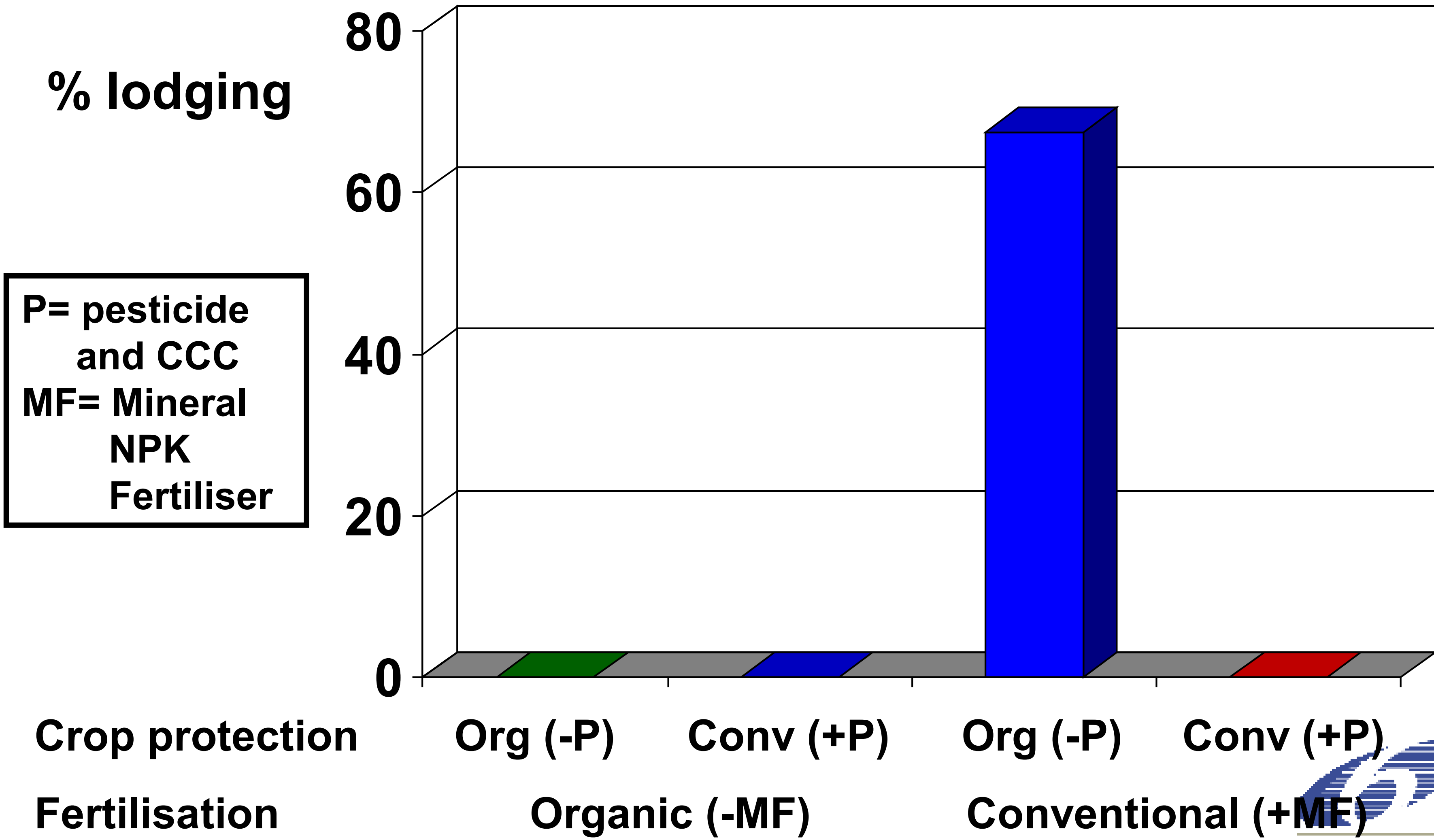
When mineral fertilisers are used, it becomes essential to use pesticides/CCC to prevent lodging



Effect of fertilisation and crop protection on wheat yield (Malacca – short straw variety)

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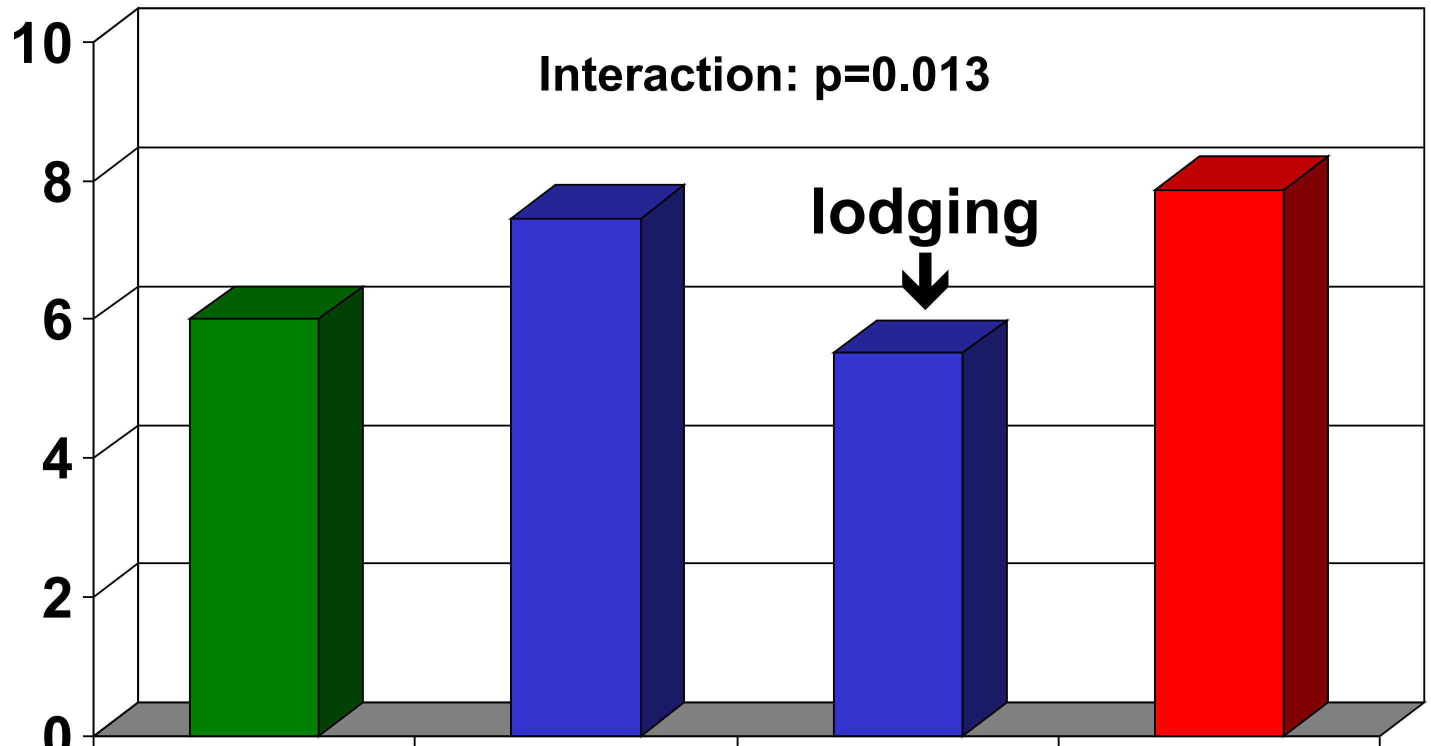
Adding mineral fertilisers to crops protected by pesticides increases yield, while adding mineral fertilisers to non-pesticide treated crops decreases yield

Yield ($t\ ha^{-1}$)



P= pesticide and CCC
MF= Mineral NPK Fertiliser

Crop protection	Org (-P)	Conv (+P)	Org (-P)	Conv (+P)
Fertilisation	Organic (-MF)		Conventional (+MF)	

What will limit crop yields in the future?

Availability and costs of:

Nitrogen (N = energy)

Phosphorus (P)

Potassium (K)

Energy use – CO_2 emissions

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Mineral N-Fertiliser

- 1 kg Nitrogen-fertiliser = 36,000kJ = 1 L fuel
- 1 kg nitrogen fertiliser (NH_3NO_3) fertiliser

  = 2.38 kg CO_2 (equivalents of CO_2, CH_4 and N_2O)
- Nafferton Farm = 100 ha cereals x 200 kg N/ha/annum

  = 20,000 Liter fuel

  = 47,600 kg CO_2 into the atmosphere

  per annum for just the wheat crop on one English farm

What will limit crop yields in the future?

Availability and costs of:

Phosphorus (P)

Potassium (K)

Nitrogen (N = energy)

Why will Phosphorus become a <u>bottleneck</u> for productivity?

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- **Phosphorus fertiliser is a mined mineral**
- **World reserves* are estimated at: 4 - 8 B t**
- **Annual extraction rates are approx.: 125 M t**
- **Period of time that currently known world deposits are estimated to last for[1]:**
  - **Pessimistic: 30-40 years**
  - **Optimistic: 60-90 years**

*** Based on estimated P-rock deposits with a minimum of 10% P**

[1] Fantel *et al.* (1985) *Natural resources forum* **9**:5-24

Why has this problem come so suddenly? Exponential increase in P-use

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Estimates of global	optimist 1975*	pessimist 2005	optimist 2005
P-reserves (Mt)#	5,000	4,000	8,000
P-use (Mt)##	10	125	125
Years left###	500	32	64

* Fink (1979) Dünger und Düngung. Verlag Chemie

\# based on P-rock deposits with a minimum of 10% P

\## 50-60% is used as fertiliser (1975 approx. 75%)

\### Length of time that P-reserves are likely to last

Where are the worlds phosphorus deposits and how secure is our current P-supply?

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- **The UK imported 206,000 t of P in 2007**
- **Most known phosphorus deposits are in North African countries[1]:**
  - **approx. 50% in Marocco,**
  - **approx. 35% in Algeria, Tunesia & Egypt**

There are also significant deposits in the USA, Russia and China

[1] Cisse & Mrabet (2004) *Phosphorous Research Bulletin.* **15:** 21-25

Nutrients limiting wheat yield in 1900 and 2000 and predicted 2100 yields without P-fertilisation

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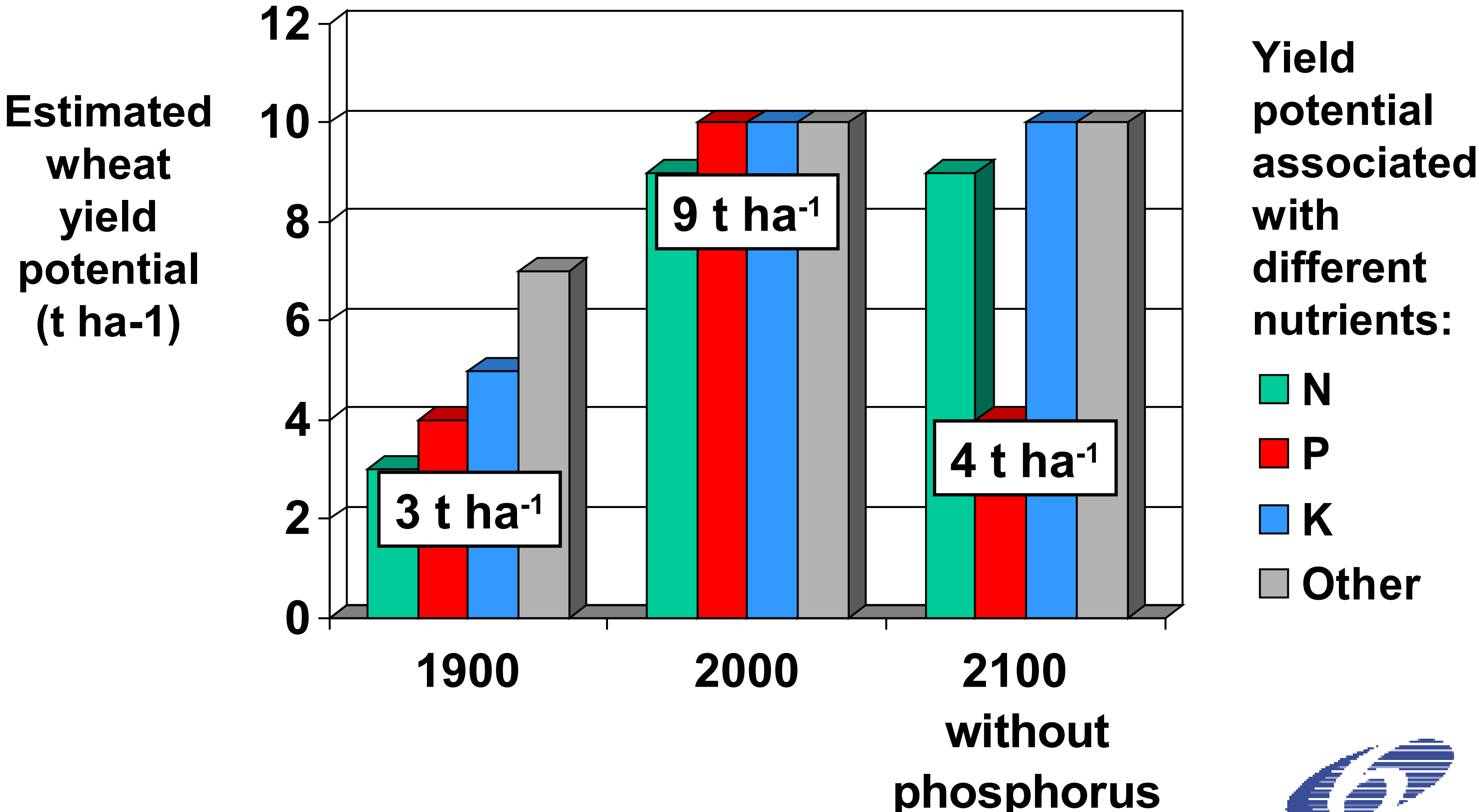
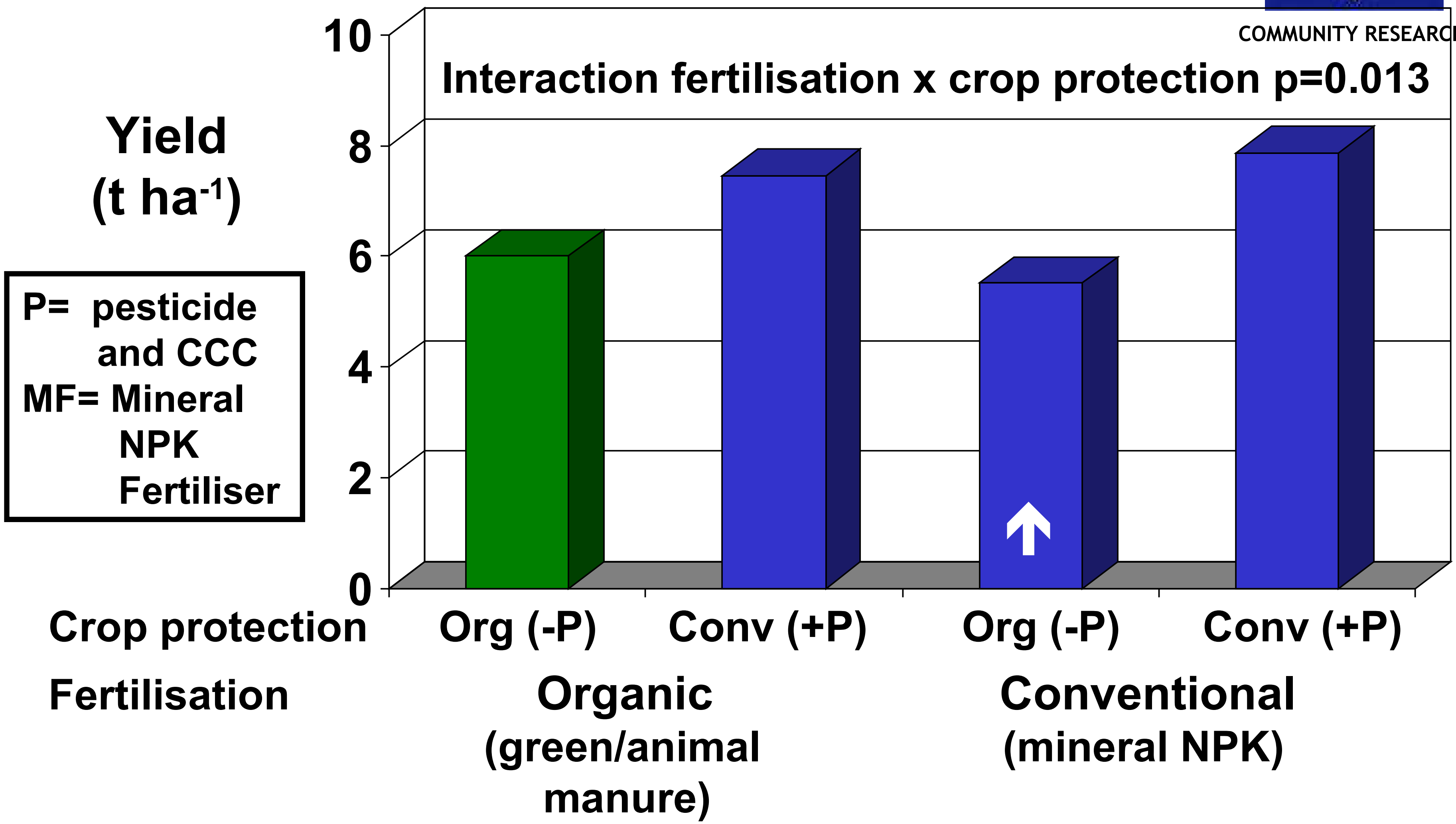


Winter Wheat Yield - Nafferton Farm 2004



Winter Wheat Yield – Estimated 2100

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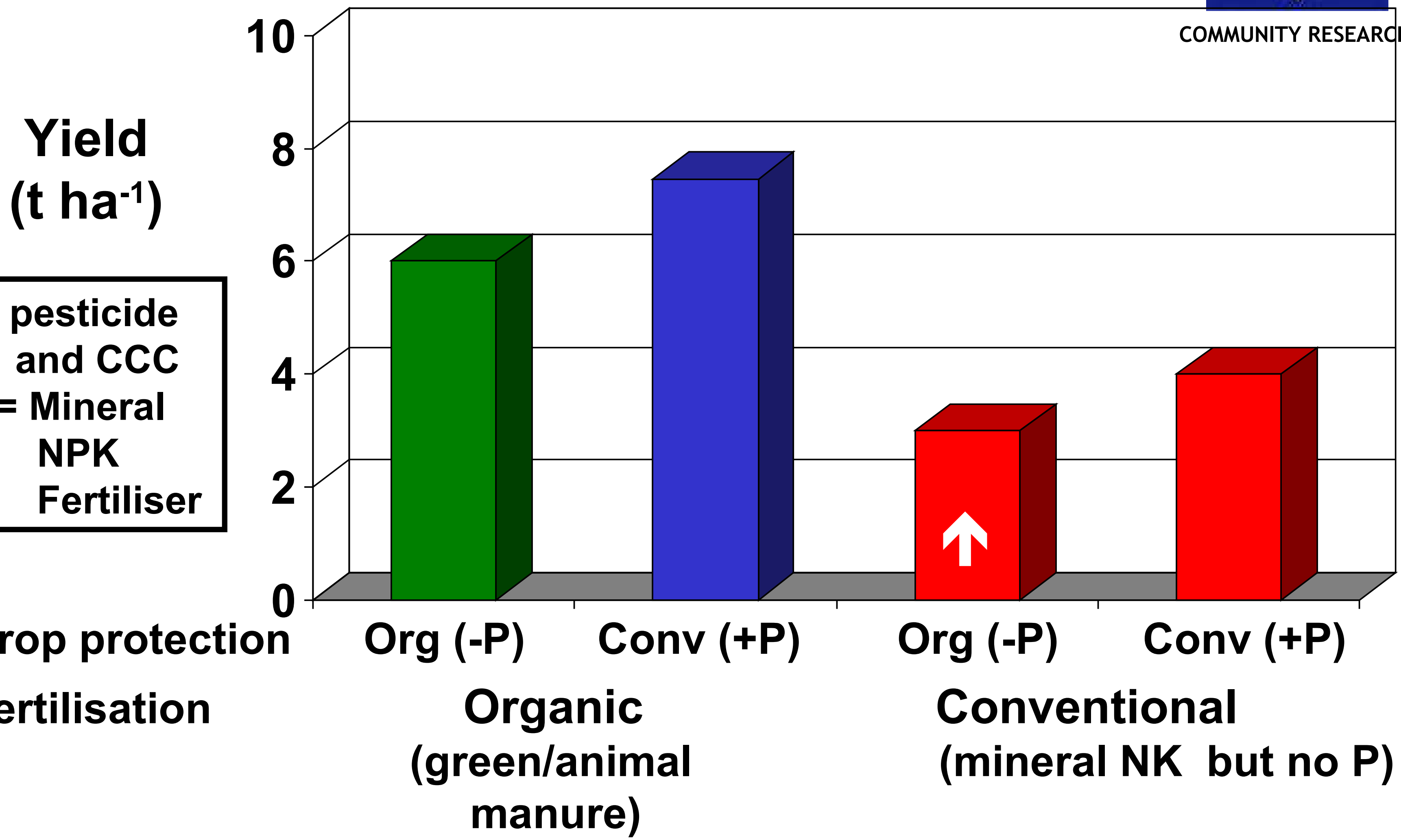
P= pesticide and CCC
MF= Mineral NPK Fertiliser



Will this affect the cost of food?

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- Price for P-mineral rock has increased **>500%** in the last 2 years
- Current Price for 1 ton of P-rock: **£ 185**
- Current Price for 1 ton of P-fertiliser: **£ 330**
- A farmer growing 100 ha of potato needs:
  - to apply 180 kg ha^{-1} phosphorus fertiliser
  - to pay **£ 5,940** for P-fertiliser alone

Are we using Phosphorus and other mineral fertilisers efficiently?

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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**

[1] Hirel et al. (2007) *Journal of Experimental Botany* **58:** 2369-2387

Why has NUE efficiency decreased?

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For the last 40 years <u>crop breeding</u> has only focused on the needs of conventional production:

- high inputs of water-soluble, mineral NPK
- undesirable side effects of NPK-use
- breeding effort to overcome the problems caused by NPK

For example, in wheat production

- mineral NPK fertilisers increased lodging risk
- semi-dwarfing genes were introduced into wheat to reduce straw length and lodging risk
- semi-dwarfing genes also reduced root length/root system size and thereby nutrient uptake efficiency[1]

[1] Chloupek et al. (2006) *Applied Genentics* **2:** 779-786

Why has nutrient use efficiency decreased?

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For the last 40 years <u>P-fertilisation</u> has been:

- **high inputs of water-soluble, mineral P-inputs**
- **less and less from organic matter recycling**
- **high P-losses (P run-off = eutrophication)**
- **inhibition of arbuscular mycorrhizas (AM)**
- **crop breeding under high mineral P-inputs**
- **selection pressure against AM-competence and AM-associated P-scavenging capacity**
- **Dependence on water-soluble, mineral P**

What are the solutions?

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The main approaches available are:

- More efficient recycling of Phosphorus and other minerals via
  - animal and green manures,
  - crop residues, food processing waste
  - communal and domestic organic waste
  - human toilet waste/sewage

3. Reduction of losses of P-fertiliser from soils
4. Development of more nutrient (especially P) efficient crop varieties
   - EU NUE-CROPS project

Wheat - Yield (2005)

Effect of using varieties adapted to organic systems

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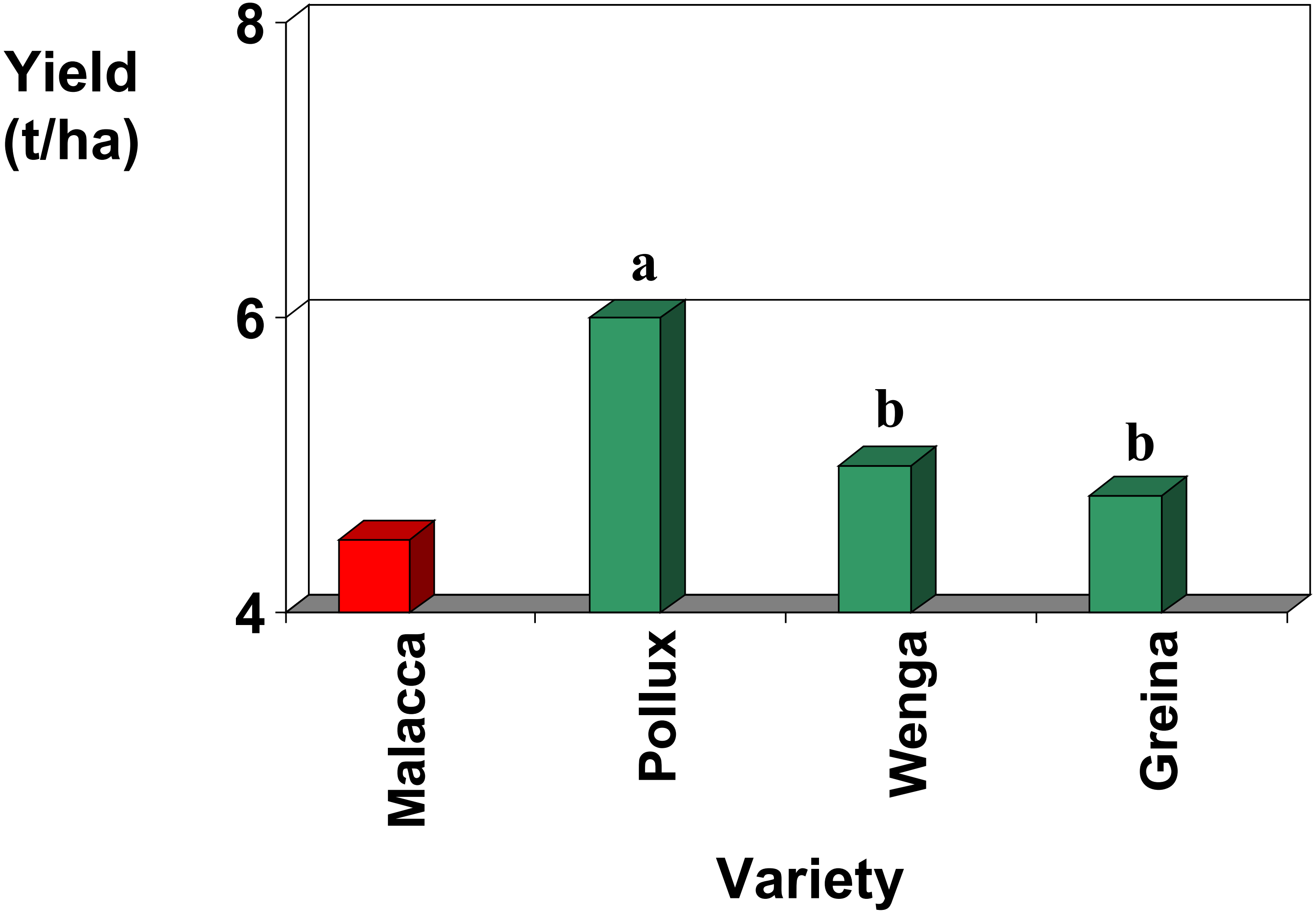
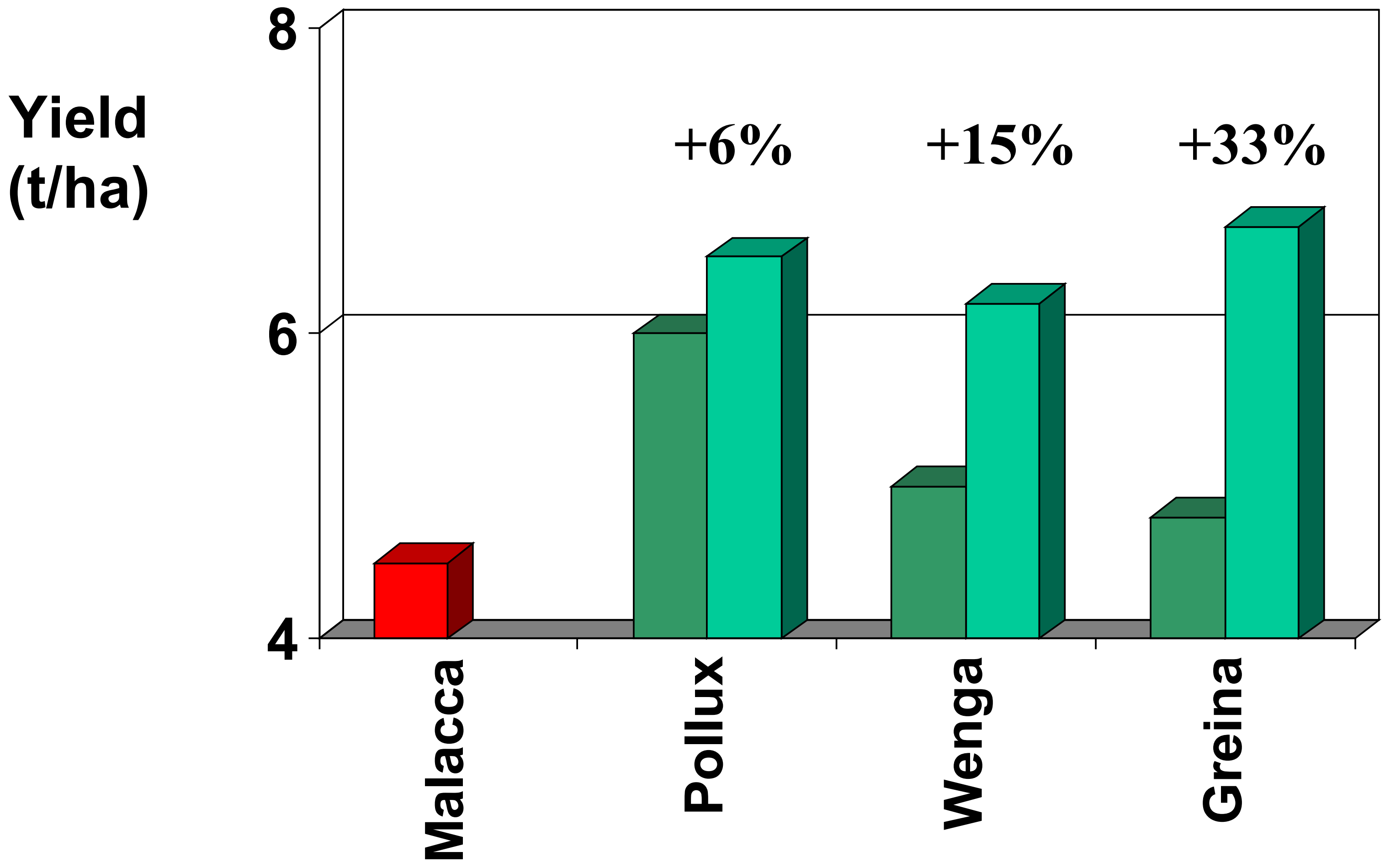


Wheat - Yield (2005)

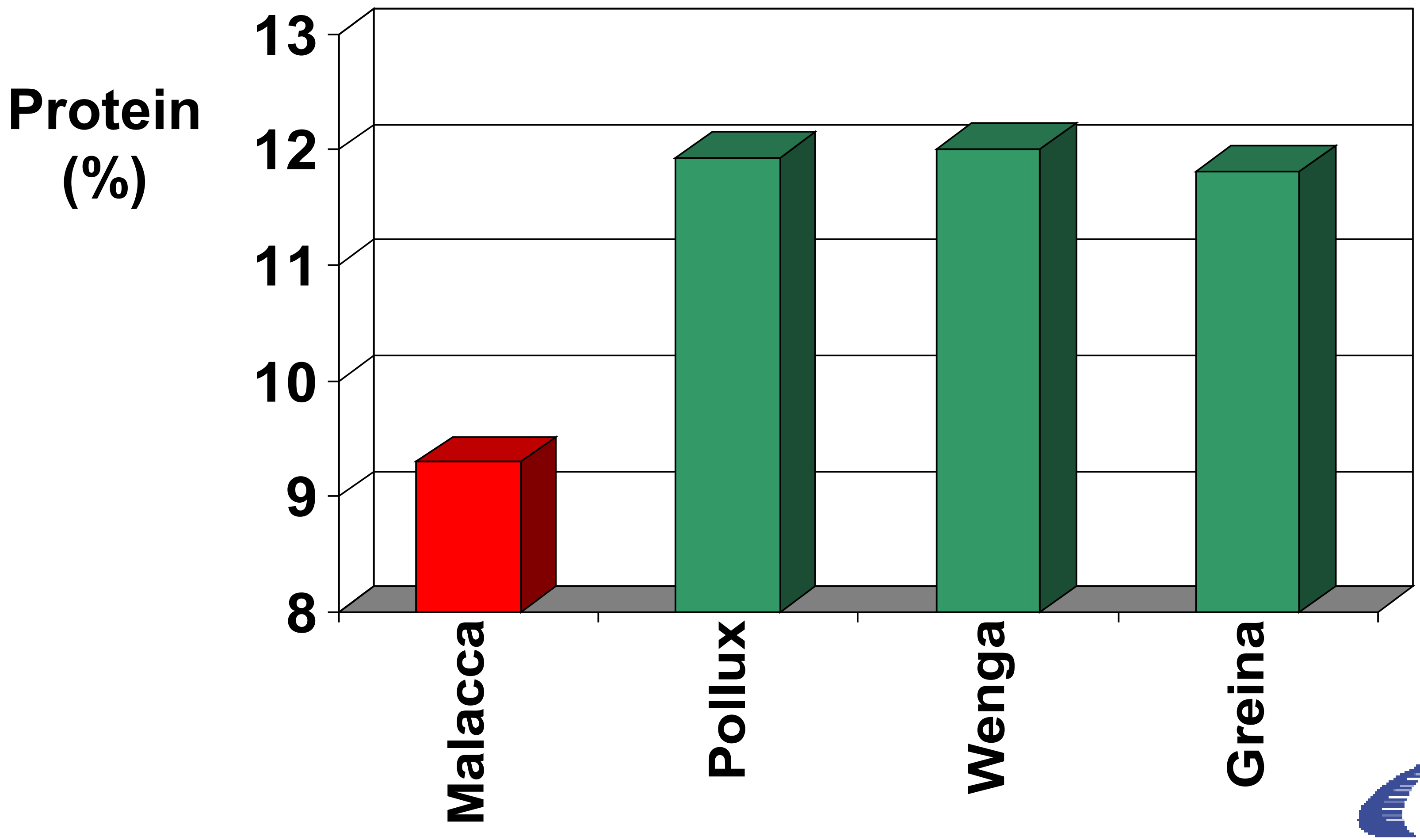
Effect of using varieties adapted to organic systems



Darker colour: standard fertility management
Lighter colour: improved fertility management

Wheat 2005 - Protein content

Effect of using varieties adapted to organic systems



A few quote from my University textbook on: Fertiliser and Fertilisation

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"These depressing prospects **(re running-out of P-fertiliser)** *are 'softened' by the fact that phosphorus is only diluted, but not destroyed when used as fertiliser"*

"P could be extracted from waste water and the oceans, but the later requires significantly more energy"

"In this age of space travel the import* (of P)** ***from other planets is also feasible,…"

Arnold Fink (1979) Dünger und Düngung. Verlag Chemie


Thank you

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