CropSustaIn conference on:
Plant health for Sustainable Agriculture
11-12 May 2015 Ljubljana, Slovenia

Sustainable Agriculture and Food Security; the need to integrate crop breeding, nutrition and health management

Carlo Leifert

School of Agriculture, Food and Rural Development
Integrated Agricultural Production (IAP) Group
www.nefg-organic.org

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COMMUNITY RESEARCH

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the need to integrate crop breeding, nutrition and health management

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Newcastle University

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1. Global crop yields

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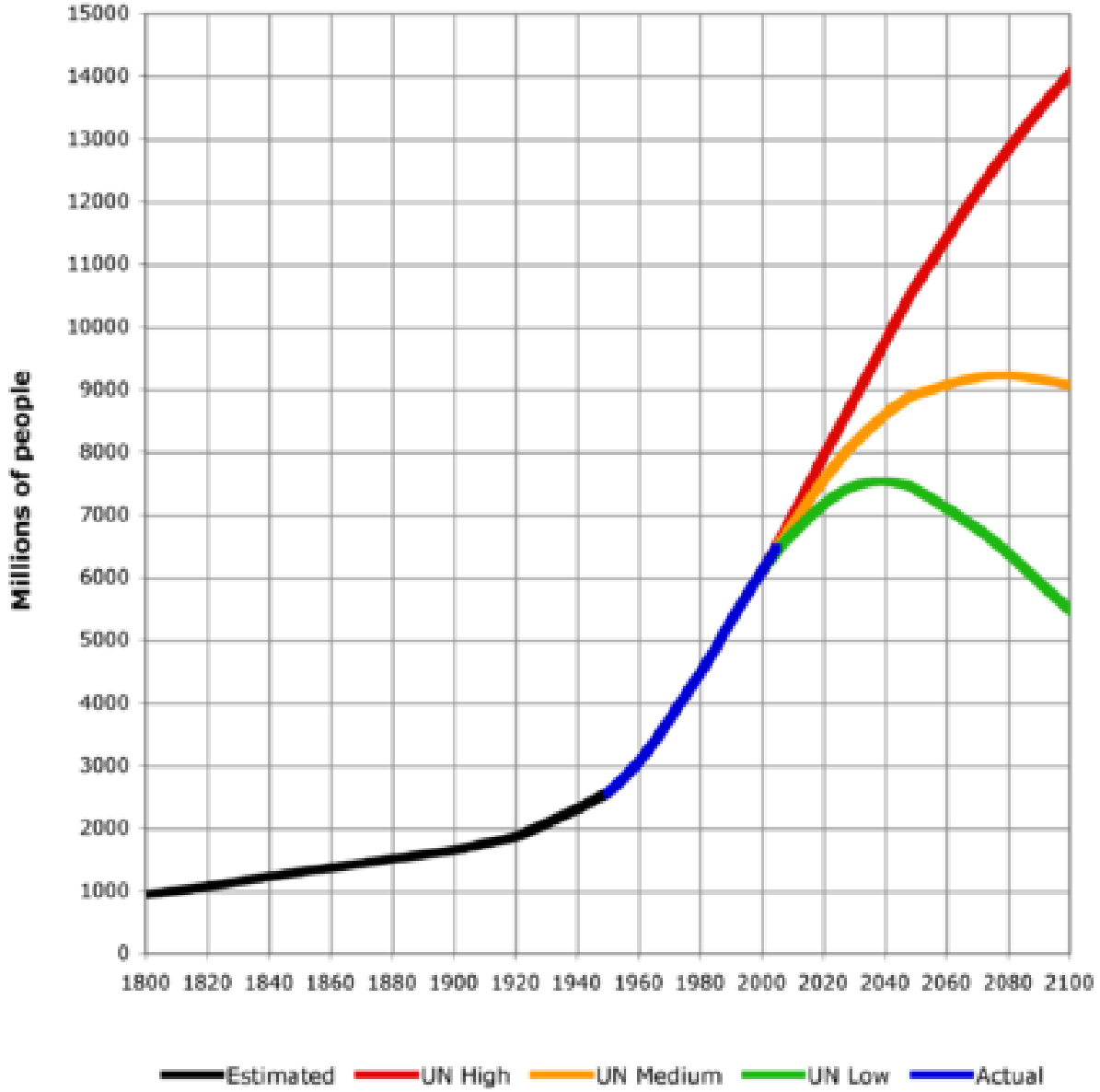
Results from UK-DEFRA, EU and industry sponsored R&D projects

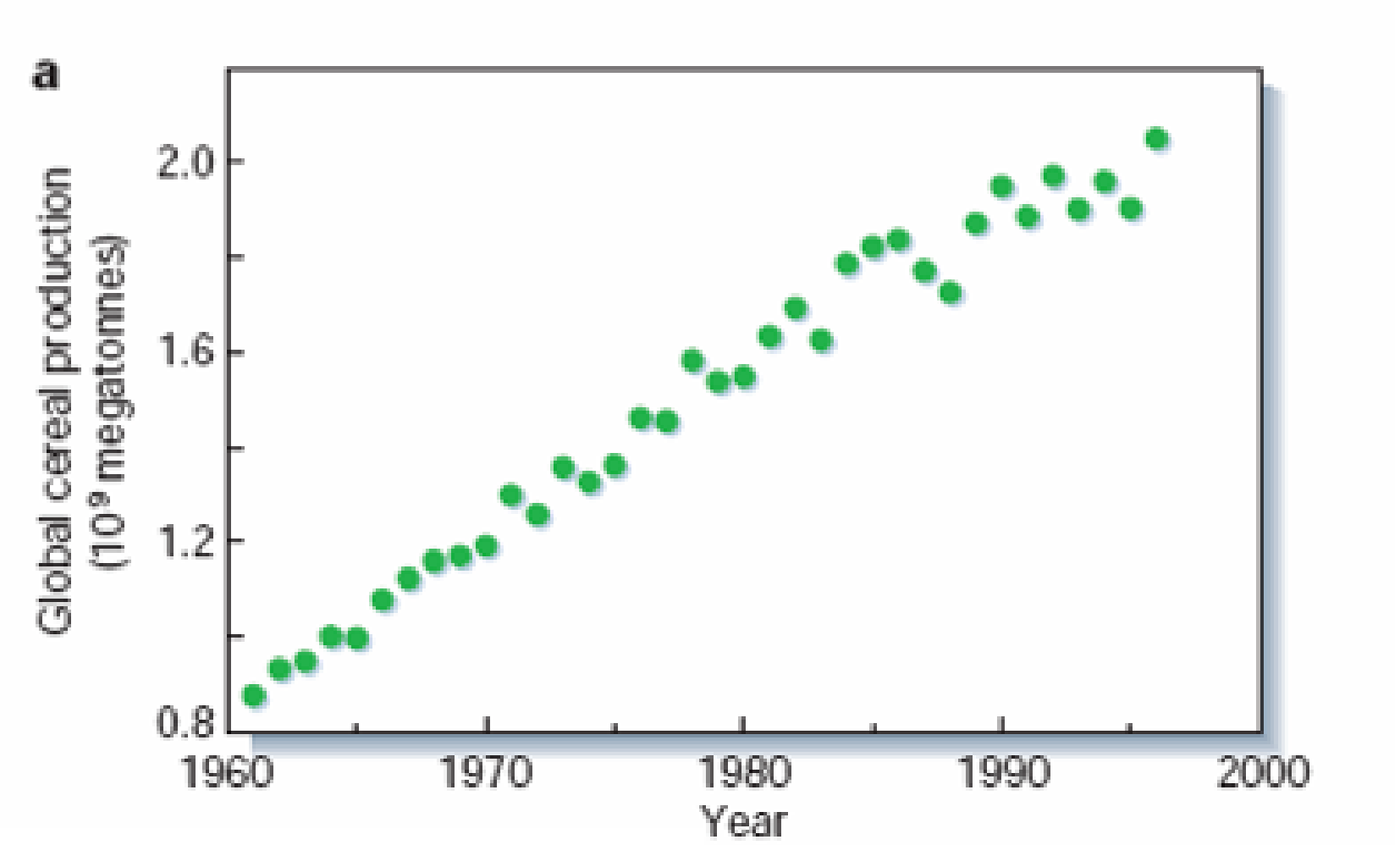
"Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist"

Kenneth Boulding, economist

Can we feed 9 Billion people in a sustainable way?



Total global cereal production



Tillman et al. (2002) ***Nature*** 418, 671-677

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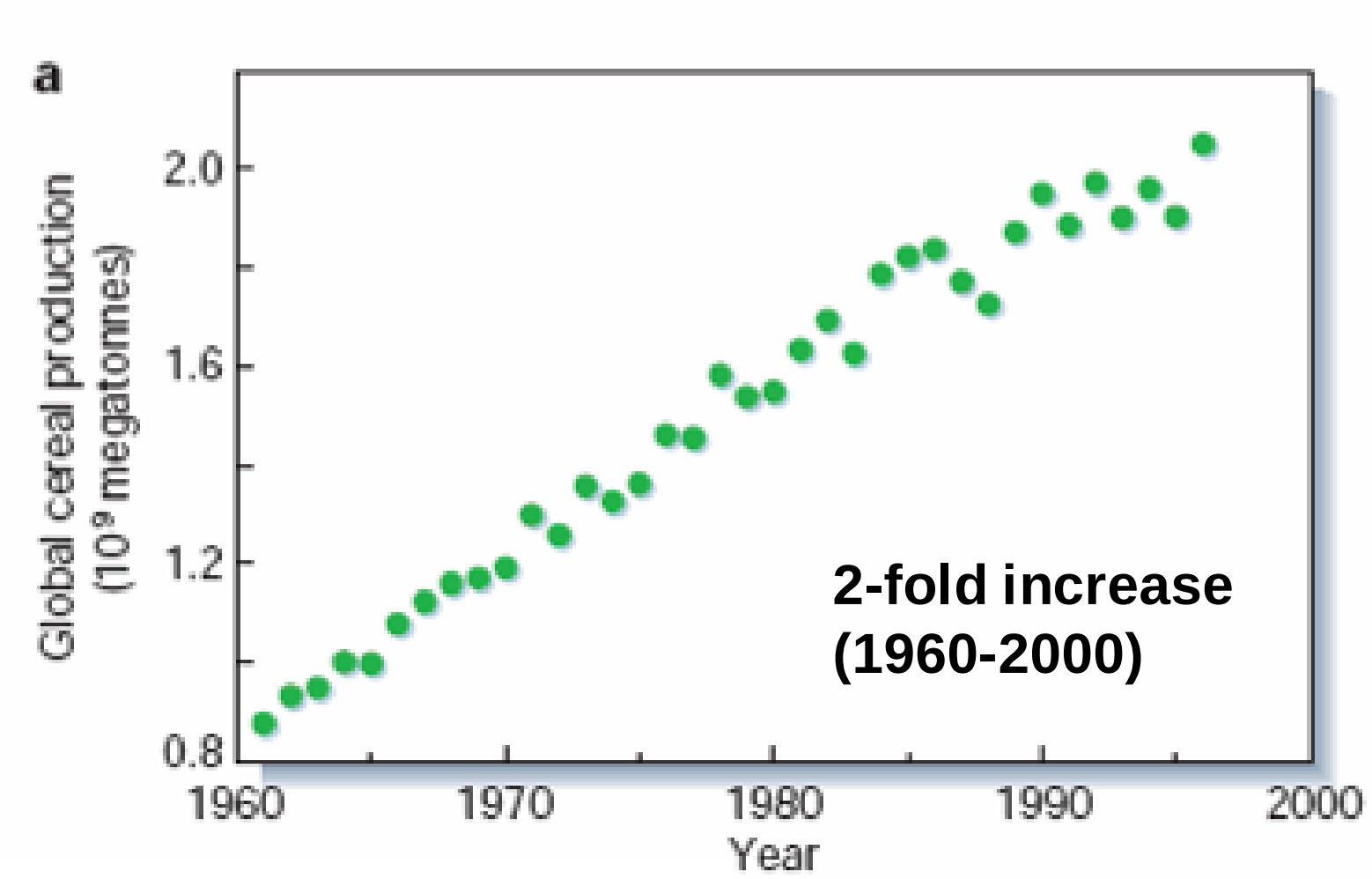
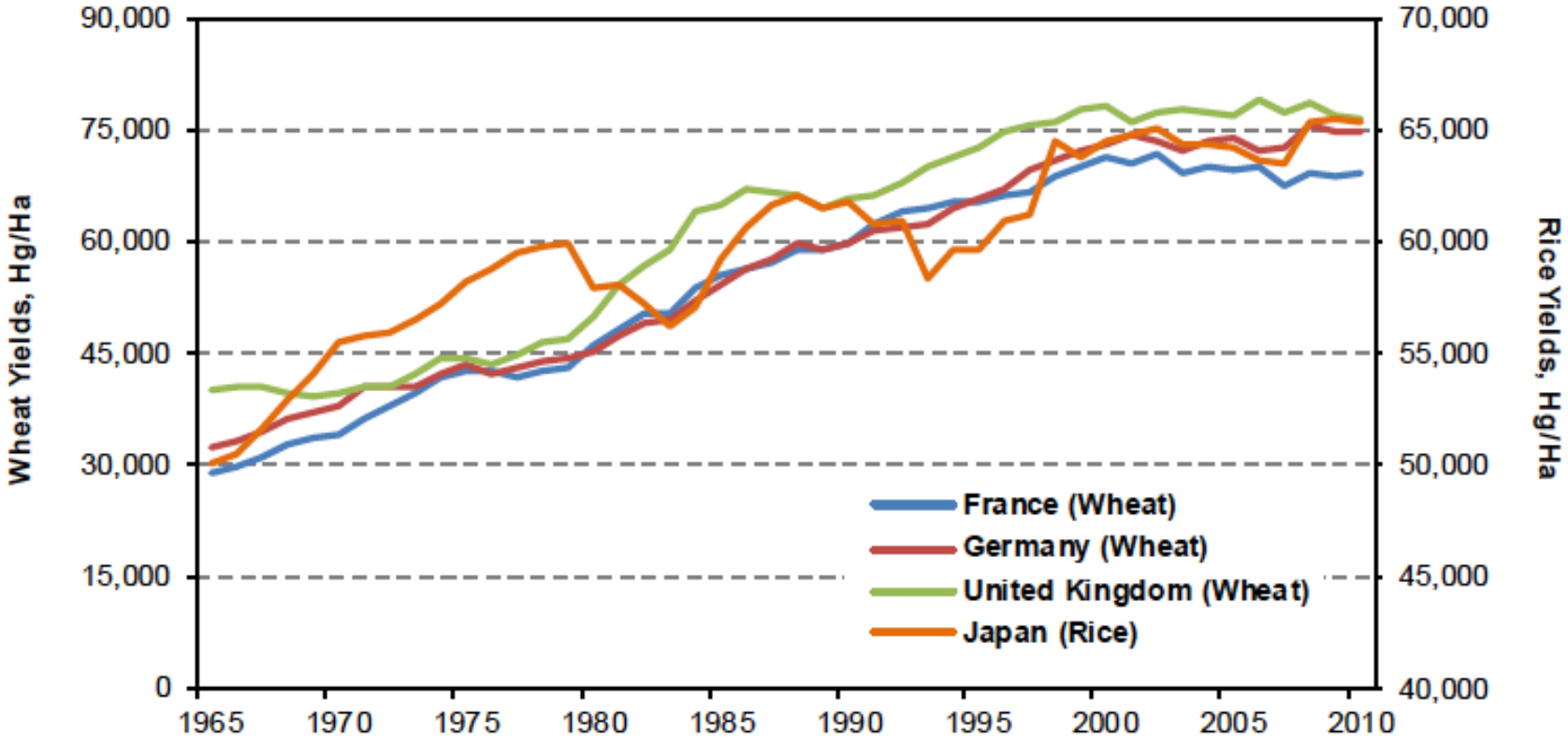


Tillman et al. (2002) ***Nature*** 418, 671-677

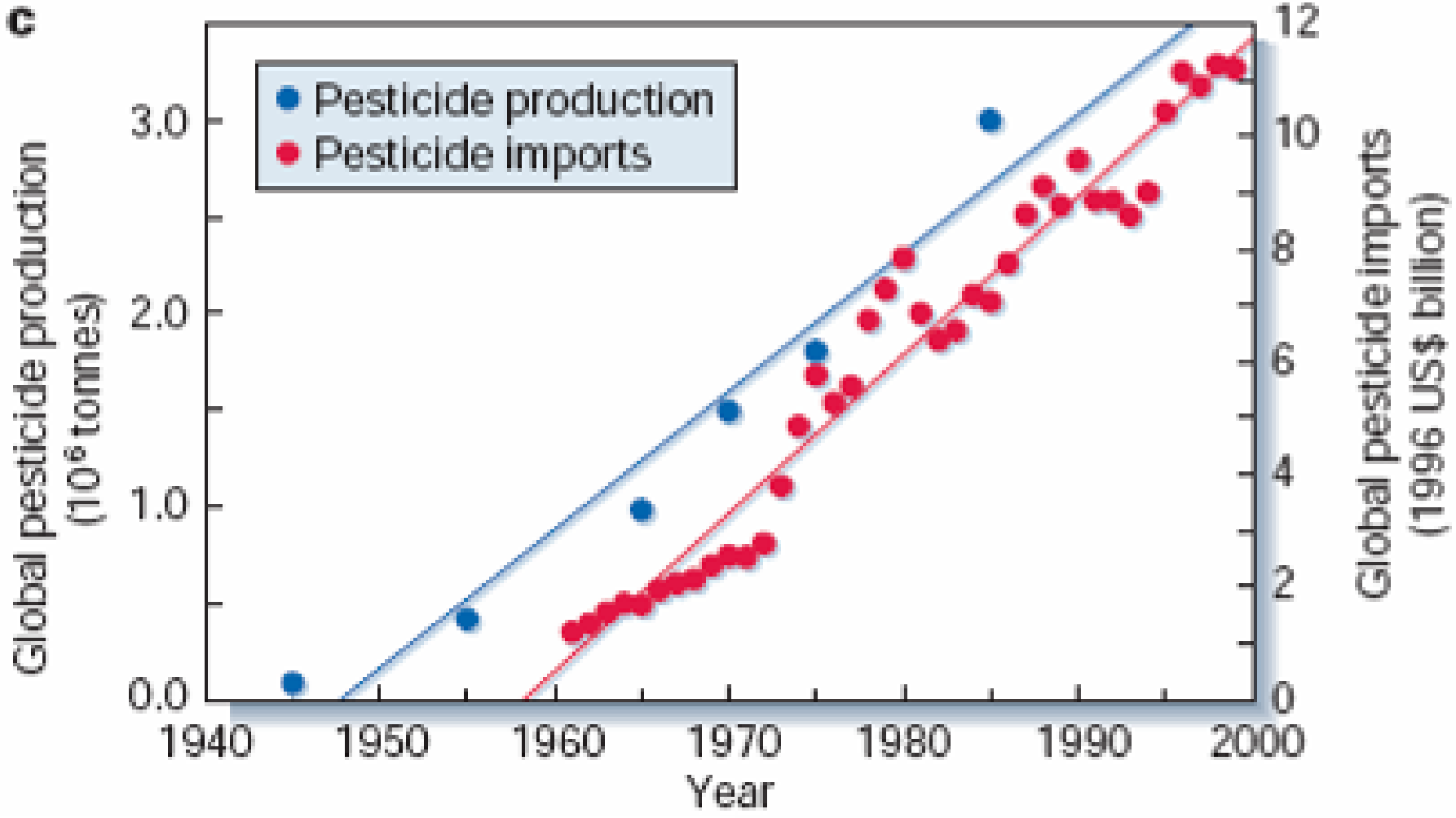
Will it be possible to increase yields in crop production further?

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



Source: UN Food and Agriculture Organization As of 12/31/10

Total global pesticide production and imports



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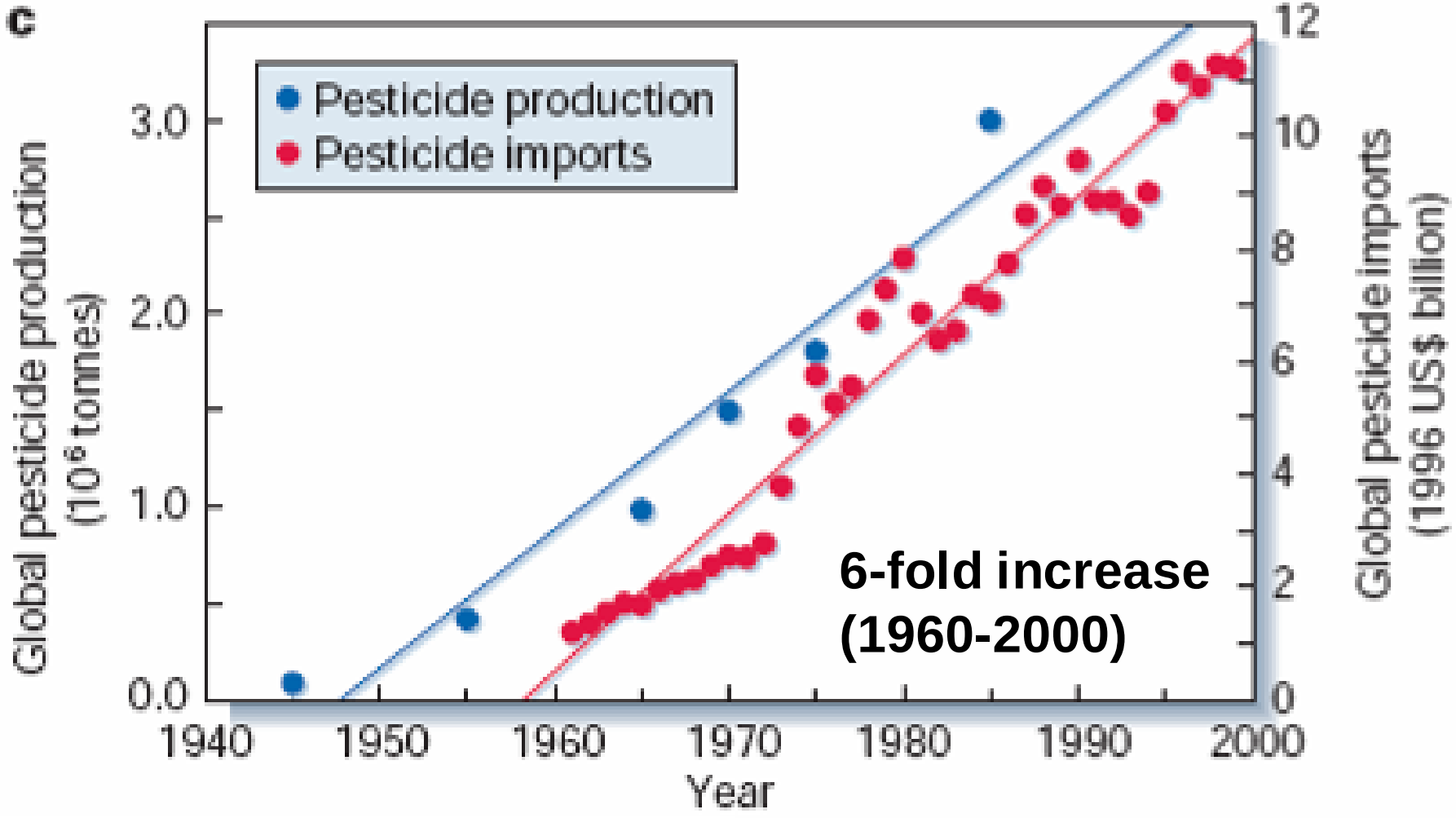

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The availability of pesticides is likely to decrease

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This be due to:

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This be due to:

- **Resistance development**
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- **Fewer new pesticides being introduced**

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This be due to:

- **Resistance development**
- **Fewer new pesticides being introduced**
- **Legislation restricting or prohibiting the use of certain groups of pesticides in response to concerns about environmental and human health impacts**

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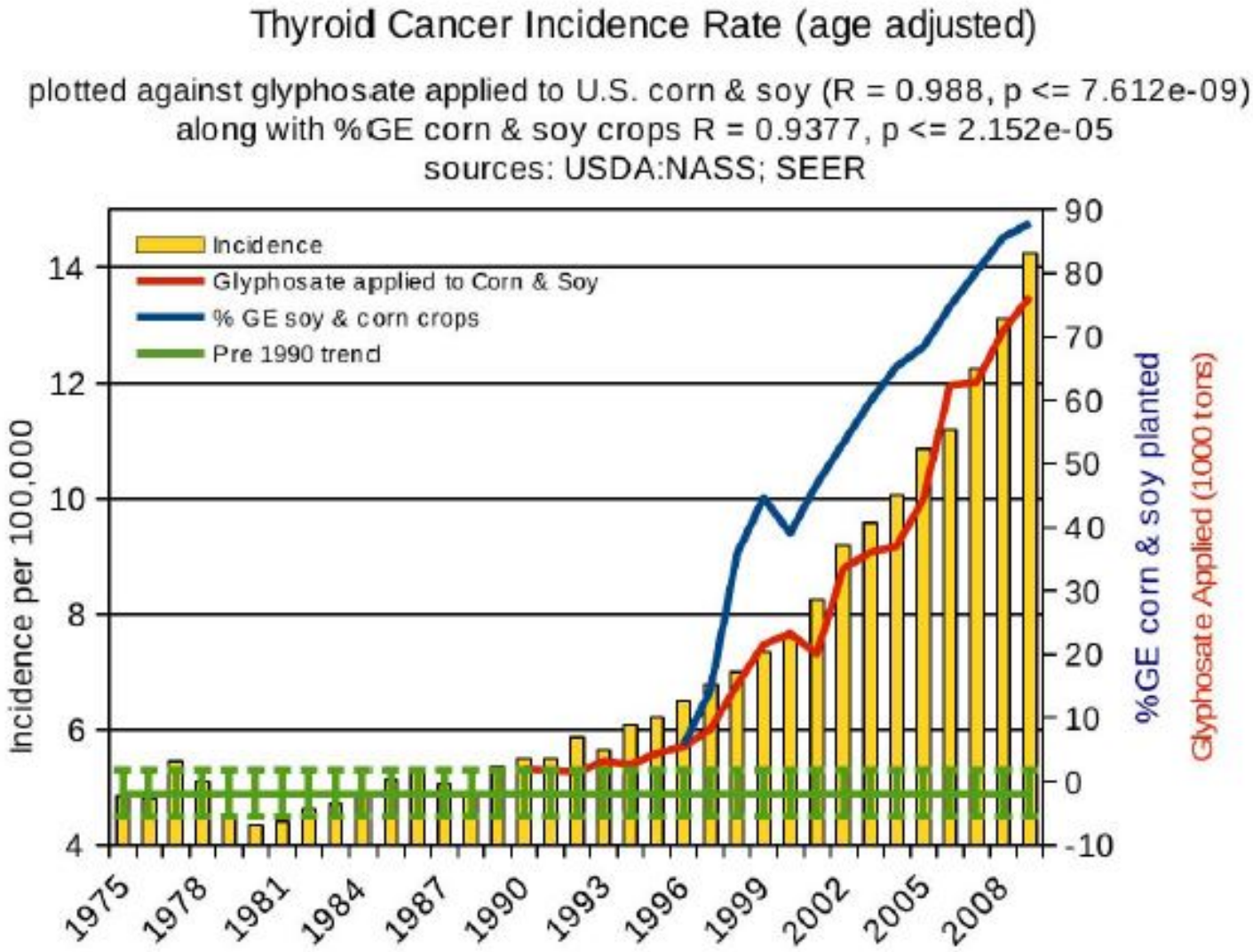
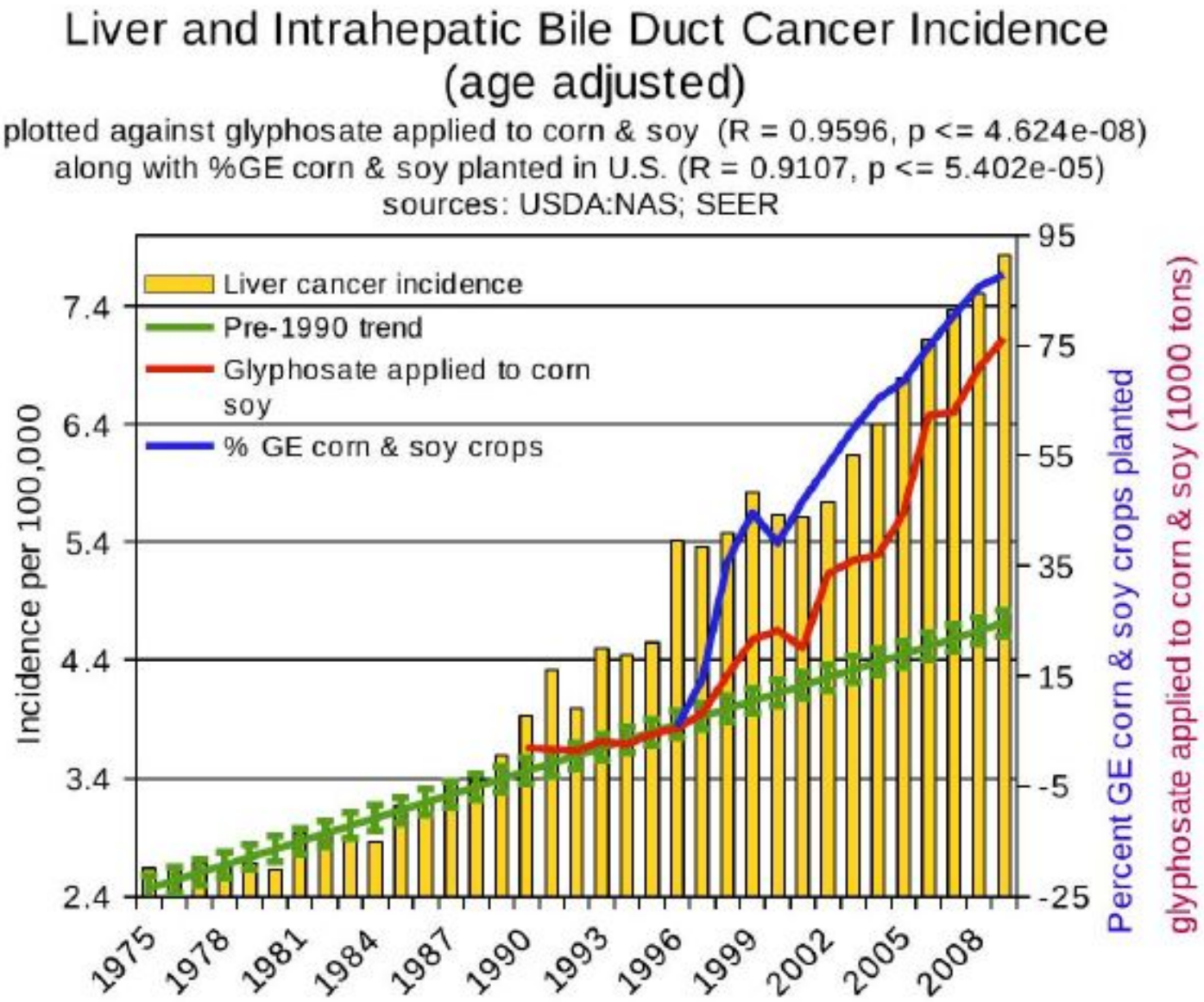
- ***"for malathion and glyphosate, the mechanistic evidence provided independent support of the 2A classification (=probably carcinogenic) based on evidence of carcinogenicity in humans and experimental animals."***
- **Glyphosate is the highest global production volume herbicide**



Swanson et al. (2014) GM-crops, glyphosate and the deterioration of health in the USA. *Journal of Organic Systems* **9,** 6-37



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Without pesticides the yields of crop production is likely to decrease

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The level of yield reduction can be estimated

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- **based on yield differences between organic and conventional crop production systems**

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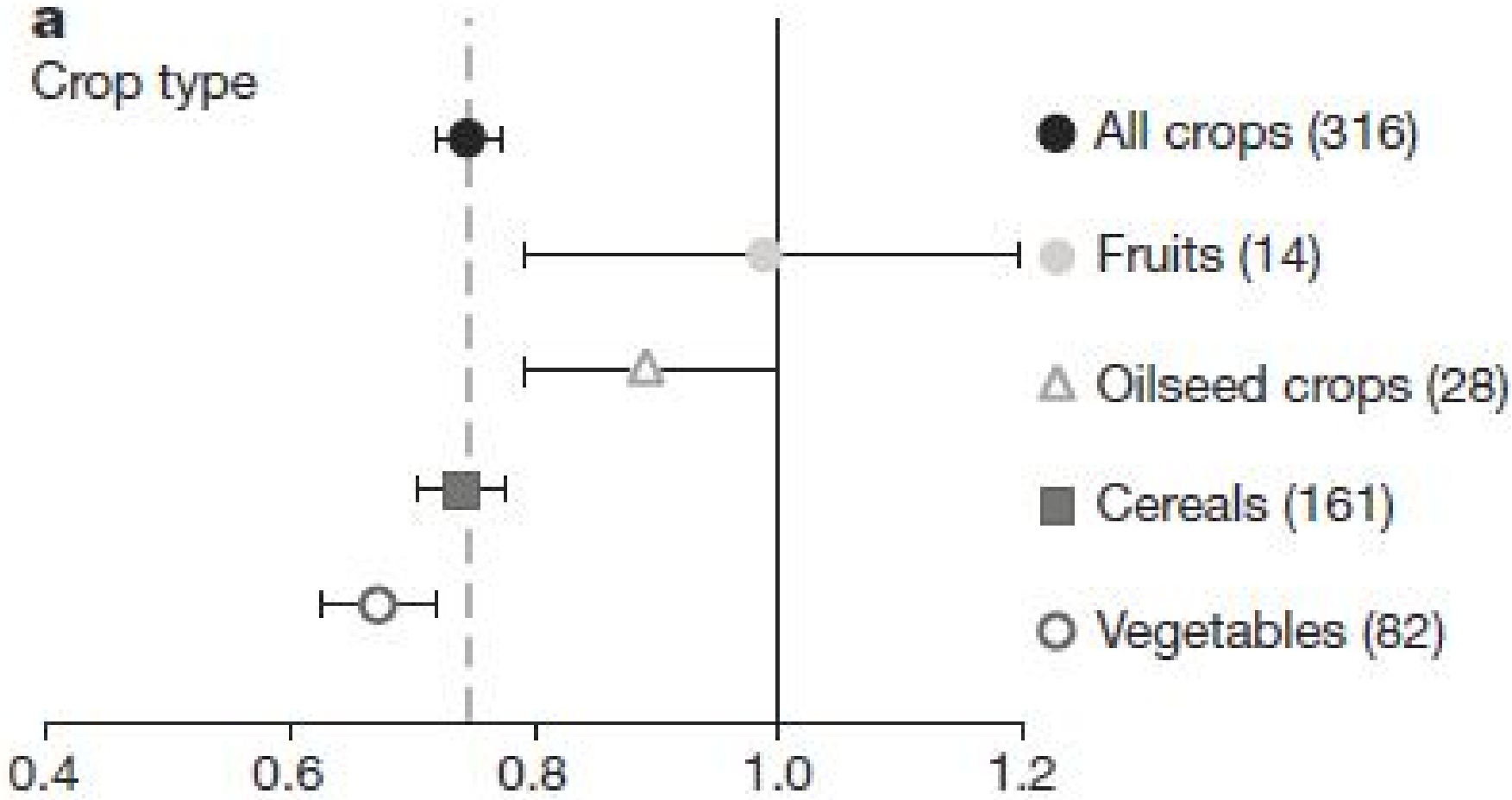
- **based on yield differences between organic and conventional crop production systems**
- **factorial field experiments can more precisely estimate the yield loss due to non-use of synthetic chemicabl pesticides**



Influence of different crop types on organic-to conventional yield ratios.

Seufert et al. (2014) Comparing the yields of organic and conventional agriculture. *Nature* **485, 229-232**

Nafferton Factorial Systems Comparison Trial
experimental design - factors

COMMUNITY RESEARCH

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Nafferton Factorial Systems Comparison Trial
experimental design - factors

COMMUNITY RESEARCH

- **Rotation design (4)**
  - **Non-diverse (2):** 2 years grass/clover 6 years cereals, 1 year potato or vegetables
  - **Diversified (2):** 3 years grass/clover, 2 years cereals 2 years potato or vegetables, 1 year faba beans)

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Nafferton Factorial Systems Comparison Trial
experimental design - factors

COMMUNITY RESEARCH

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- **Crop protection (2)**
  - **Conventional (pesticides used to farm assured standards)**
  - **Organic (according to soil association standards)**

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Nafferton Factorial Systems Comparison Trial
experimental design - factors

COMMUNITY RESEARCH

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- **Fertilisation (2)**
  - Conventional (Mineral NPK used to farm assured standards)
  - Organic (composted manure inputs only)

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experimental design - factors

COMMUNITY RESEARCH

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experimental design - factors

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- **Replicate blocks (4)**
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Total area: 6 ha

Experimental Design

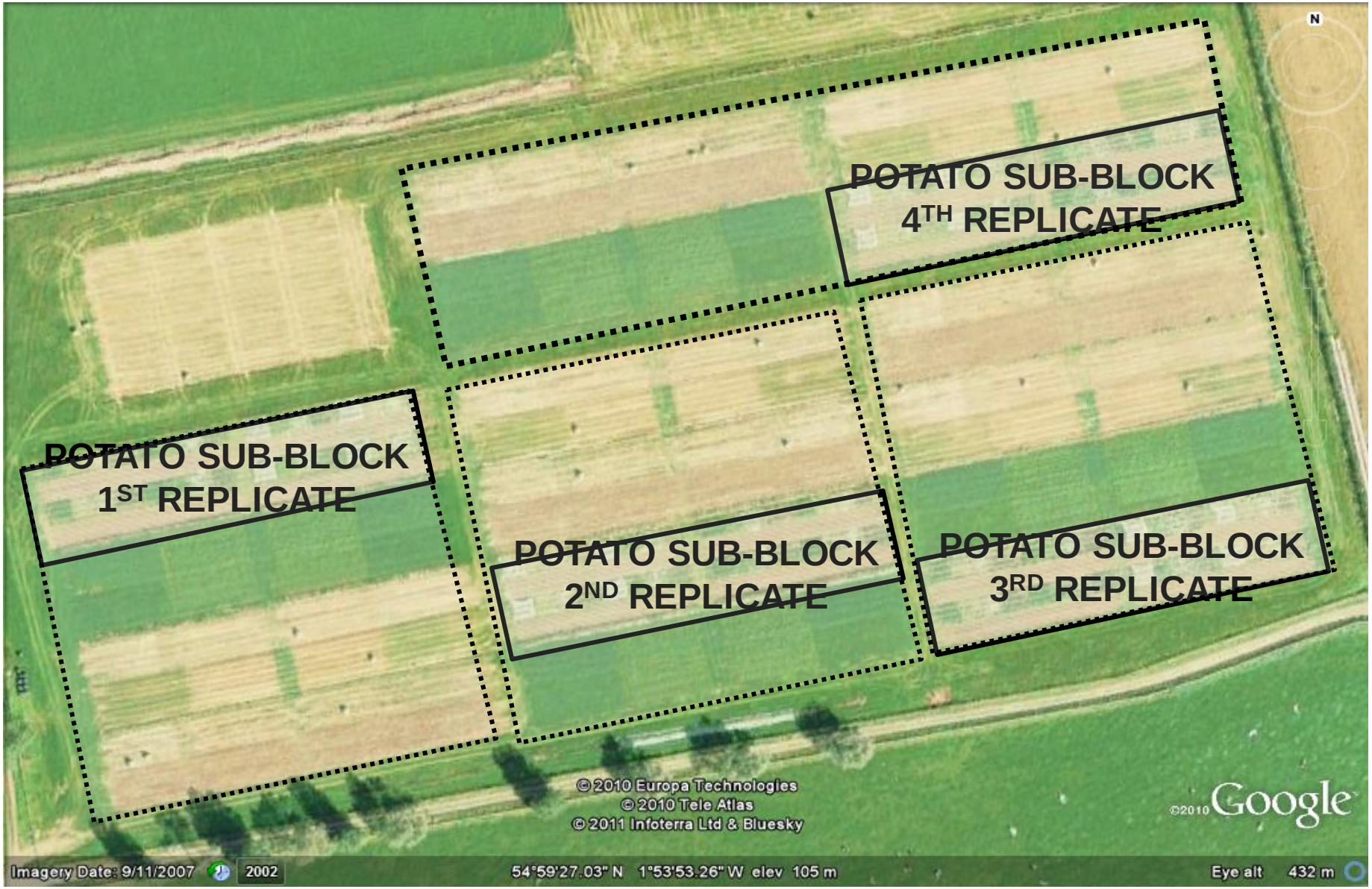
Nafferton **F**actorial **S**ystems **C**omparison **T**rial

Experimental Design

Nafferton **F**actorial **S**ystems **C**omparison **T**rial

Experimental Design

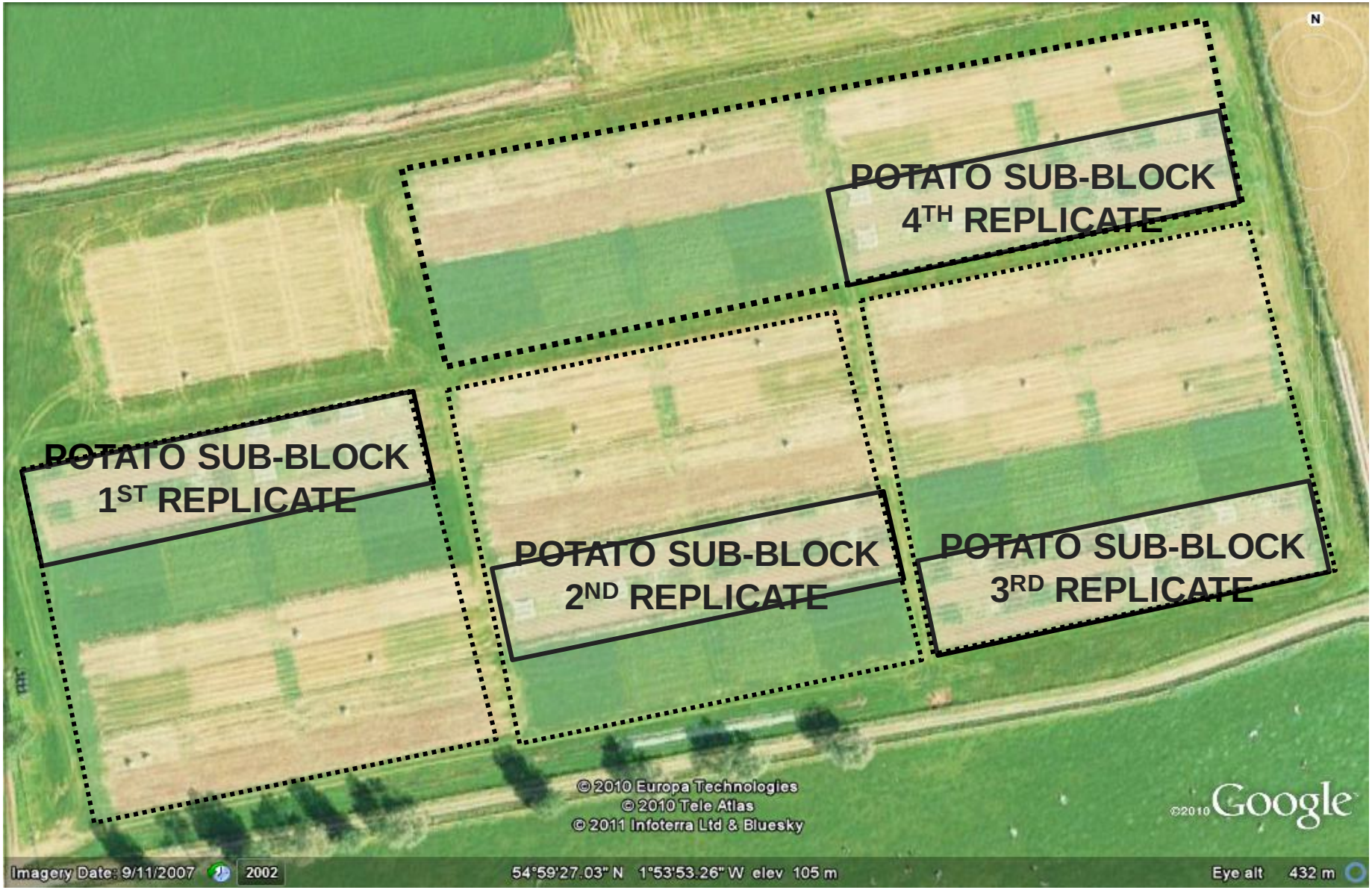
Nafferton Factorial Systems Comparison Trial



Experimental Design

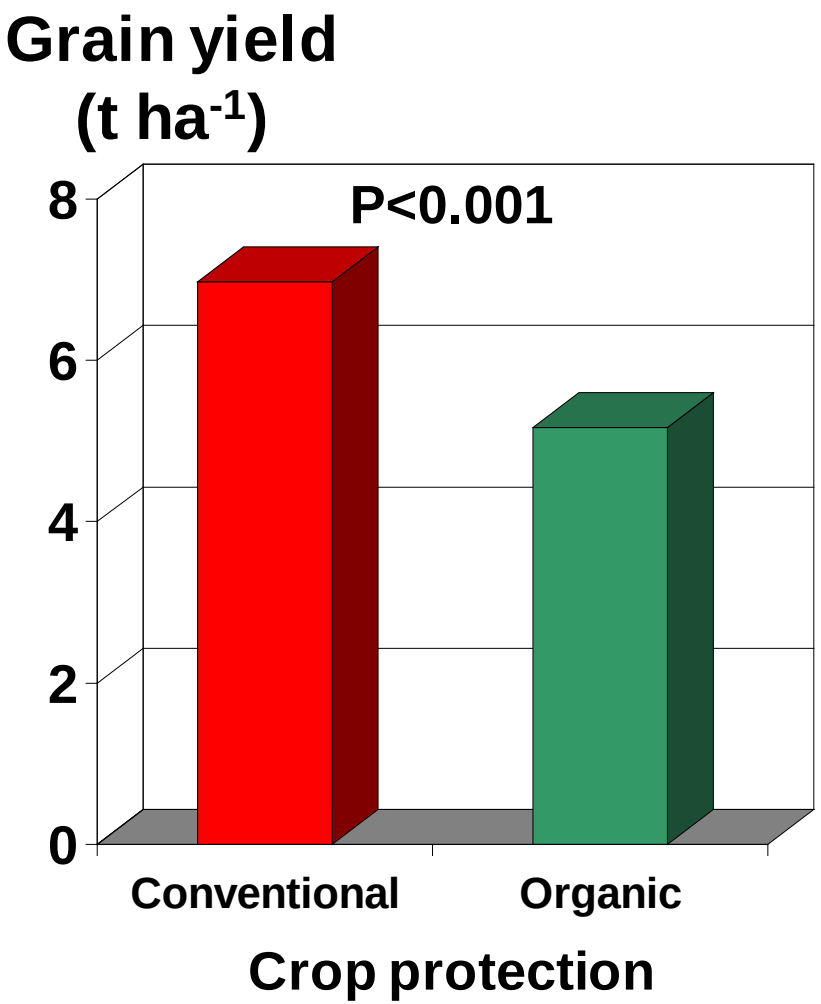
Nafferton Factorial Systems Comparison Trial

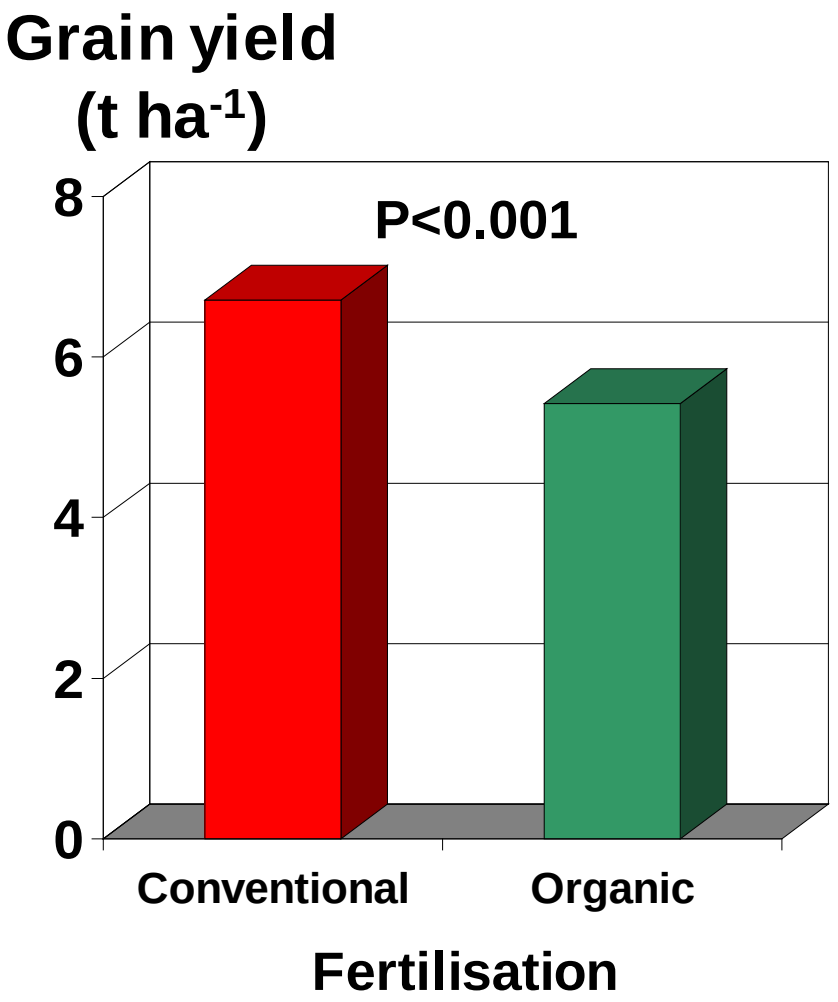
COMMUNITY RESEARCH



Effect of fertilisation and crop protection on the wheat yield (average of 4 seasons)

COMMUNITY RESEARCH

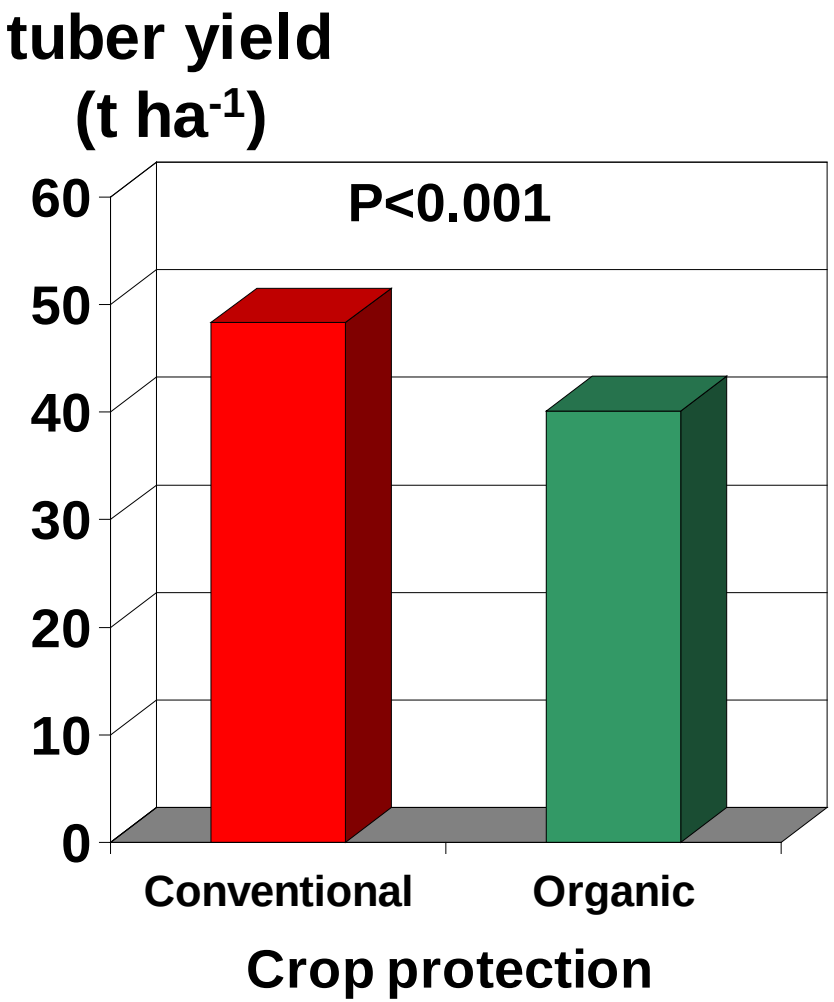


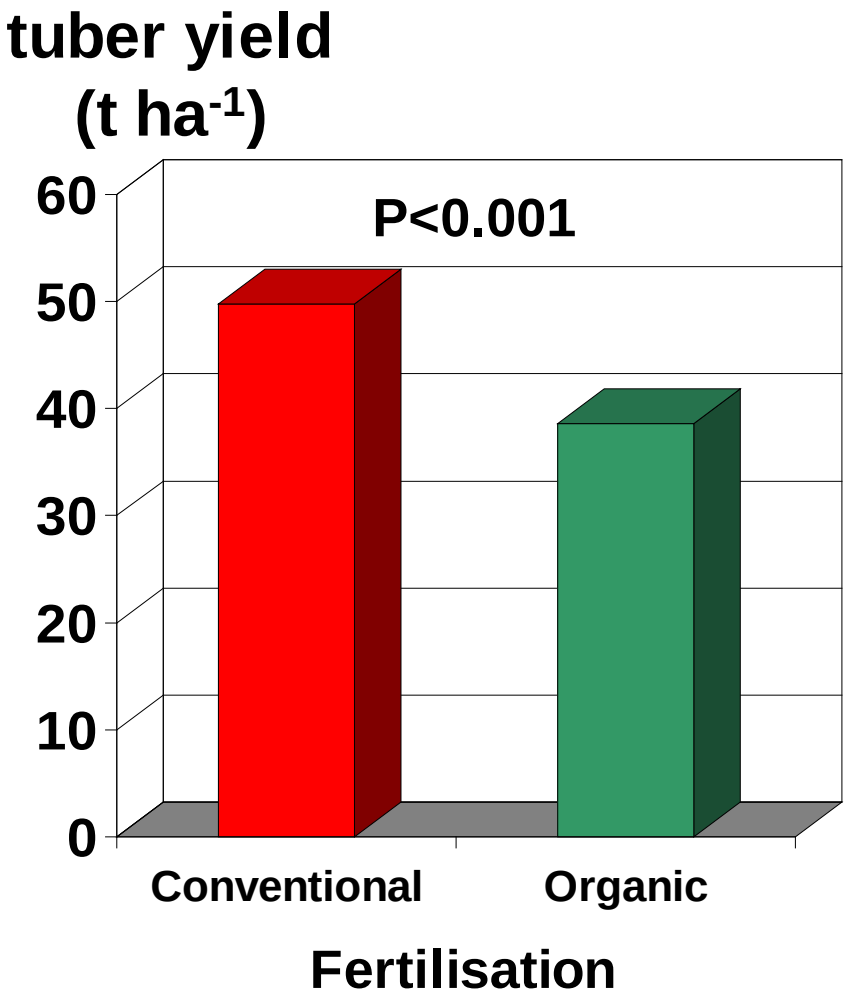


Bilsborrow et al . (2013) Eur. J. Agron. **51**, 71-80

Effect of fertilisation and crop protection on the potato yield (average of 4 seasons)

COMMUNITY RESEARCH





Palmer et al . (2013) Eur. J. Agron. **49**, 83-92.

The dependence on pesticides to sustain current crop yield levels has increased

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There is evidence that this is partially due to:

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There is evidence that this is partially due to:

- **increased mineral (especially N) fertiliser use**

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There is evidence that this is partially due to:

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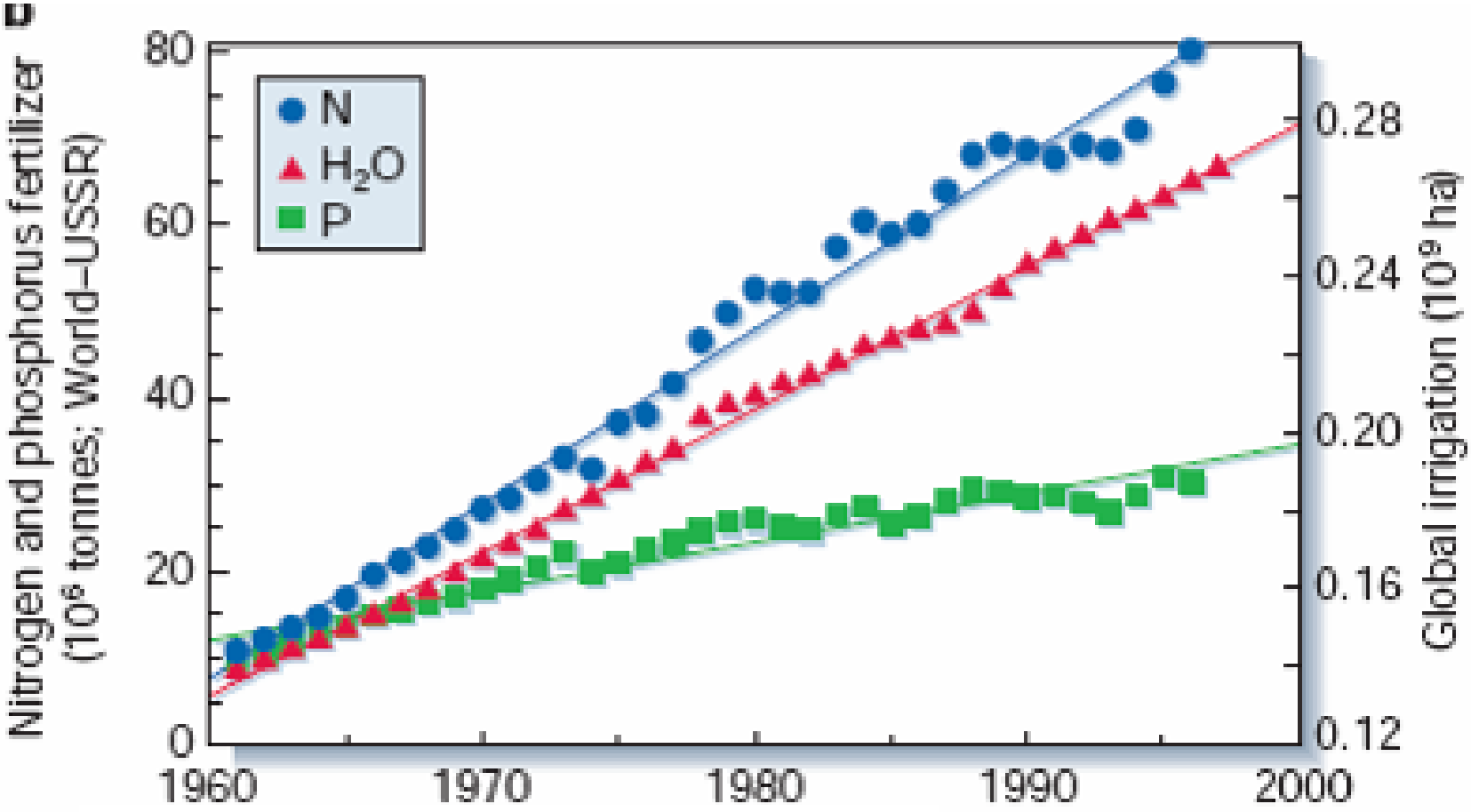
- **crop breeding**

Total global use of nitrogen, phosphorus and area of irrigated land



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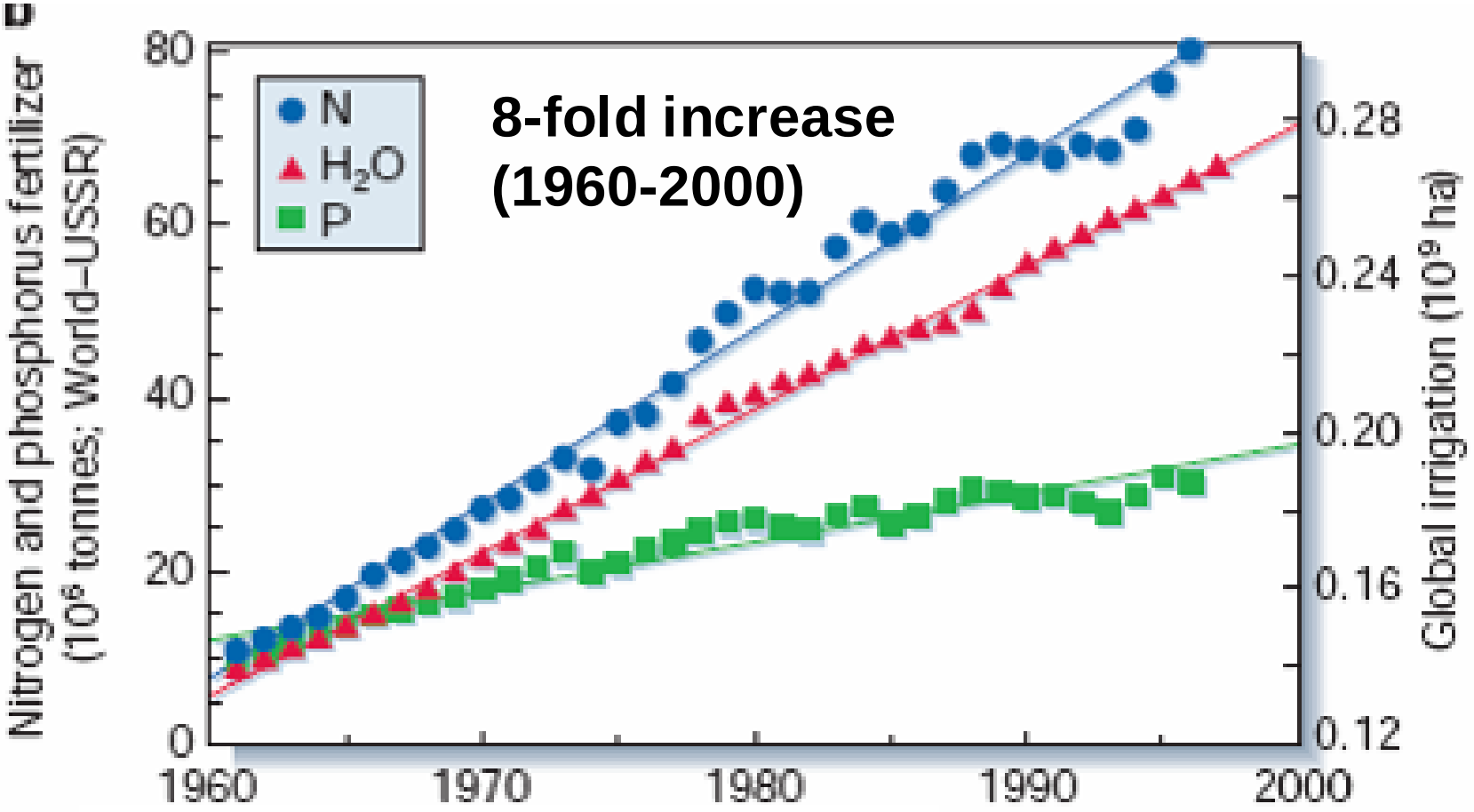

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Lodging in wheat – Interaction between fertilisation and crop protection

COMMUNITY RESEARCH

Lodging in wheat – Interaction between fertilisation and crop protection

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FERTILITY MANAGEMENT

Organic

(clover/manure based)

Lodging in wheat – Interaction between fertilisation and crop protection

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CROP PROTECTION	FERTILITY MANAGEMENT Organic (clover/manure based)
NO pesticides or CCC used (Organic)	

Lodging in wheat – Interaction between fertilisation and crop protection

COMMUNITY RESEARCH

FERTILITY MANAGEMENT

CROP PROTECTION

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NO pesticides or CCC used (Organic)

Lodging in wheat – Interaction between fertilisation and crop protection

COMMUNITY RESEARCH

	FERTILITY MANAGEMENT	
CROP PROTECTION	**Organic (clover/manure based)**	**Conventional (mineral NPK-based)**
NO pesticides or CCC used (Organic)		

Lodging in wheat – Interaction between fertilisation and crop protection

COMMUNITY RESEARCH

CROP PROTECTION	FERTILITY MANAGEMENT: Organic (clover/manure based)	FERTILITY MANAGEMENT: Conventional (mineral NPK-based)
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Lodging in wheat – Interaction between fertilisation and crop protection

COMMUNITY RESEARCH

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Lodging in wheat – Interaction between fertilisation and crop protection

COMMUNITY RESEARCH

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COMMUNITY RESEARCH

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Wheat – Interaction CP x FM

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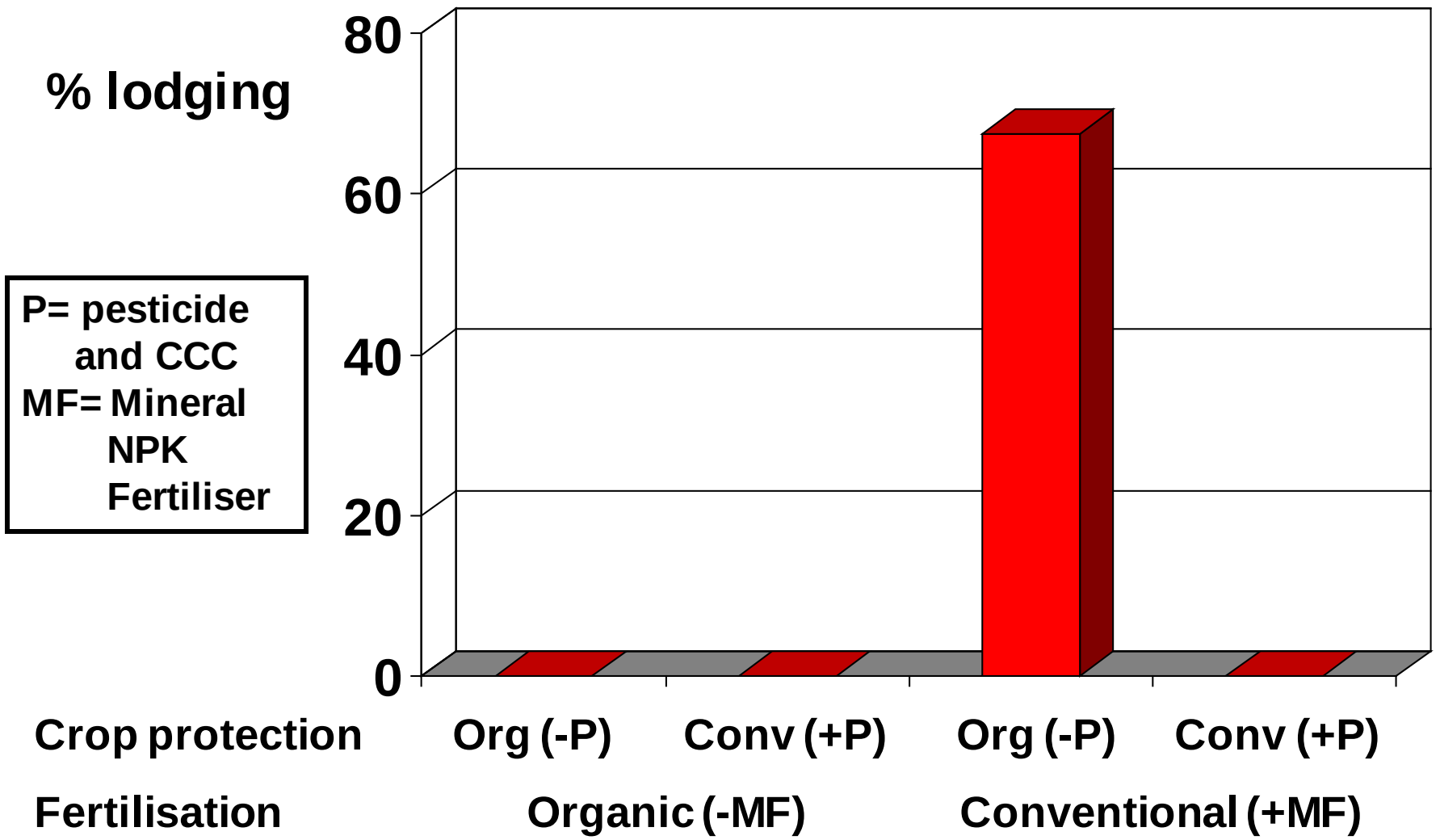
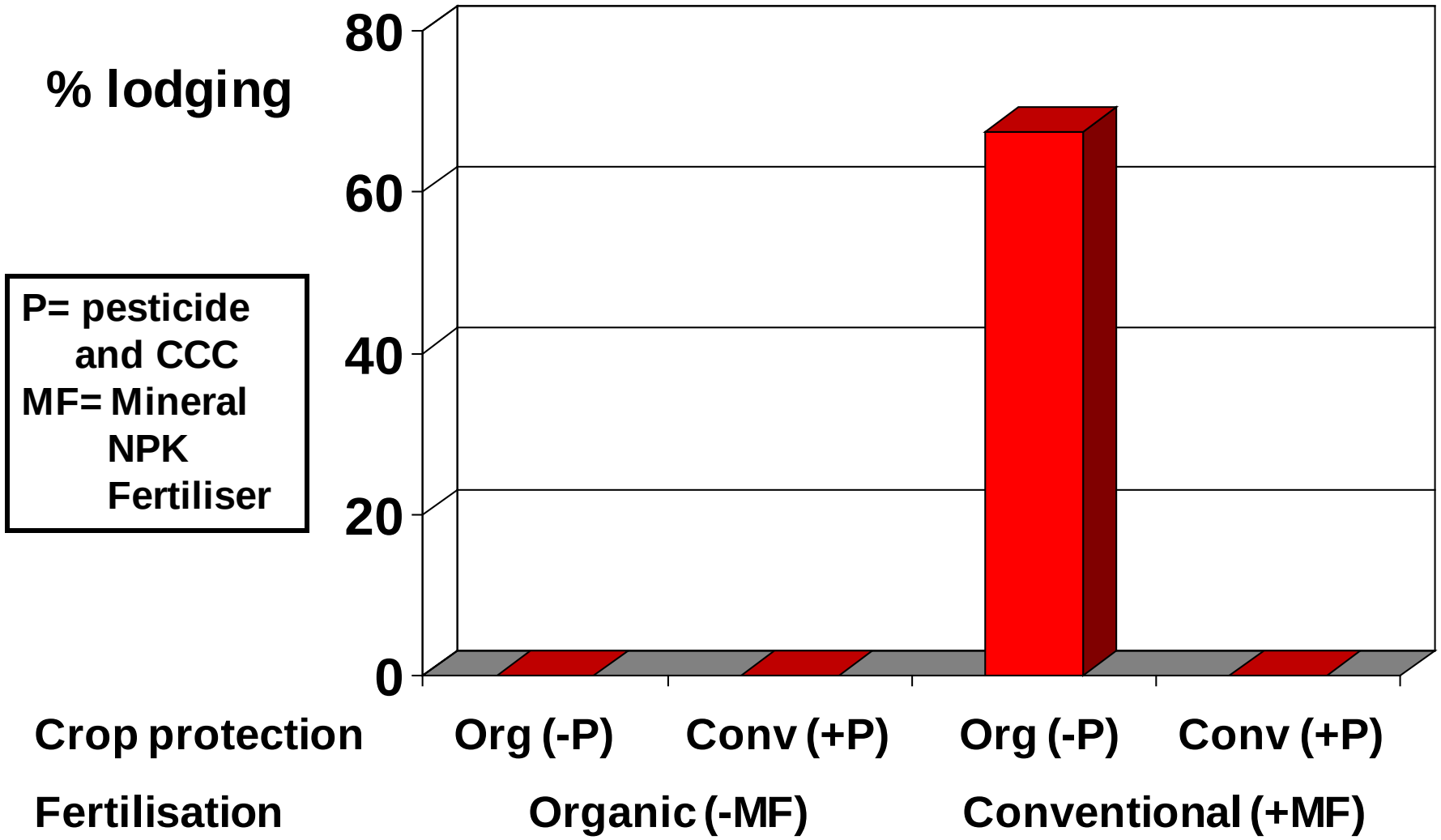


Wheat – Interaction CP x FM

COMMUNITY RESEARCH

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



Has nutrient use efficiency and weed competitiveness in weed decreased?

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For the last 40 years crop breeding has

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- **traits that reduce negative side effects of NPK-use**

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For example, in wheat production

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For the last 40 years crop breeding has focused on the needs of conventional production:

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For example, in wheat production

- **mineral NPK fertilisers increased lodging risk**

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ater-soluble, mineral NPK

side effects of NPK-use

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ncreased lodging risk

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Has nutrient use efficiency and weed competitiveness in weed decreased?

- **semi-dwarfing genes were introduced into wheat to reduce straw length and lodging risk**

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Has nutrient use efficiency and weed competitiveness in weed decreased?

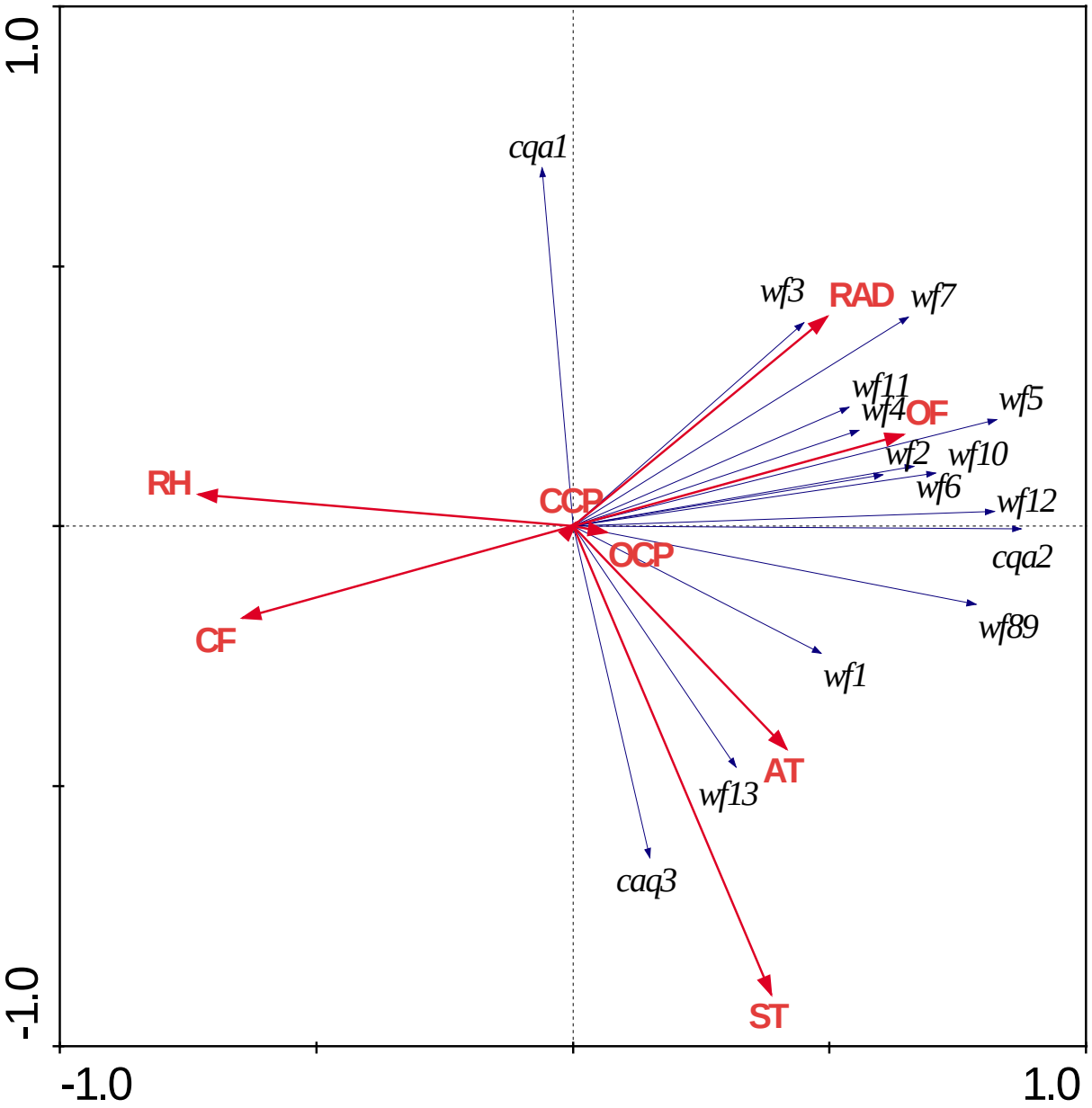
- semi-dwarfing genes also affect competitiveness against weeds and nutrient uptake efficiency[1]

Has nutrient use efficiency and weed competitiveness in weed decreased?

- **semi-dwarfing genes also affect competitiveness against weeds and nutrient uptake efficiency[1]**

[1] Hawkesford (2014) Reducing the reliance on nitrogen fertilizer for wheat production. *J Cereal Sci.* **59**, 276-283

Relationship between climatic and agronomic drivers and phenolic acids and flavanoids in wheat leaves



Drivers

RAD radiation
RH relative humidity
ST soil temperature
AT air temperature
OF organic fertiliser
CF mineral fertiliser
OCP no pesticides used
CCP pesticides used

Response variables

wf flavanoids
cqa chlorogenic acid derivatives

Replacing/reducing pesticide use relies on integration of crop breeding, nutrition and health management innovations

Nafferton
Ecological Farming Group

EXAMPLE

EU-FP6 IP QualityLowInputFood

Alternative strategies to soil chemical (e.g. methyl-bromide) and steam disinfection

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EXAMPLE
EU-FP6 IP QualityLowInputFood

Alternative strategies to soil chemical (e.g. methyl-bromide) and steam disinfection

Soil steaming

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EXAMPLE
EU-FP6 IP QualityLowInputFood

Alternative strategies to soil chemical (e.g. methyl-bromide) and steam disinfection

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- permitted under organic farming standards

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Ecological Farming Group

EXAMPLE
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Ecological Farming Group

EXAMPLE
EU-FP6 IP QualityLowInputFood

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Approach: Integrated use of:

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Ecological Farming Group

EXAMPLE
EU-FP6 IP QualityLowInputFood

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Approach: Integrated use of:

➢ **Resistant rootstocks** (soil fungal and nematode diseases)

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Nafferton
Ecological Farming Group

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Ecological Farming Group

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- Suppressive composts and/or elicitors
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Effect of soil steam disinfection, chitin soil amendments and grafting onto resistant rootstocks on root disease severity and fruit yield in organic tomato production

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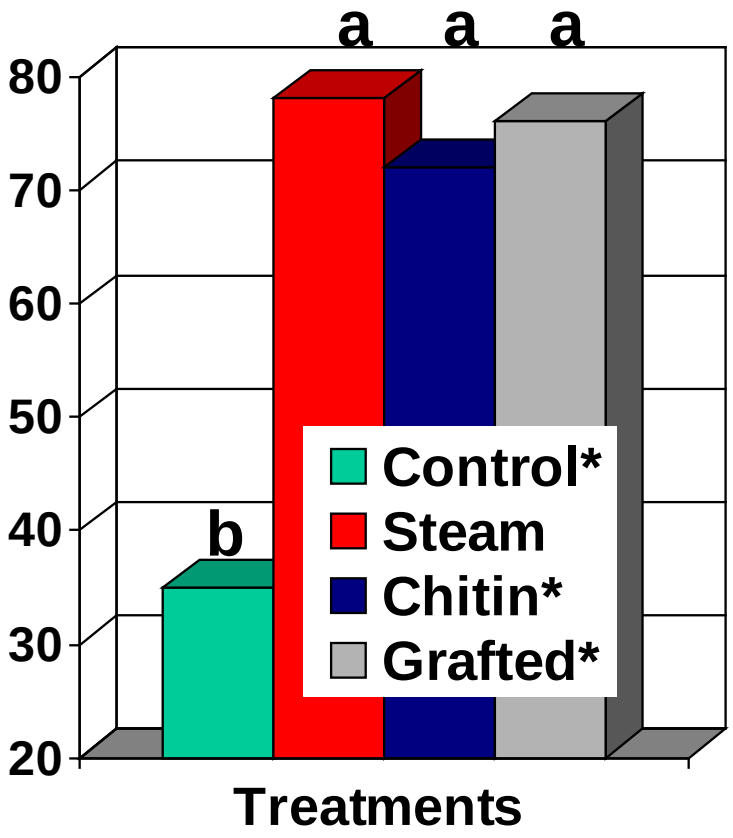

* untreated corky root rot infected soil

Giotis et al. unpublished

Effect of soil steam disinfection, chitin soil amendments and grafting onto resistant rootstocks on root disease severity and fruit yield in organic tomato production

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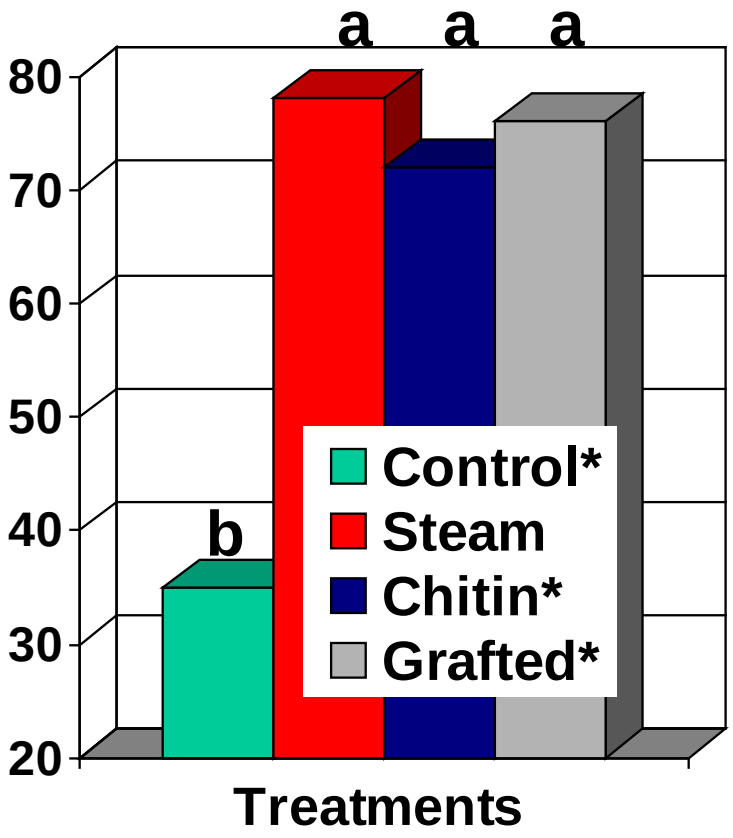
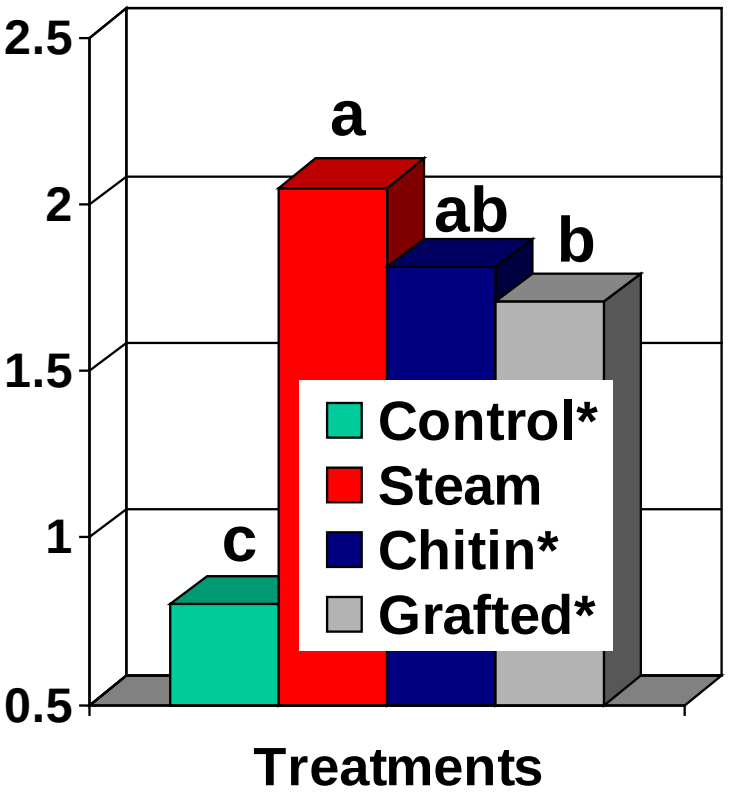
RFW (g plant^{-1})



Fruit yield (kg plant^{-1})



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Effect of soil steaming (ST), organic matter inputs (CCM, HWC, FBT), elicitor soil amendment (Chi, SWE) and biological control agents (Bs, Po) on root disease severity (RFW) in organic tomato crops

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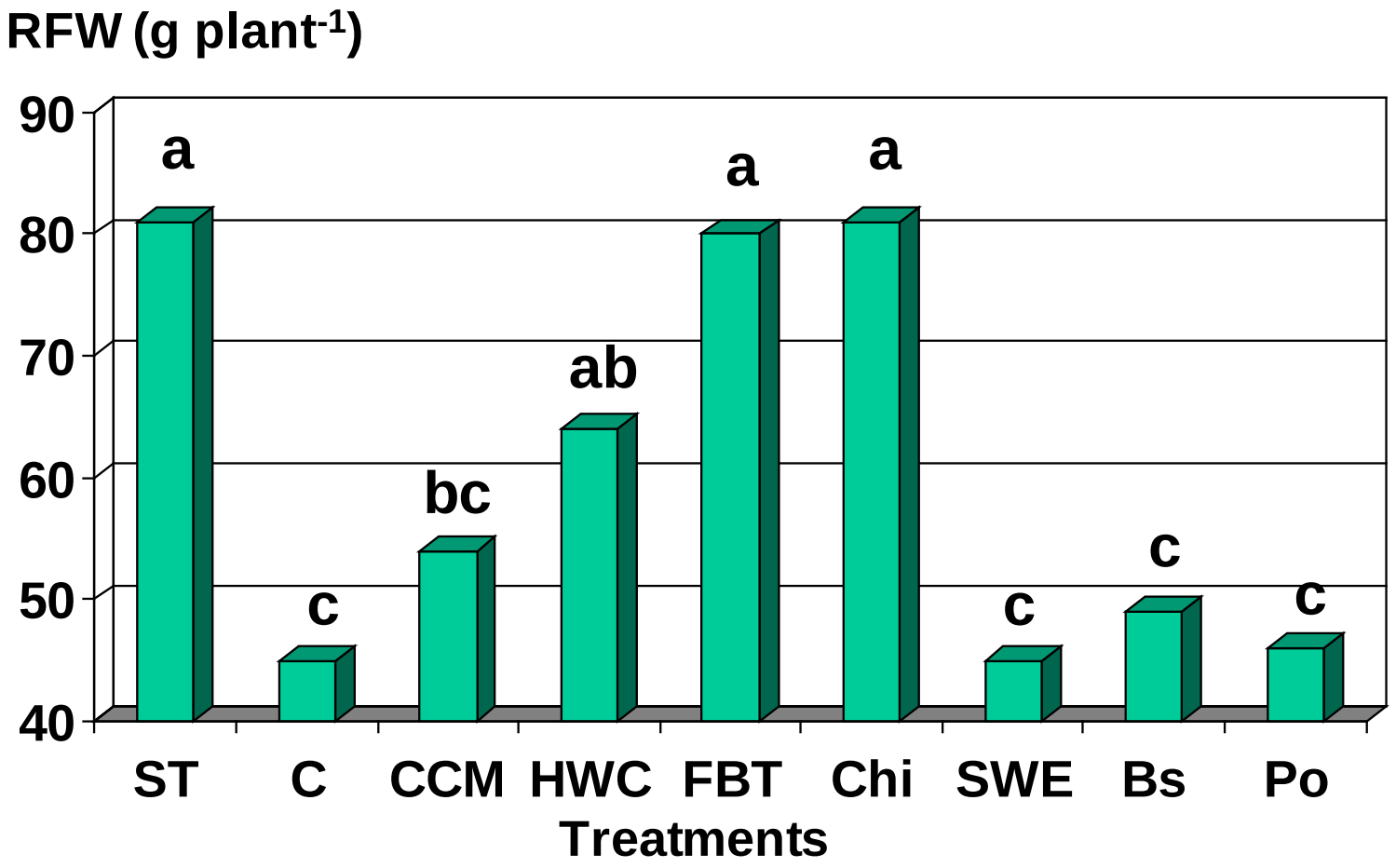

Giotis et al. (2009) *Eur. J. Plant Pathol.* 123, 387-400

Effect of soil steaming (ST), organic matter inputs (CCM, HWC, FBT), elicitor soil amendment (Chi, SWE) and biological control agents (Bs, Po) on total fruit yield in organic tomato crops

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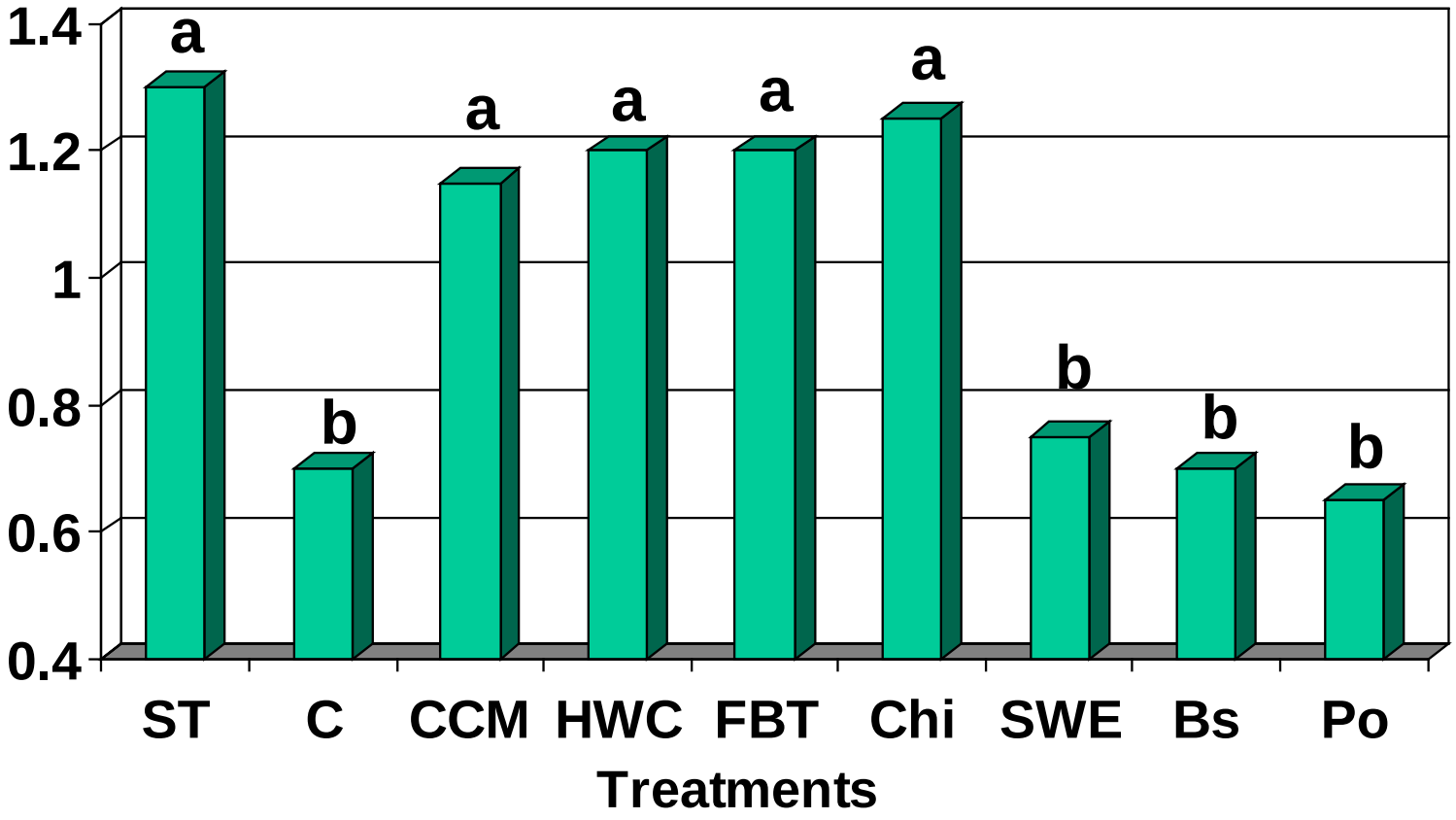

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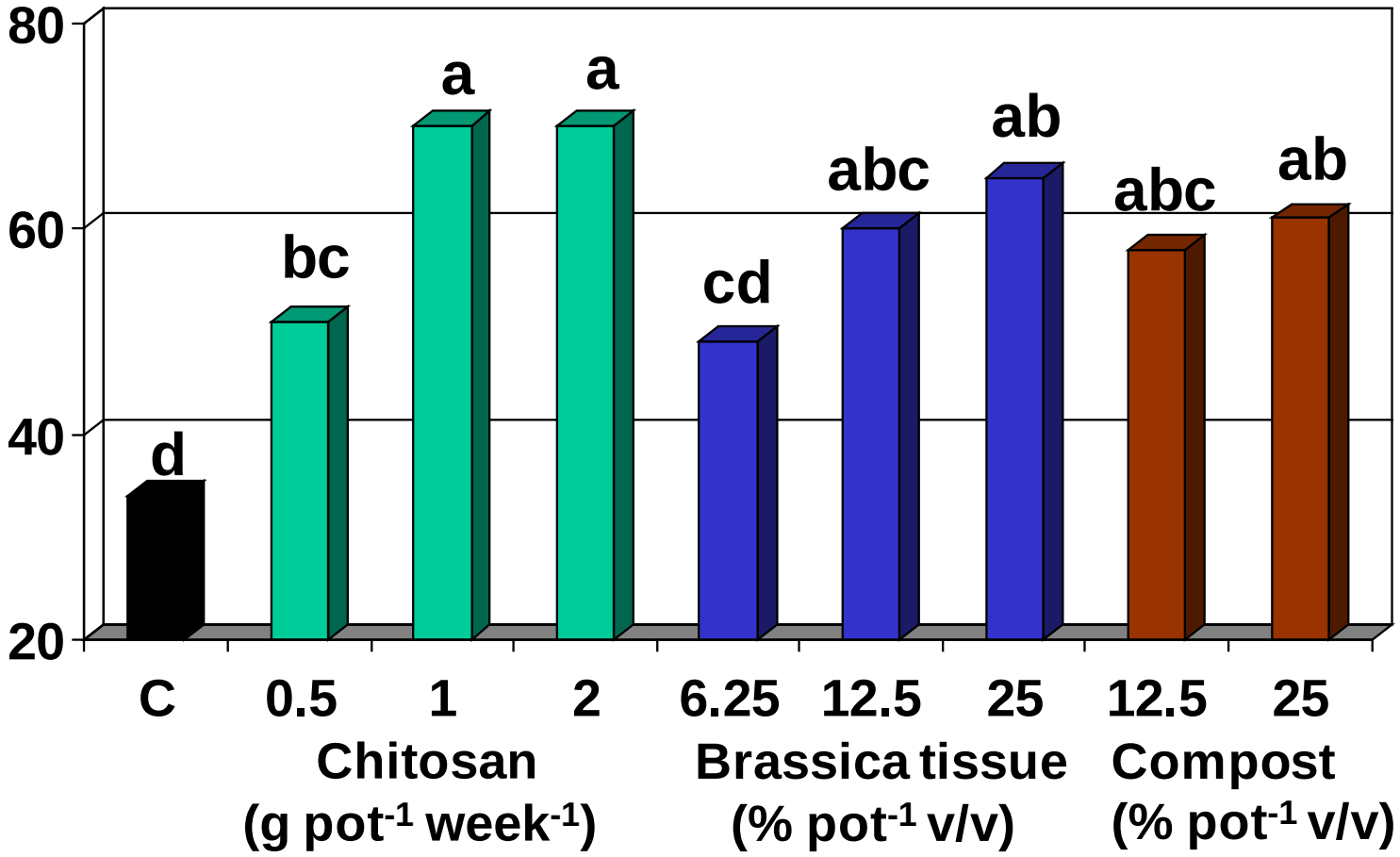
Effect of different concentrations of organic matter inputs (Chi, Chitosan; FBT, fresh Brassica tissue, CCM, composted cow manure) root disease severity (RFW) in tomato crops

Nafferton Ecological Farming Group

RFW (g plant^{-1})

Giotis et al. (2009) *Eur. J. Plant Pathol.* 123, 387-400

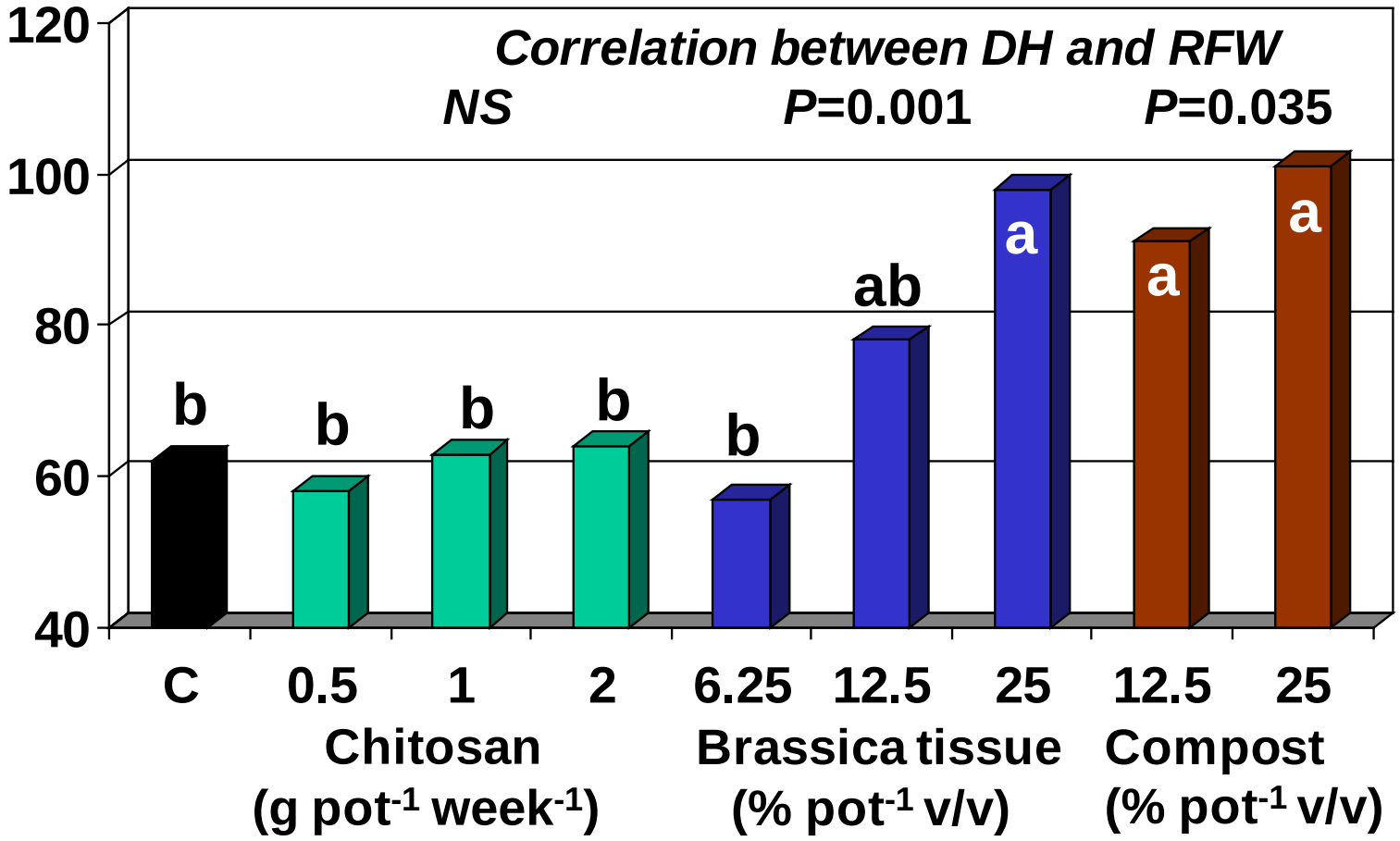


Effect of different concentrations of organic matter inputs (Chi, Chitosan; FBT, fresh Brassica tissue, CCM, composted cow manure) on soil biological activity (DH, dehydrogenase activity)

Nafferton Ecological Farming Group

DH (µg INTF g^{-1} DM $2h^{-1}$)

Giotis et al. (2009) *Eur. J. Plant Pathol.* 123, 387-400



Conclusions

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Conclusions

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- **Safety evaluation system for new pesticide in Europe and elsewhere need to be revised/significantly improved**

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- **Safety evaluation system for new pesticide in Europe and elsewhere need to be revised/significantly improved**
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Conclusions

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Ecological Farming Group

- **Safety evaluation system for new pesticide in Europe and elsewhere need to be revised/significantly improved**
- **A range of widely used pesticides may not be available in the future**
- **If alternatives are not found, this will reduce yields in intensive crop production systems especially broad acre crops such as cereals, maize, potato and soya**

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Conclusions

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Ecological Farming Group

- Safety evaluation system for new pesticide in Europe and elsewhere need to be revised/significantly improved
- A range of widely used pesticides may not be available in the future
- If alternatives are not found, this will reduce yields in intensive crop production systems especially broad acre crops such as cereals, maize, potato and soya
- The development of alternative crop protection strategies should focus on an integration of innovations in crop breeding, crop nutrition and novel more acceptable/benign crop protection products

  (including microbials such as spinosat, elicitors, semiochemicals, BCAs)


Thank you

Additional slides

Newcastle University

Farming practices/standards; Crop production

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Farming practices/standards; Crop production

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ORGANIC

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Farming practices/standards; Crop production

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ORGANIC

- long rotations (6-9yrs)

Farming practices/standards; Crop production

Nafferton Ecological Farming Group

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Farming practices/standards; Crop production

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Farming practices/standards; Crop production

Nafferton Ecological Farming Group

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Farming practices/standards; Crop production

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Nafferton Ecological Farming Group

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- short rotations (1-5yrs)
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  - 220 Herbicides
  - 186 Pesticides
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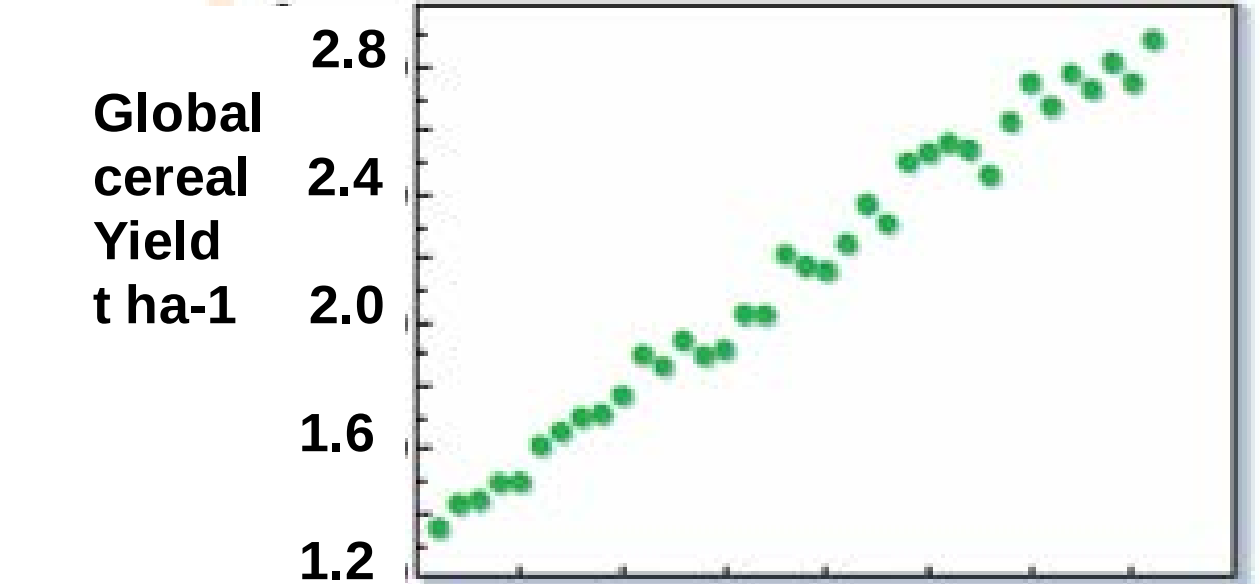
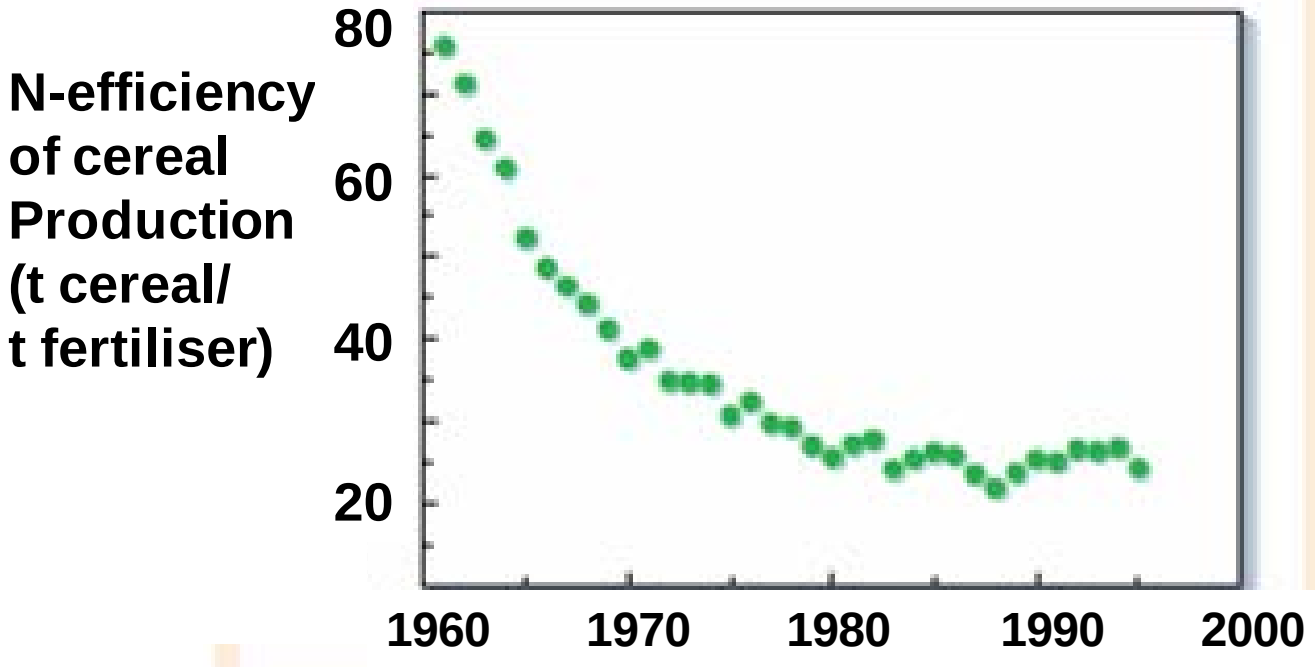
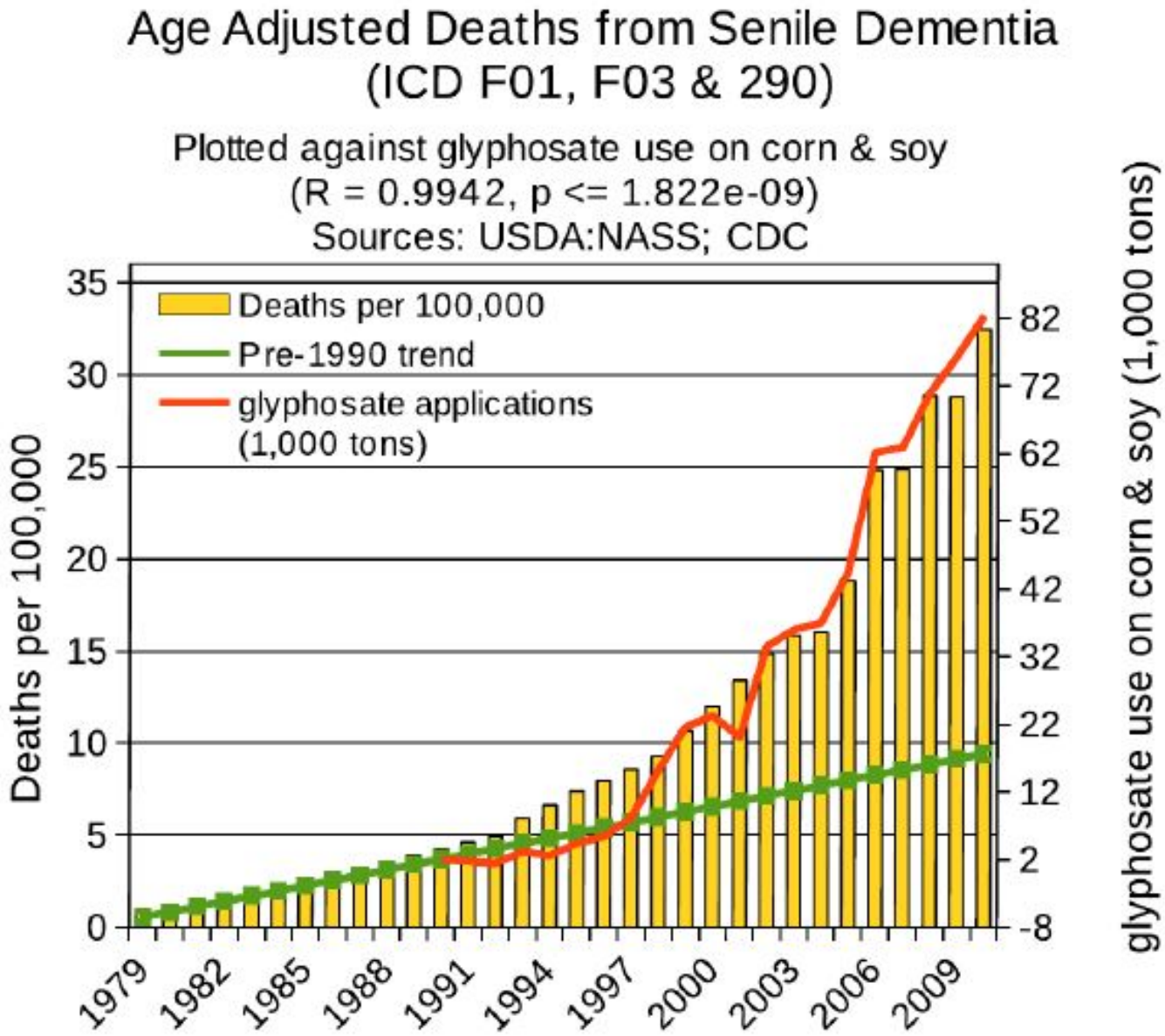
- NO_3, NH_4, urea, KCl, super-phosphate main NPK inputs

Diminishing returns of fertiliser applications





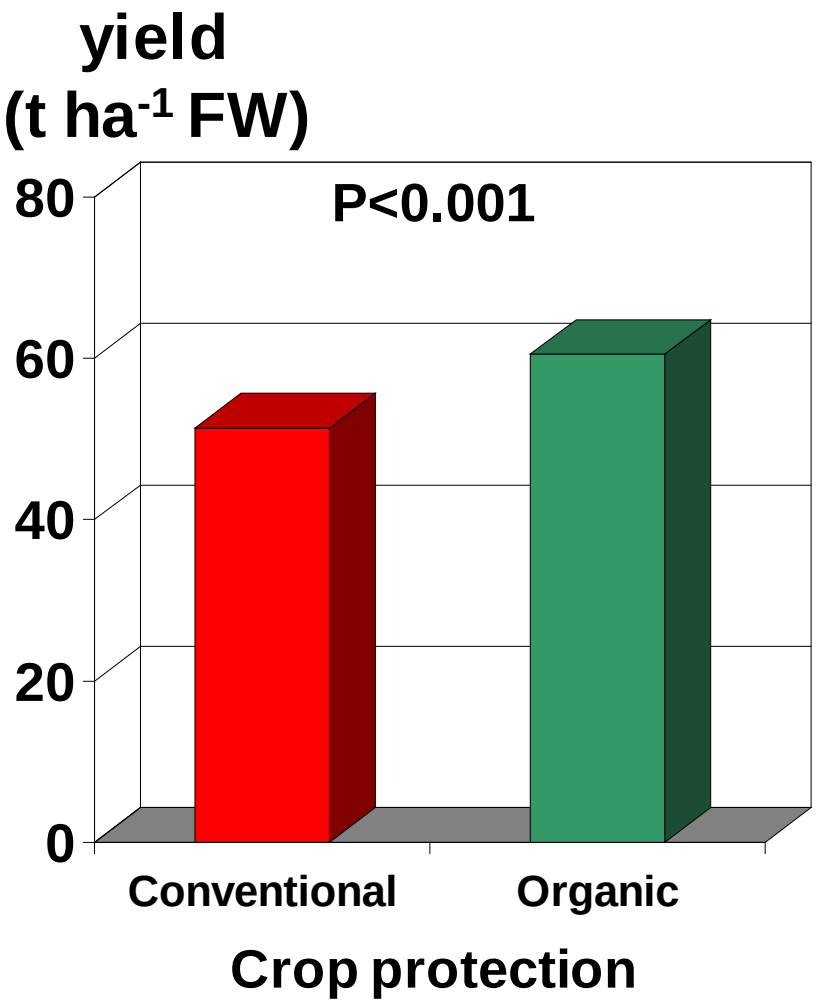
Tillman et al. (2002)
Nature 418, 671-677

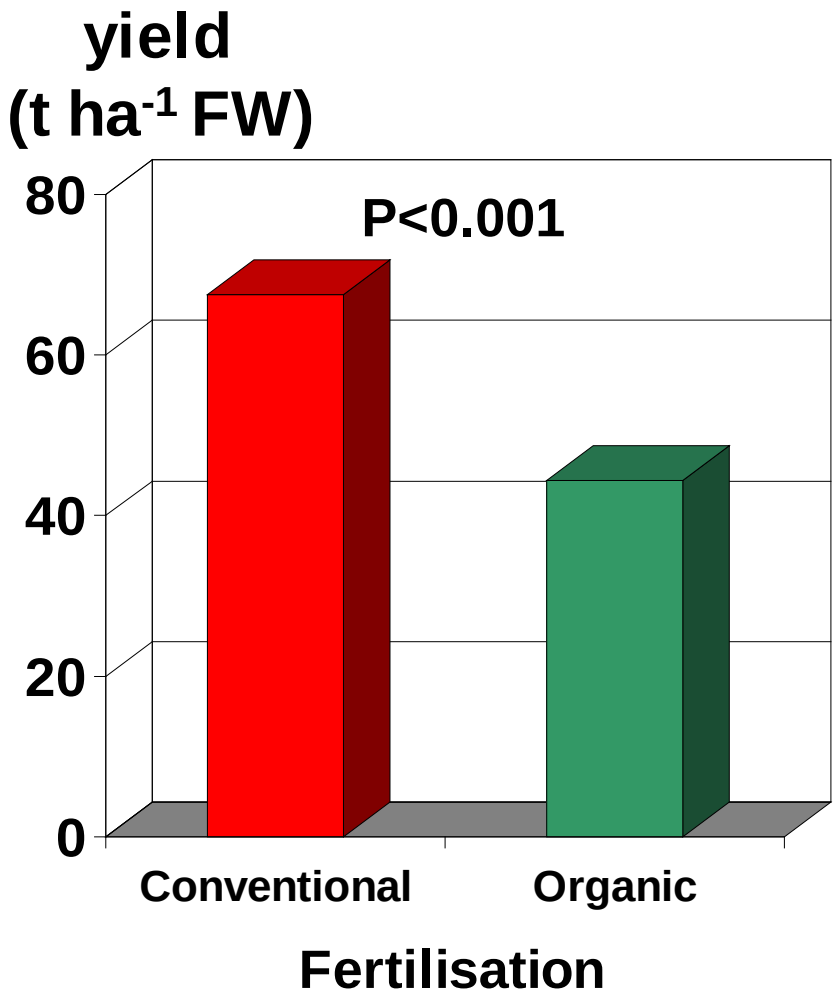


Swanson et al. (2014) GM-crops, glyphosate and the deterioration of health in the USA. *Journal of Organic Systems* **9,** 6-37

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

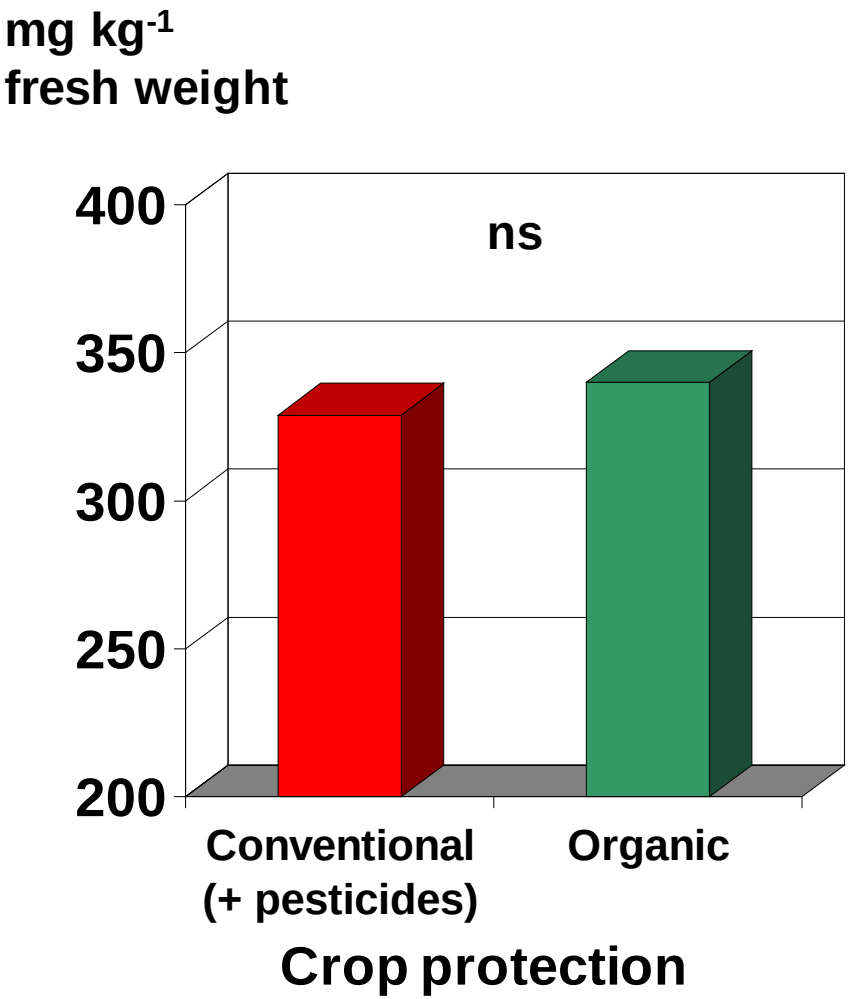
COMMUNITY RESEARCH

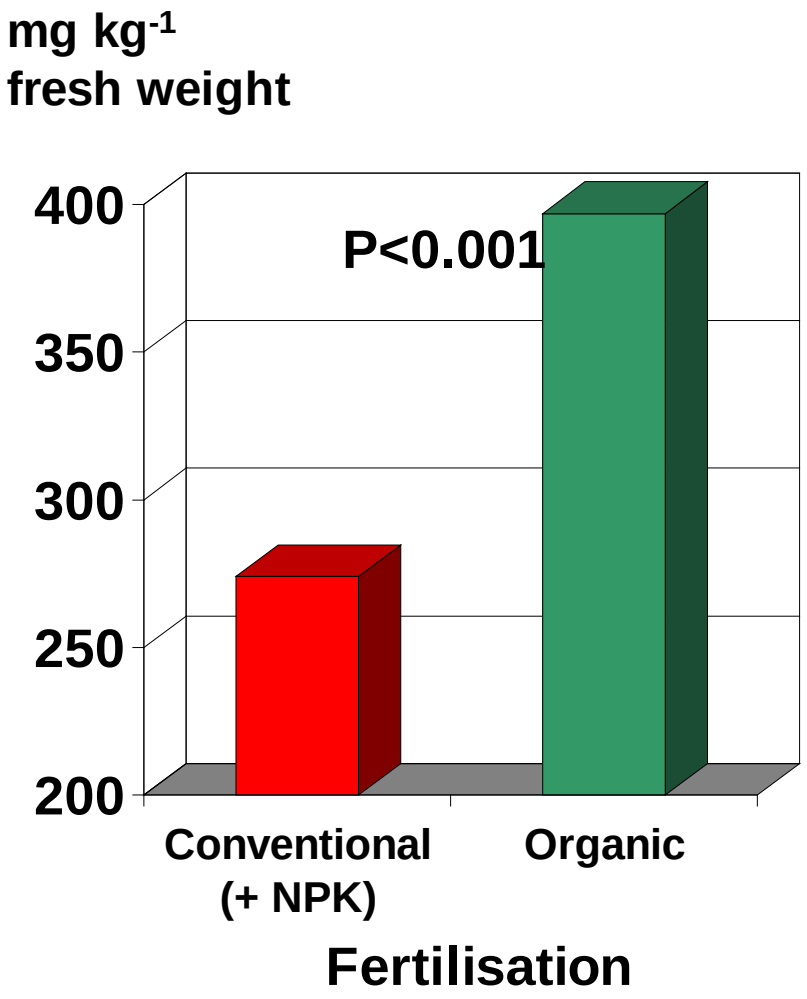




Effect of fertilisation and crop protection on the glycosinolate content in cabbage (average of 2 seasons)

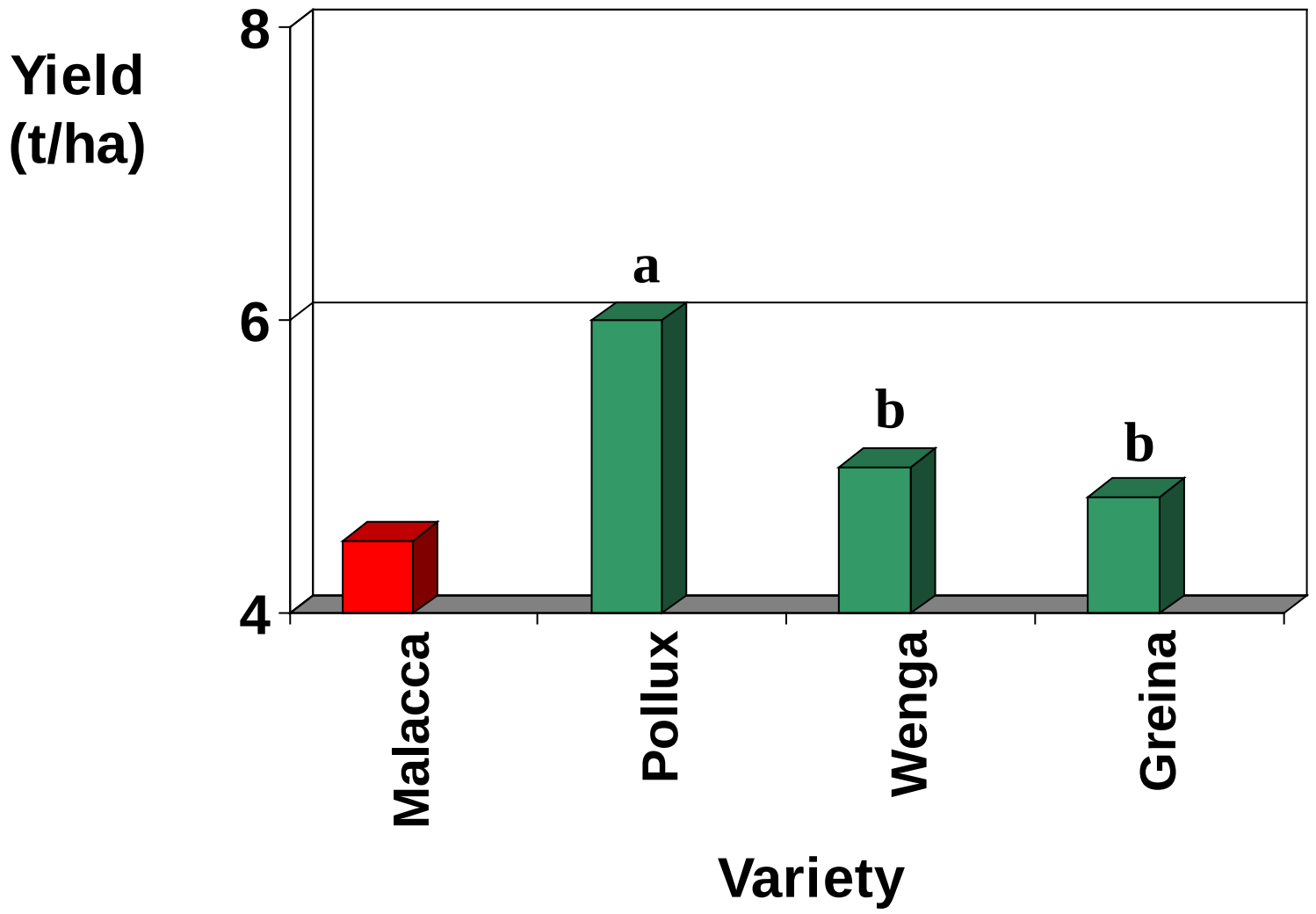
COMMUNITY RESEARCH





Wheat - Yield (2005)

Effect of using varieties adapted to organic systems



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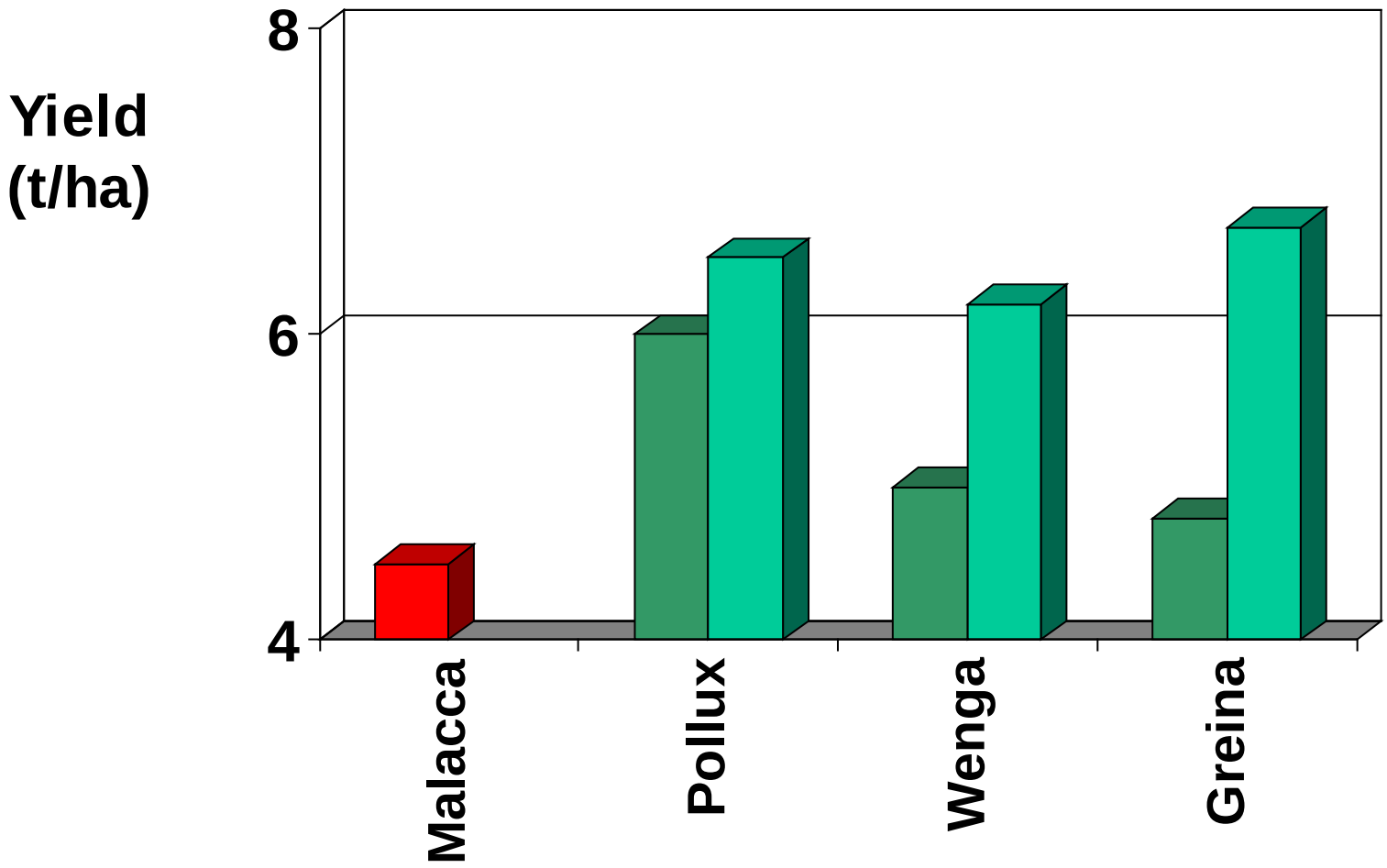

Darker colour: standard fertility management
Lighter colour: improved fertility management

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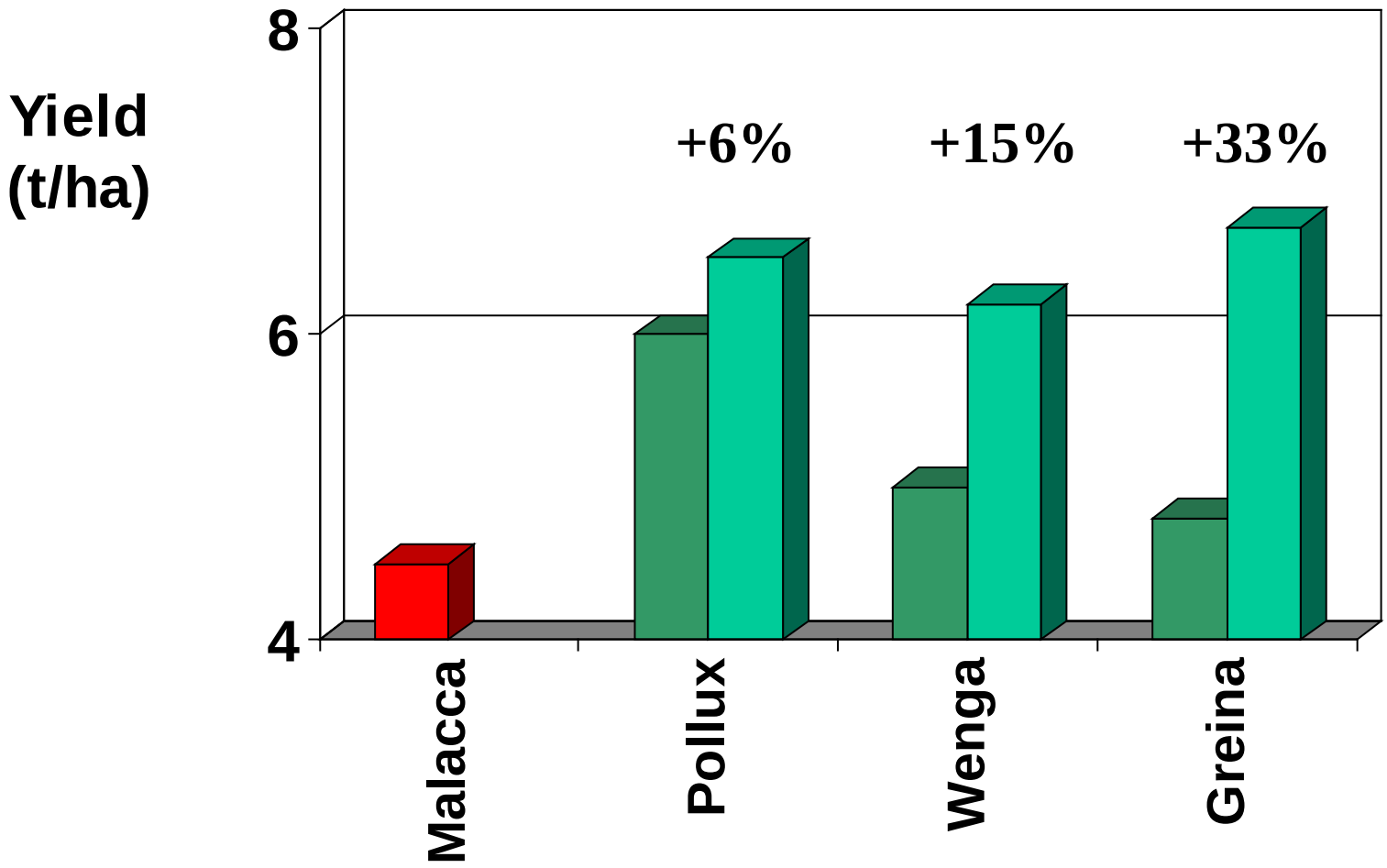

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Wheat 2005 - Protein content

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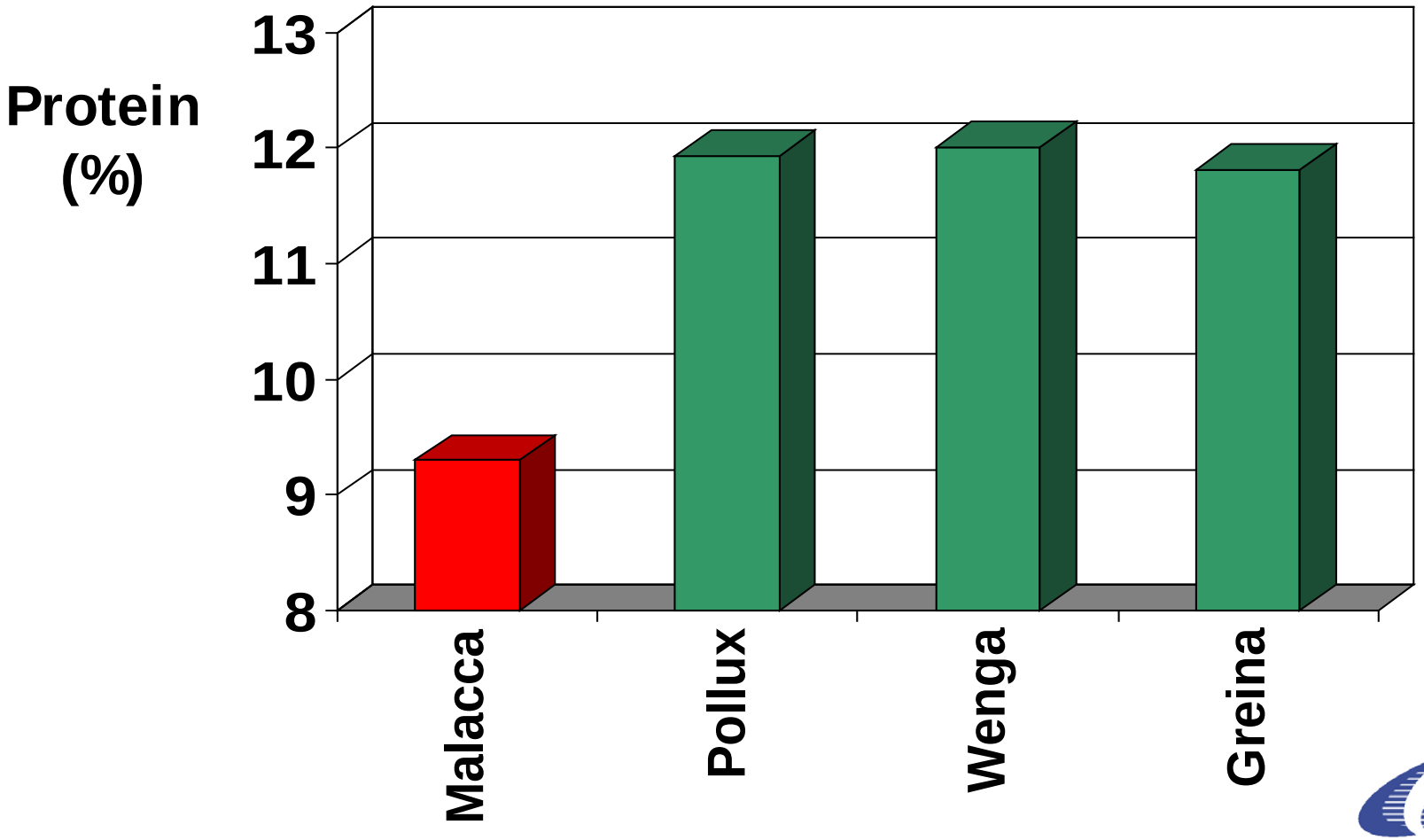

Control of soil borne disease

COMMUNITY RESEARCH

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Control of soil borne disease

COMMUNITY RESEARCH

Methyl bromide

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Control of soil borne disease

COMMUNITY RESEARCH

Methyl bromide

⑩tomato, soft fruit, Brassicas, etc.

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Control of soil borne disease

Methyl bromide

- tomato, soft fruit, Brassicas, etc.
- 50 times more powerful than CFCs in destroying ozone
- estimated to have contributed 10 to 20% of the destruction of the earth ozone layer

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- even the US accepts the evidence
- still in use !!!!! in the EU
- Increasingly used in the developing world

Effect of methyl bromide use: stratospheric ozone depletion

COMMUNITY RESEARCH

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Effect of methyl bromide use: stratospheric ozone depletion

COMMUNITY RESEARCH

Increased UV-B radiation
results in higher levels of:

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COMMUNITY RESEARCH

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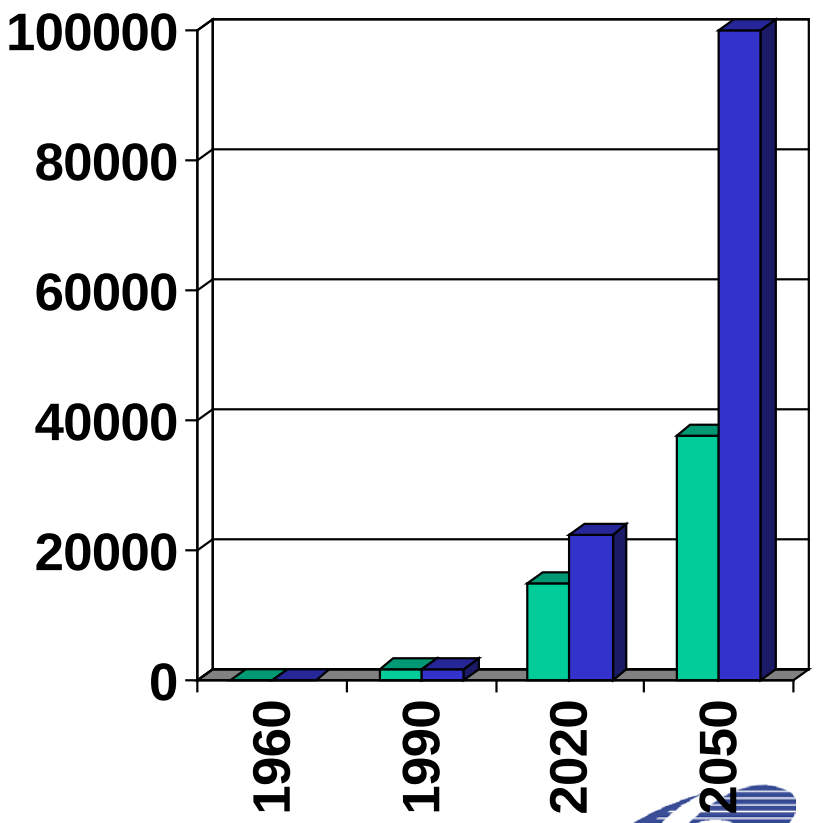

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COMMUNITY RESEARCH

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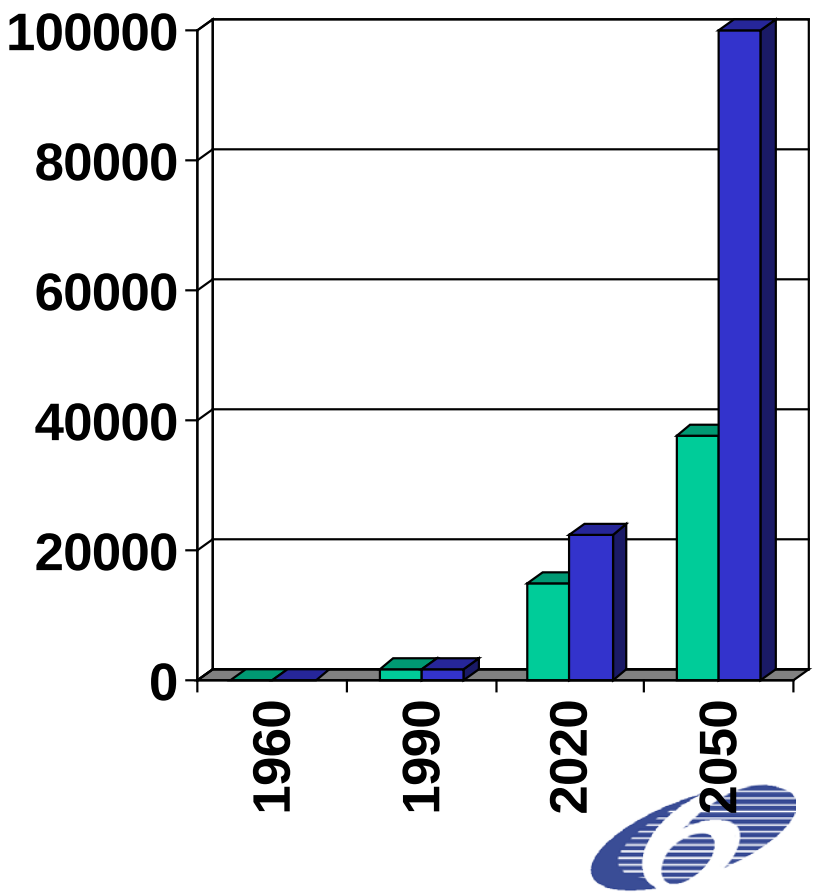
Excess skin cancer cases in NW-Europe



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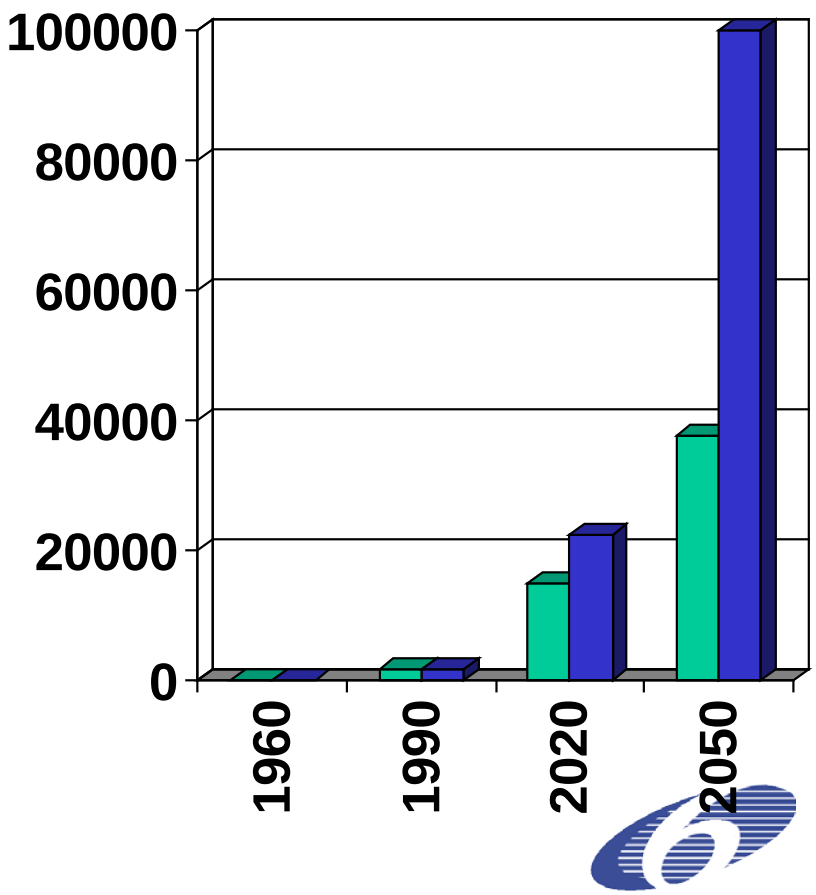

RIVM (2000) Report 48150511
Slaper *et al.* (1996) Nature 384,256-258