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Agronomy as a manipulative tool

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COST 926 Conference 2005

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- General ecological mechanisms affecting the content of phytochemicals
- What a farmer can do to increase (optimise) phytochemical content
- Consequences of existing practices on phytochemical content
- Consequences of differences in phytochemical content on human health

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General ecological mechanisms affecting the content of phytochemicals

- Growth/differentiation balance (GDB)
  - Fast-growing plants don't bother about defence
  - Abundance of nutrients depresses the accumulation of some defence compounds
- Specific evolutionary responses (SER)
  - Plants must be able to adapt to changes in environment within the range normally encountered
  - Regulatory mechanisms are fine-tuned genetically

Physiological response to nutrient availability

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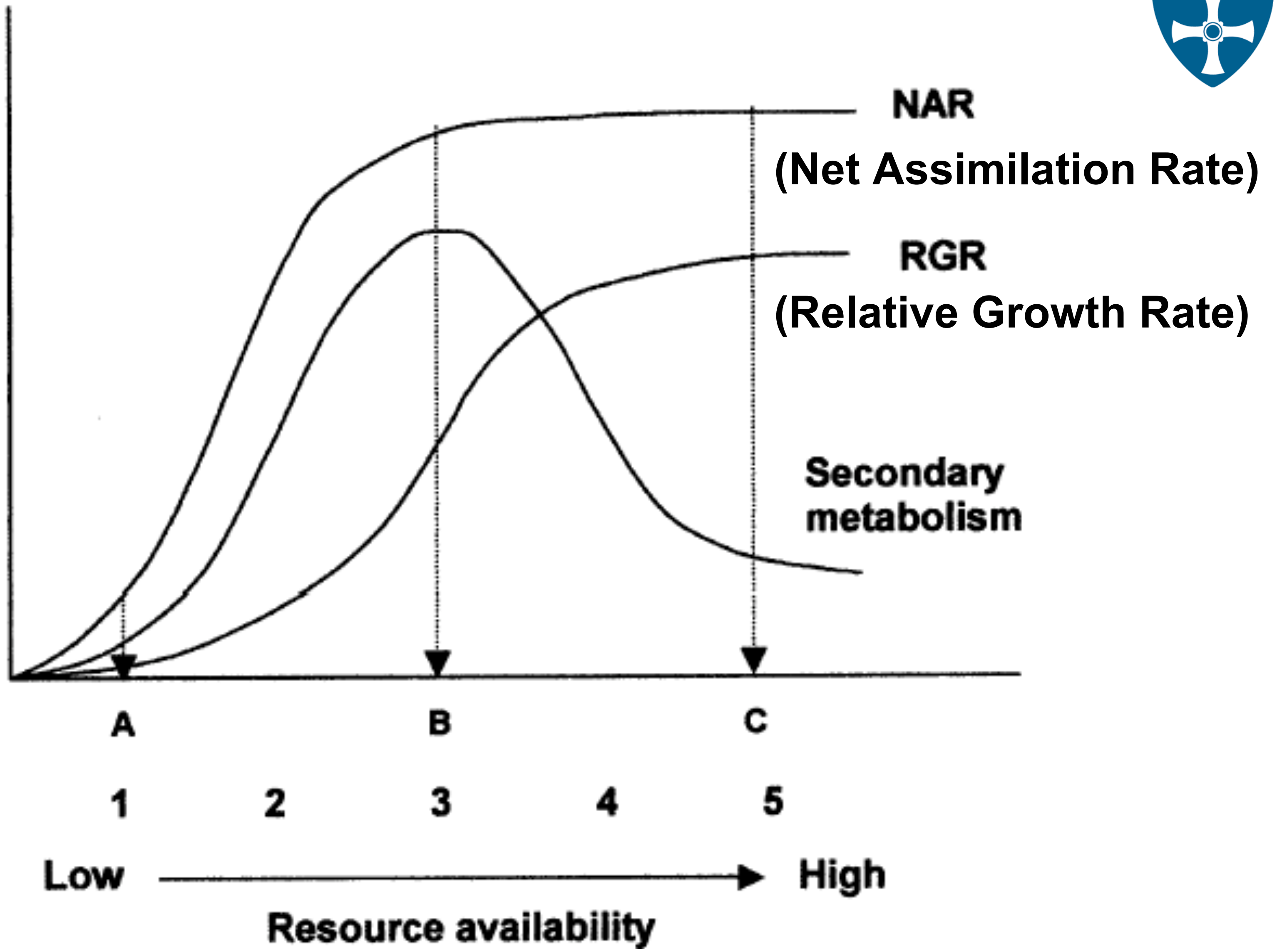
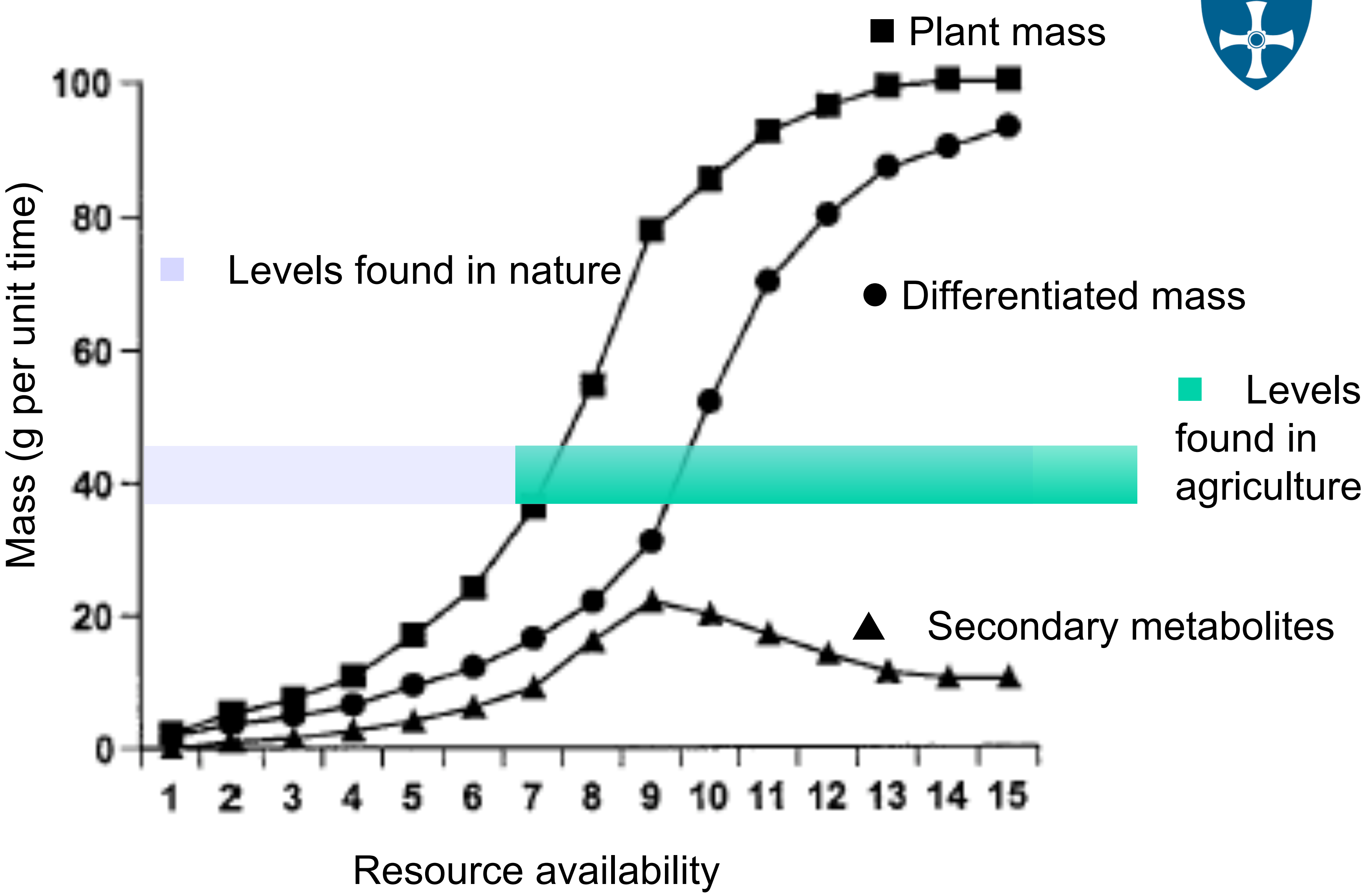


(Stamp 2003)



Plant mass
Differentiated mass
Secondary metabolites
Levels found in nature
Levels found in agriculture
Mass (g per unit time)
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Resource availability

(Stamp 2003)

Overview of regulation hierarchy for carbon based secondary compounds

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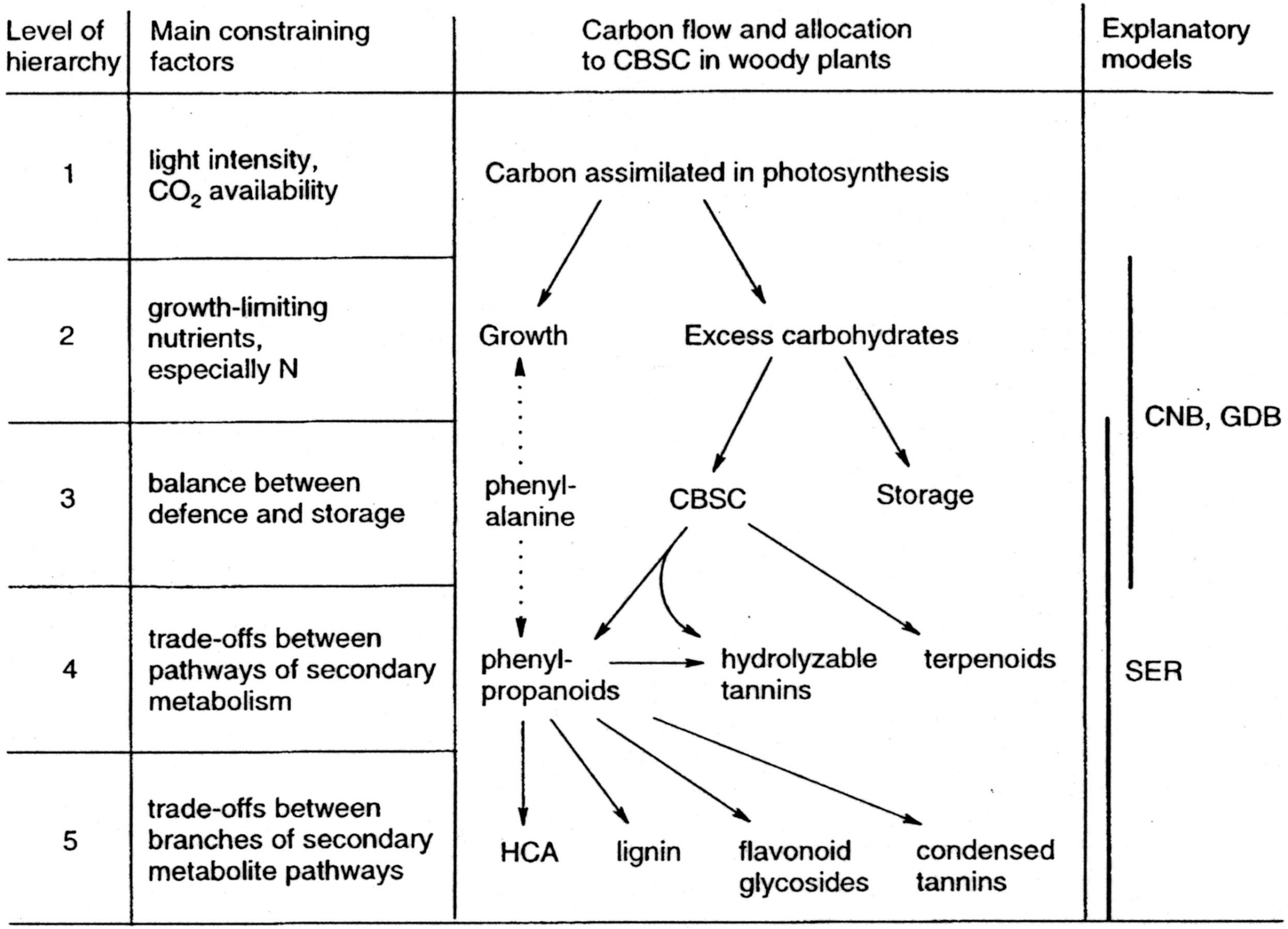
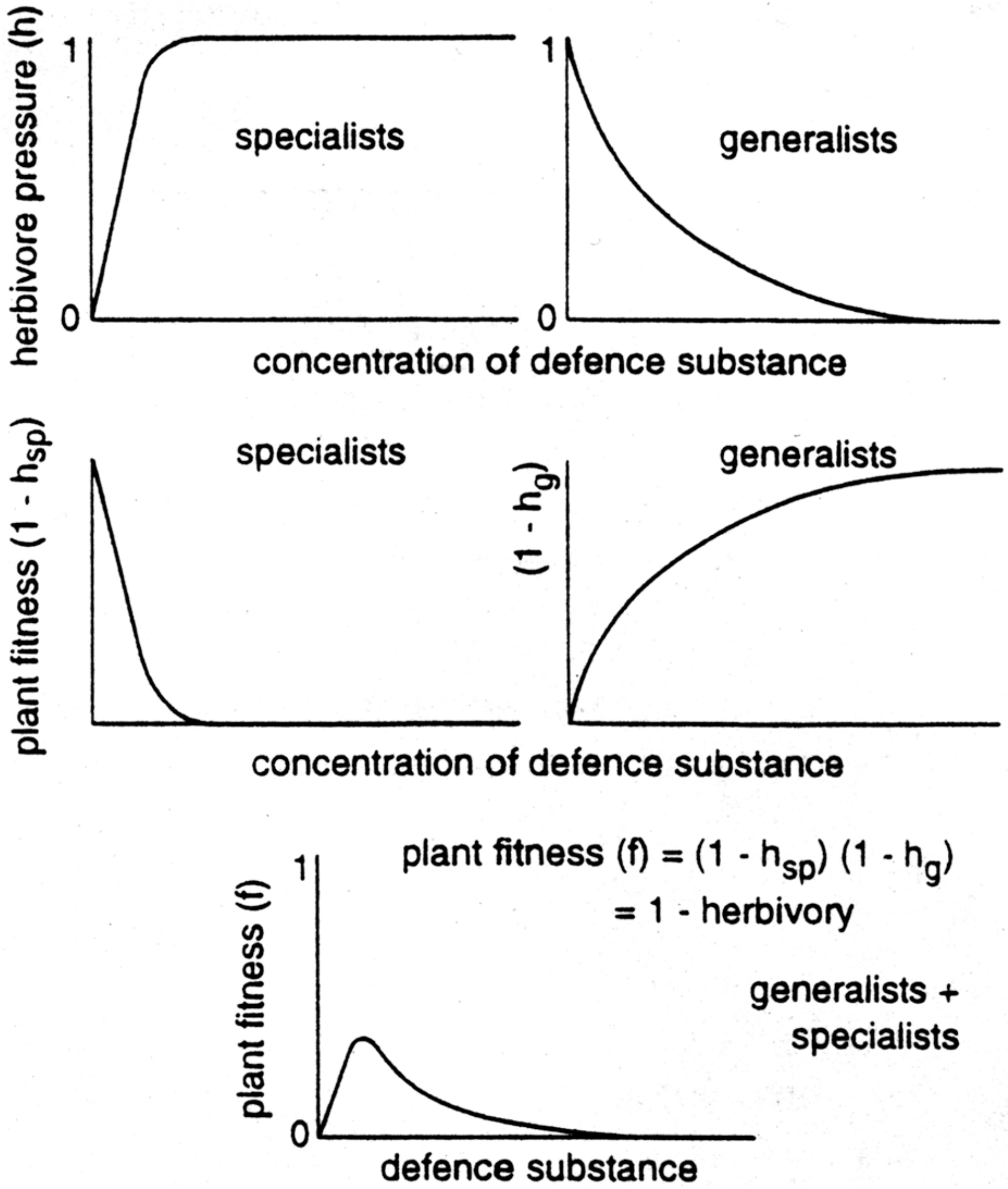


Koricheva et al. 1998

Evolutionary optimisation of concentrations of defence compounds



"Rule of thumb": 1% of genotypes contain 3 times the median value

van den Meijden 1996

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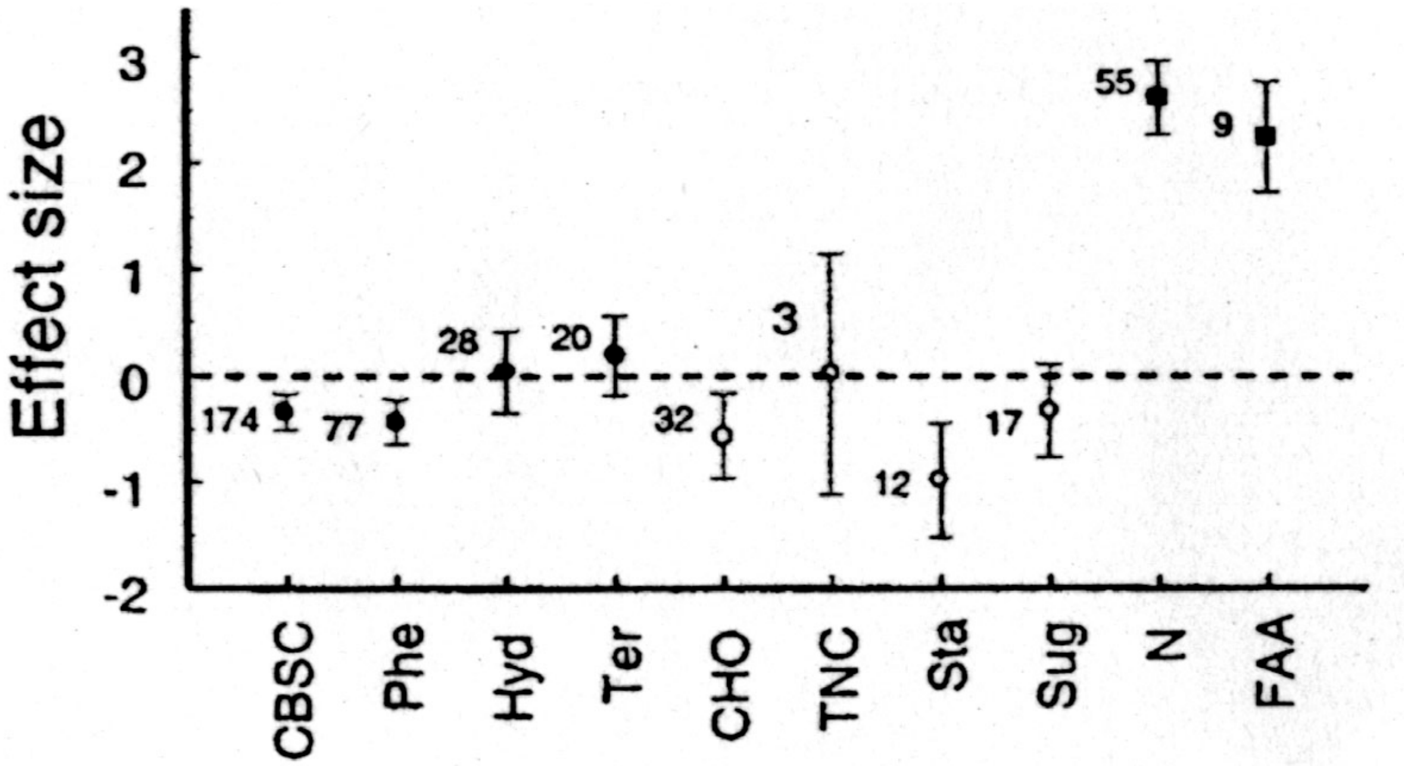
Effects of N fertilisation on plant metabolites



Koricheva et al. 1998

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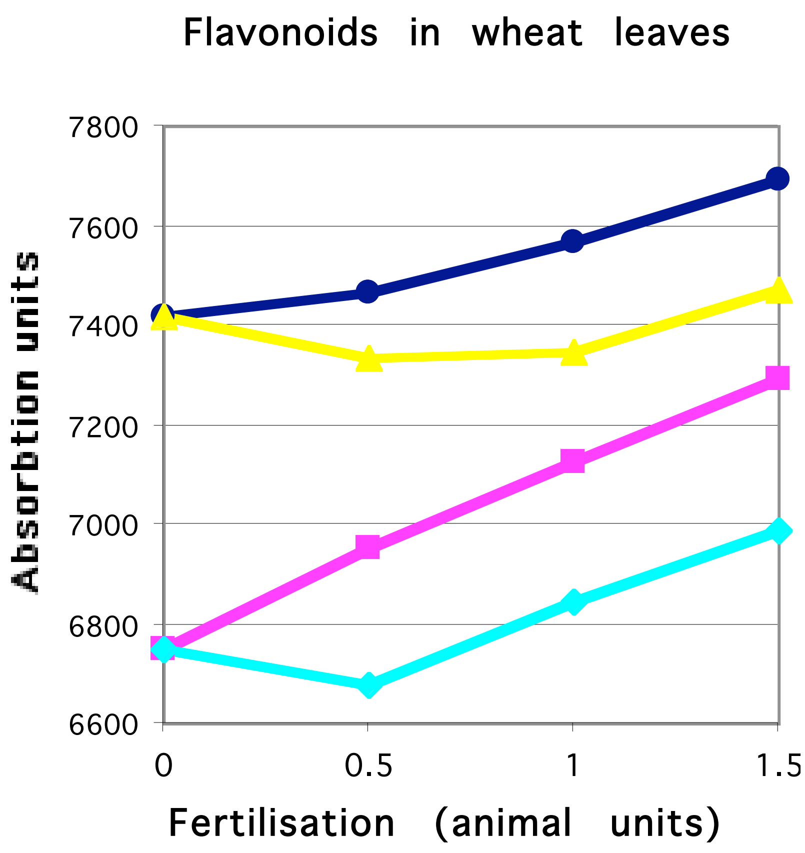
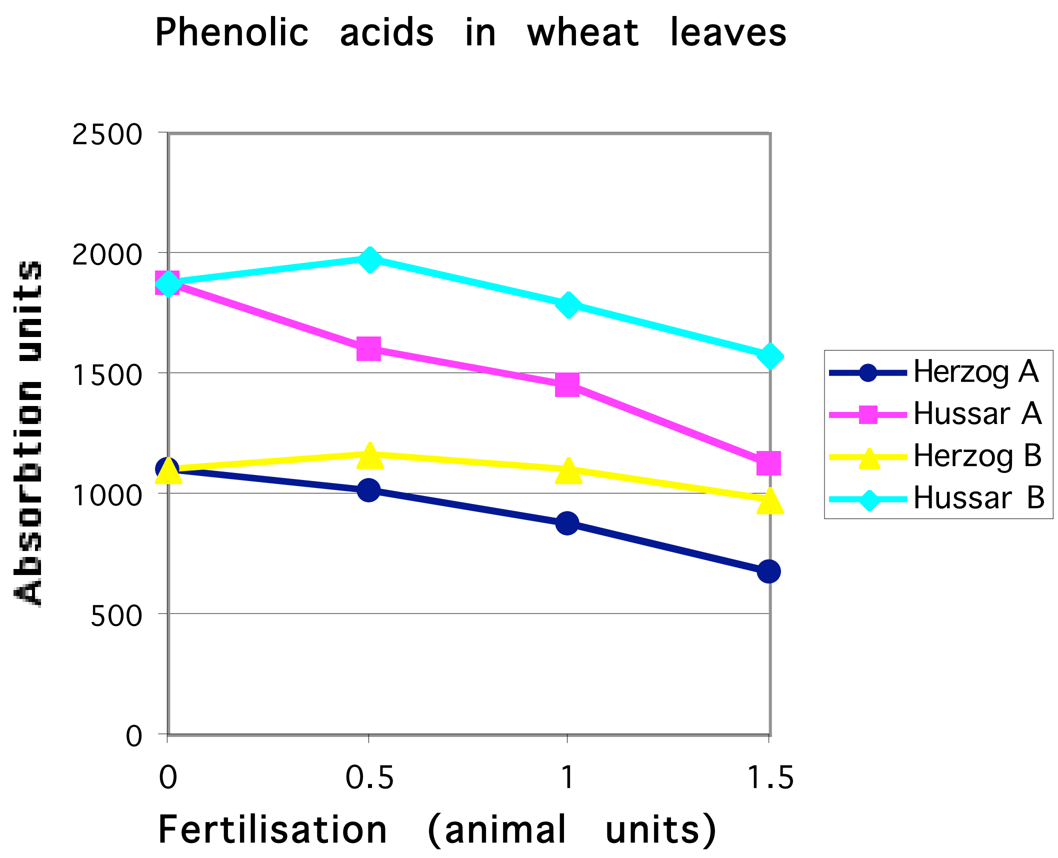
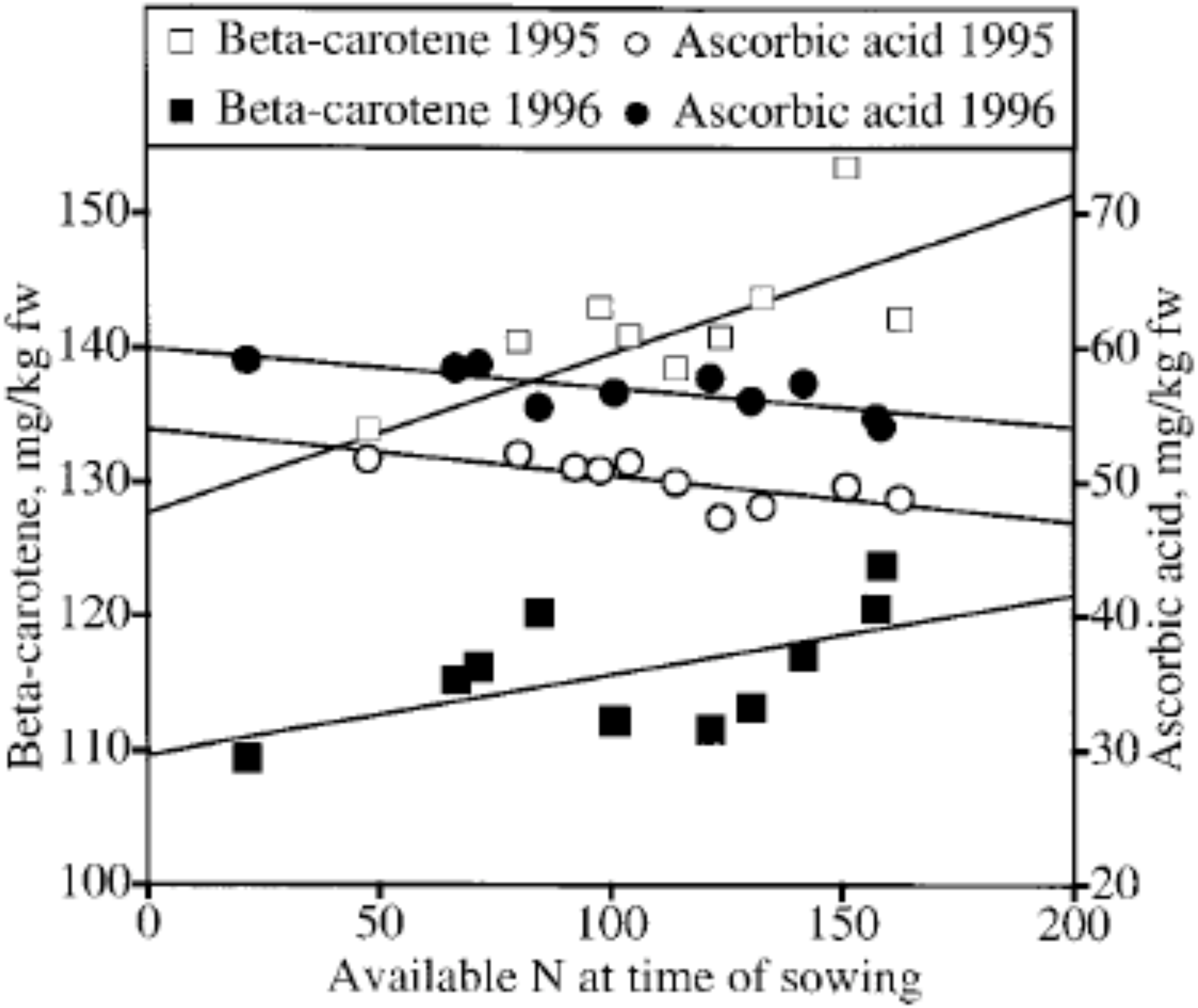
Effects of fertilisation on compounds for defence and sunscreens







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Nutrient content of carrots as affected by N supply

(Brandt & Mølgaard 2001)

Effects of fertilisation on content of phenolic acids in barley leaves

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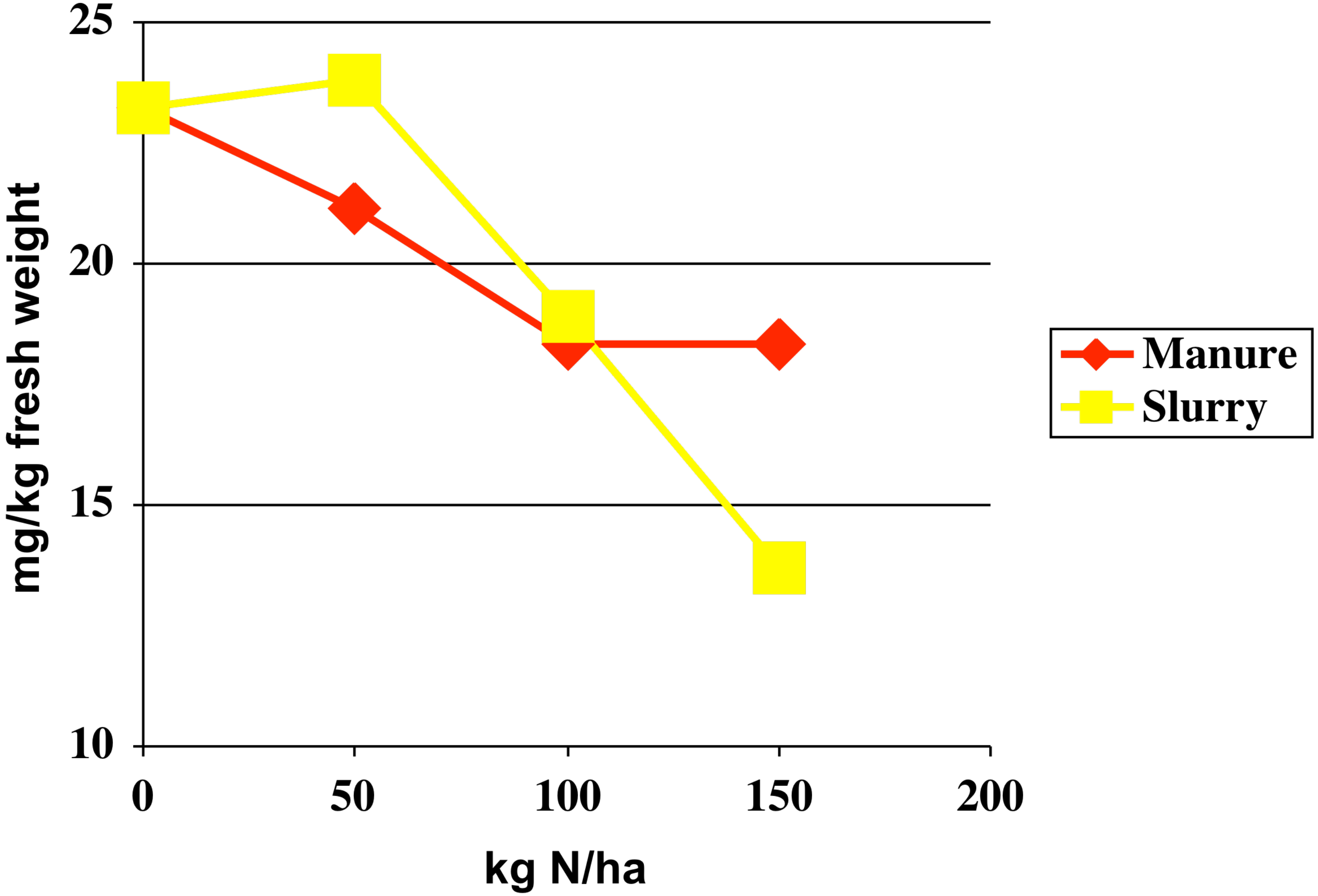
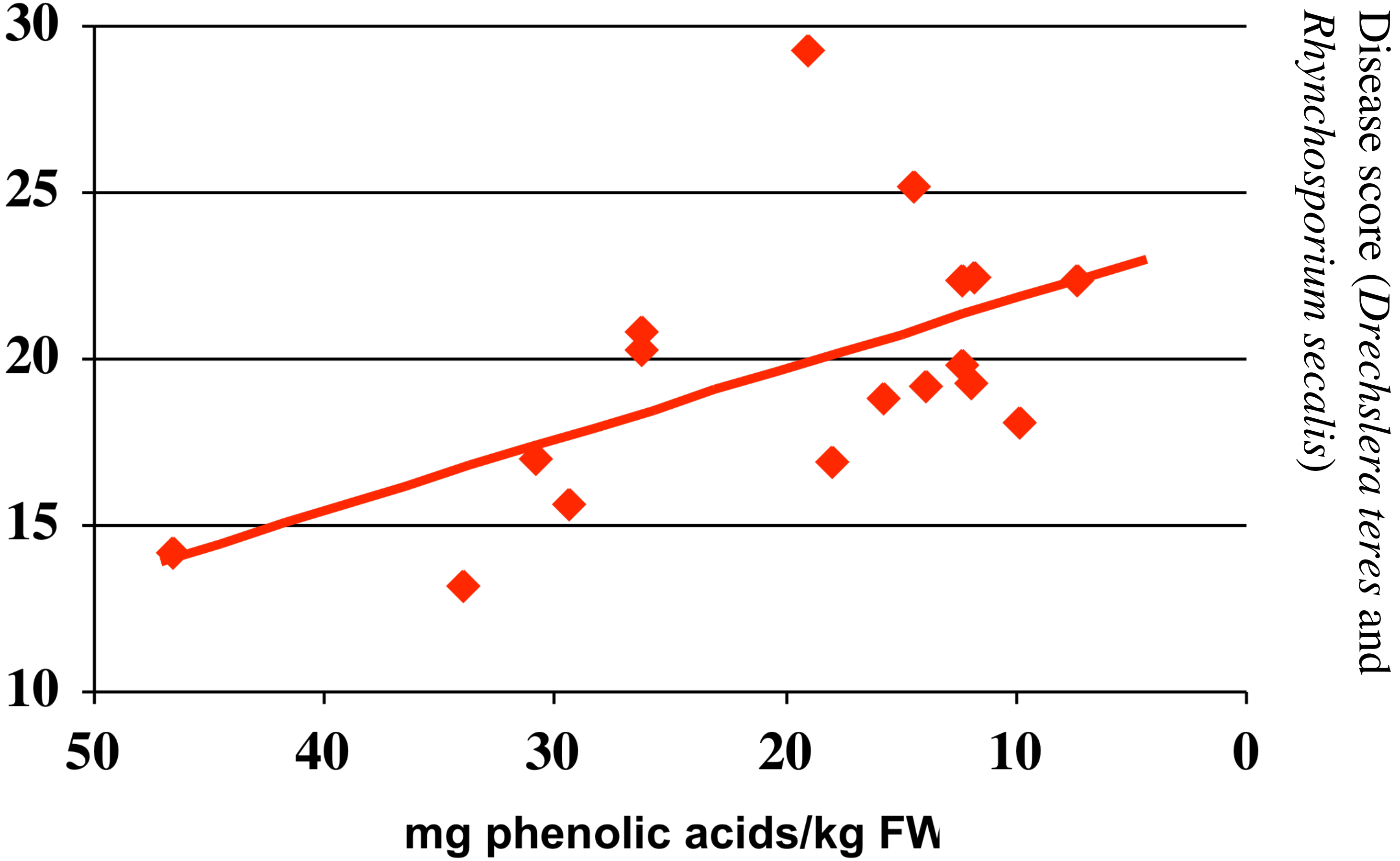


(Nørbæk et al. 2003)

Correlation of disease severity and content of phenolic acids in barley leaves



(Aaboer et al. 2003)

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What a farmer can do to increase (optimise) phytochemical content

1. Avoid over-fertilisation

- Take contributions from crop residues etc. into account when planning the use of fertiliser
- Observe the crop carefully and make additional reductions of fertiliser in areas where diseases tend to be more severe (also within fields)

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What a farmer can do to increase (optimise) phytochemical content

2. Allow moderate waterstress

- Let the soil become dry before watering
- If feasible (e.g. drip irrigation), water alternate rows and shift when soil is completely dry in the non-irrigated rows

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What a farmer can do to increase (optimise) phytochemical content

3. Favour generative growth

- Provide adequate space for each plant
- Adjust timing of planting and harvest to ensure full maturation on the plant
- Choose genotypes that are well suited to the climate and soil conditions

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Example of optimised content of phytochemicals: High quality wine

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Effect of nutrient supply on quality of apples (Otava)

High N
(Annual
clovergrass)

Medium N
(Perennial
clovergrass)

Low N
(Perennial
grass)

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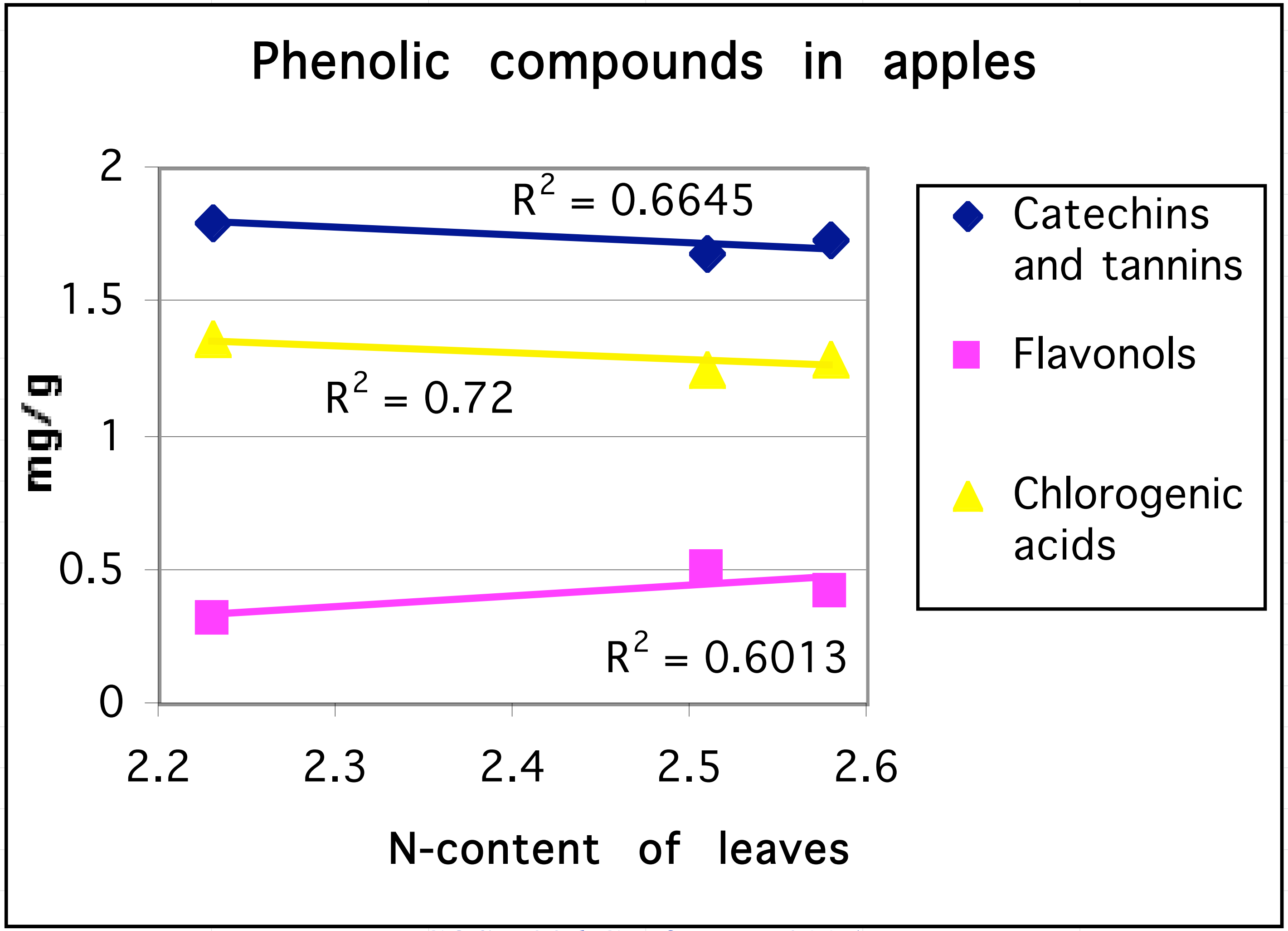
Effects of nutrient supply on chemical composition of apples



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Consequences of existing practices on phytochemical content

- Few well controlled studies, many confounding factors (genotype, maturity etc.)
- Three main groups of practices:
  - High input (nutrient surplus)
  - Low input/organic (nutrient offtake = net mineralisation)
  - Subsistence farming (nutrient offtake > net mineralisation)

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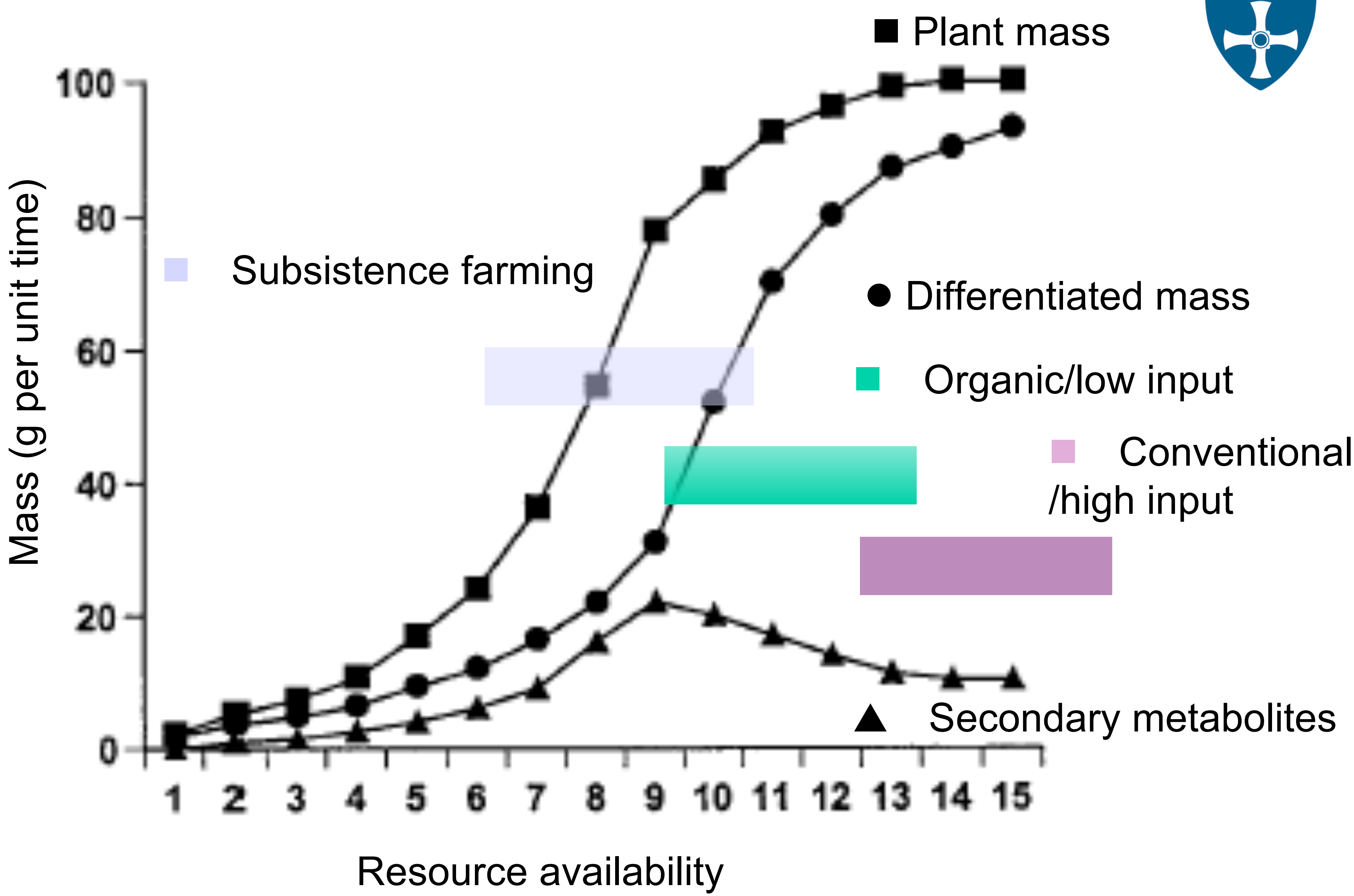
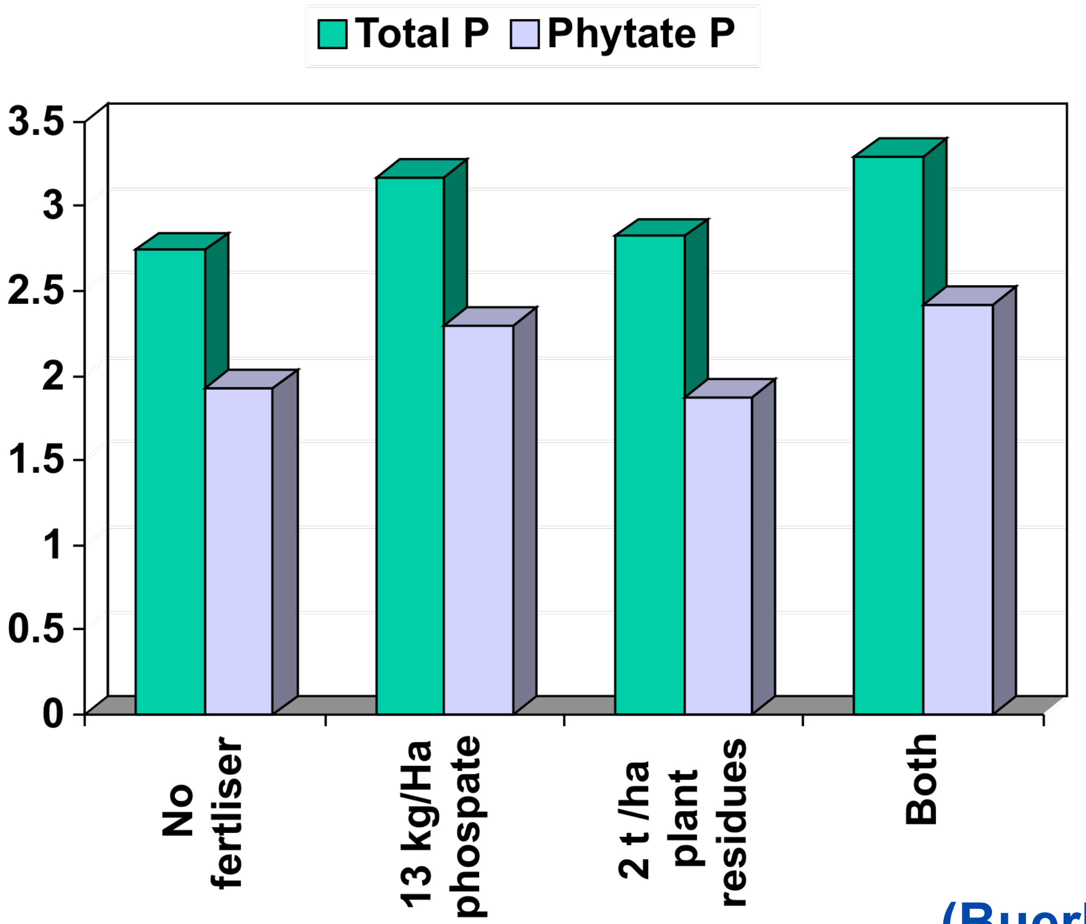
Consequences of existing practices on phytochemical content

- High input/conventional: Highest yield, most variable concentration of phytochemicals, low average values
- Low input/organic: Intermediate yield, most constant concentrations, highest average
- Subsistence farming: Lowest yield, moderately variable concentrations, intermediate average (very little data).

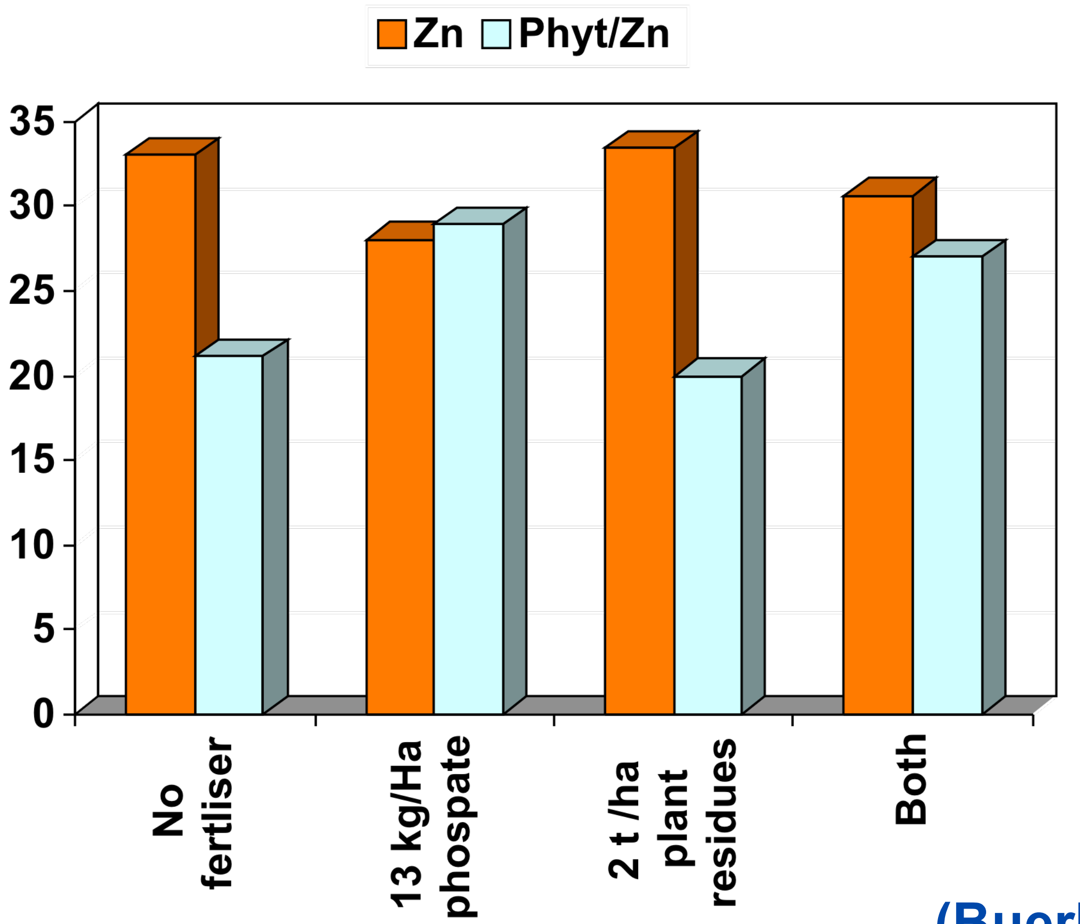

Plant mass
100
80
60
40
20
0
Mass (g per unit time)
Subsistence farming
Differentiated mass
Organic/low input
Conventional
/high input
Secondary metabolites
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Resource availability

Effects on subsistence farmed millet



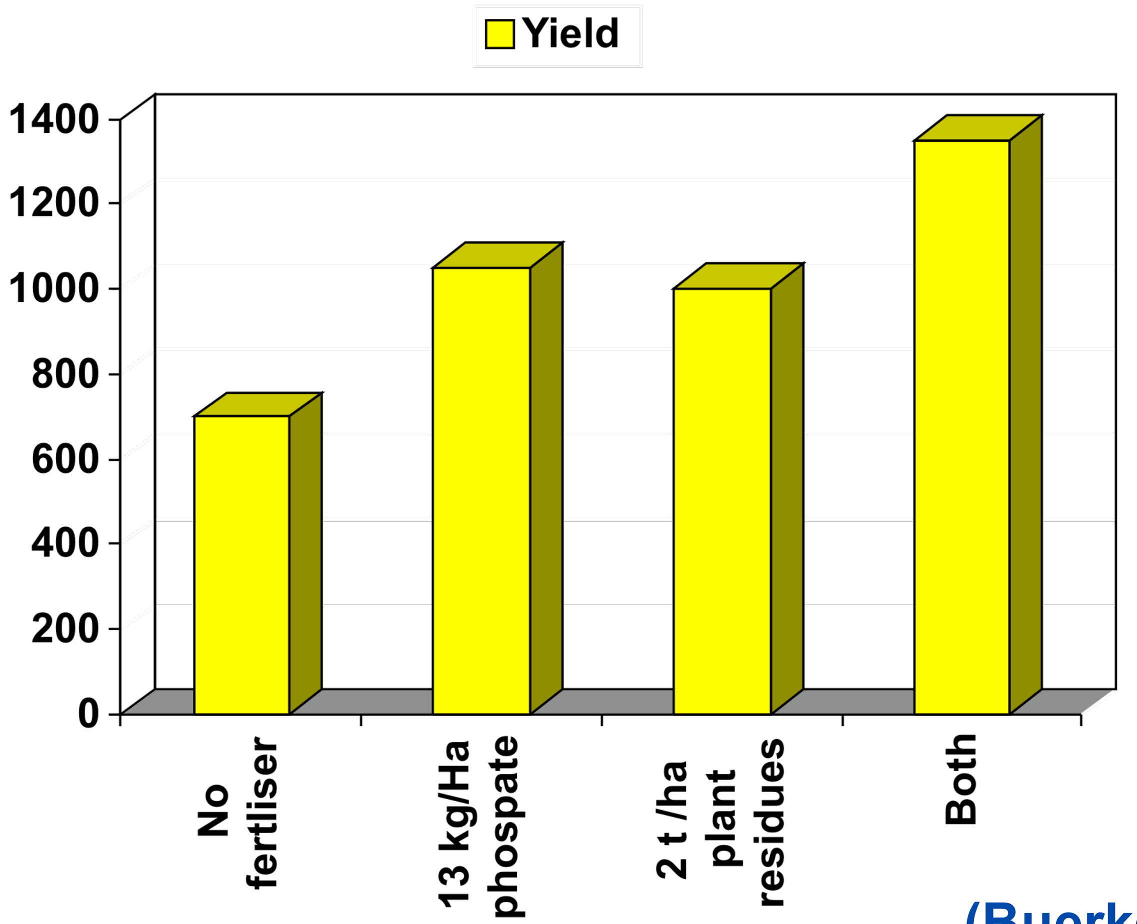
(Buerkert et al. 1998)

Effects on subsistence farmed millet



(Buerkert et al. 1998)

Effects on subsistence farmed millet



(Buerkert et al. 1998)

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Consequences of differences in phytochemical content on human health

- Positive effects of an increase can be calculated if we know the relative importance of each phytochemical for human health
- Or we can measure the combined effects of changing many phytochemicals at the same time
- The outcome can be expressed in %, as more or less "concentrated"

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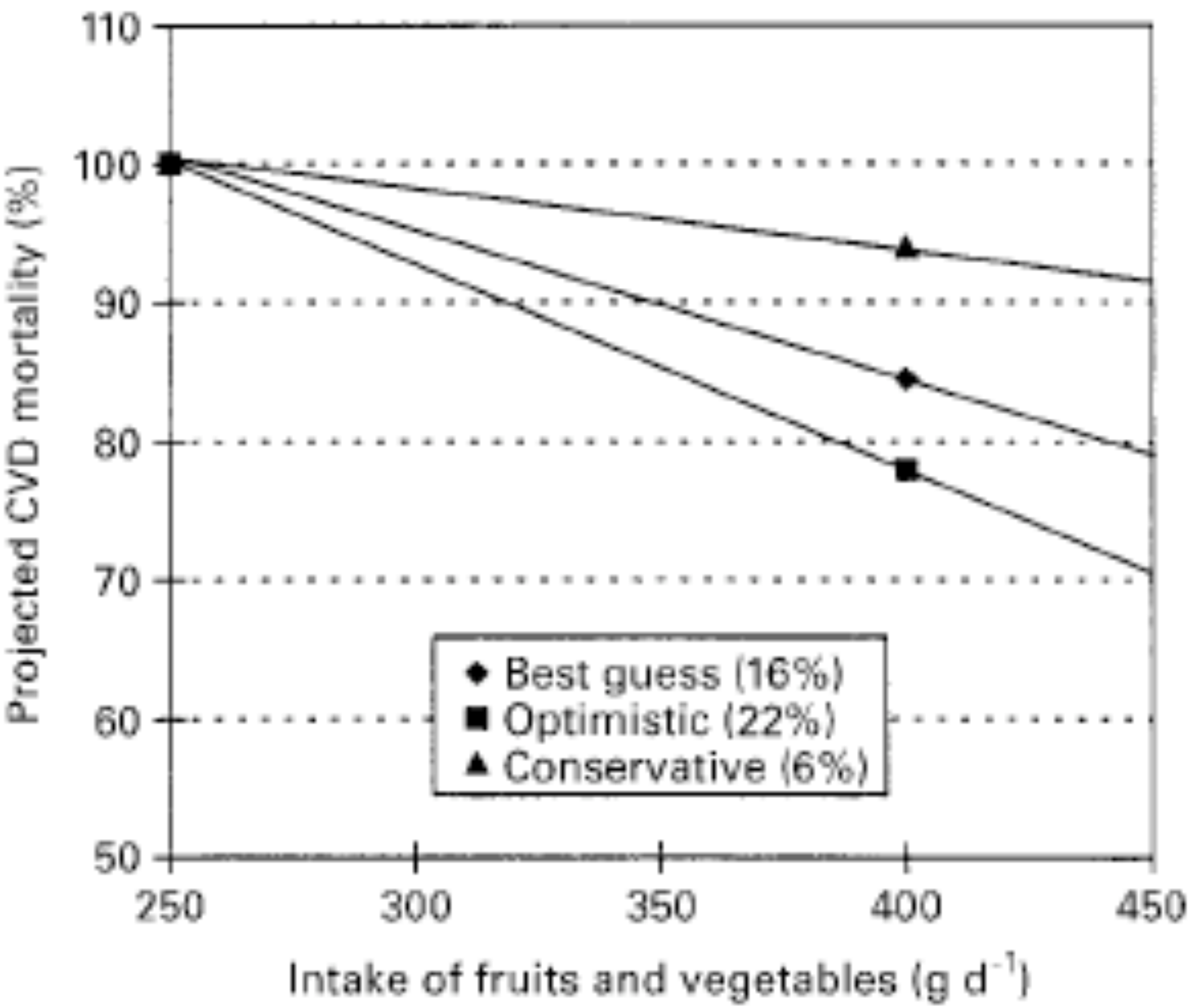
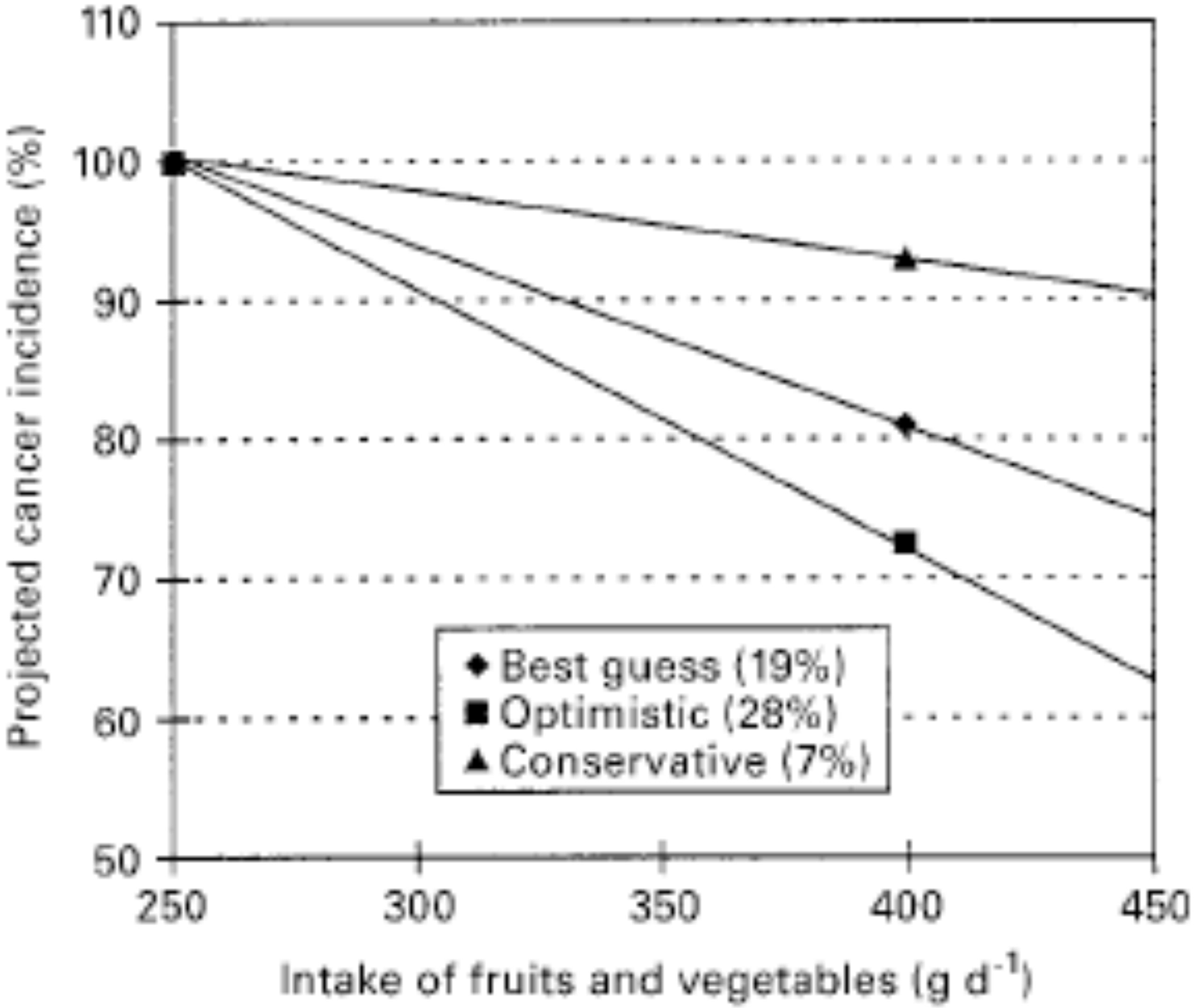


Fig. 1 Preventable proportion of chronic diseases as related to the intake of fruits and vegetables

(van't Veer et al. 2000)



(van't Veer et al. 2000)

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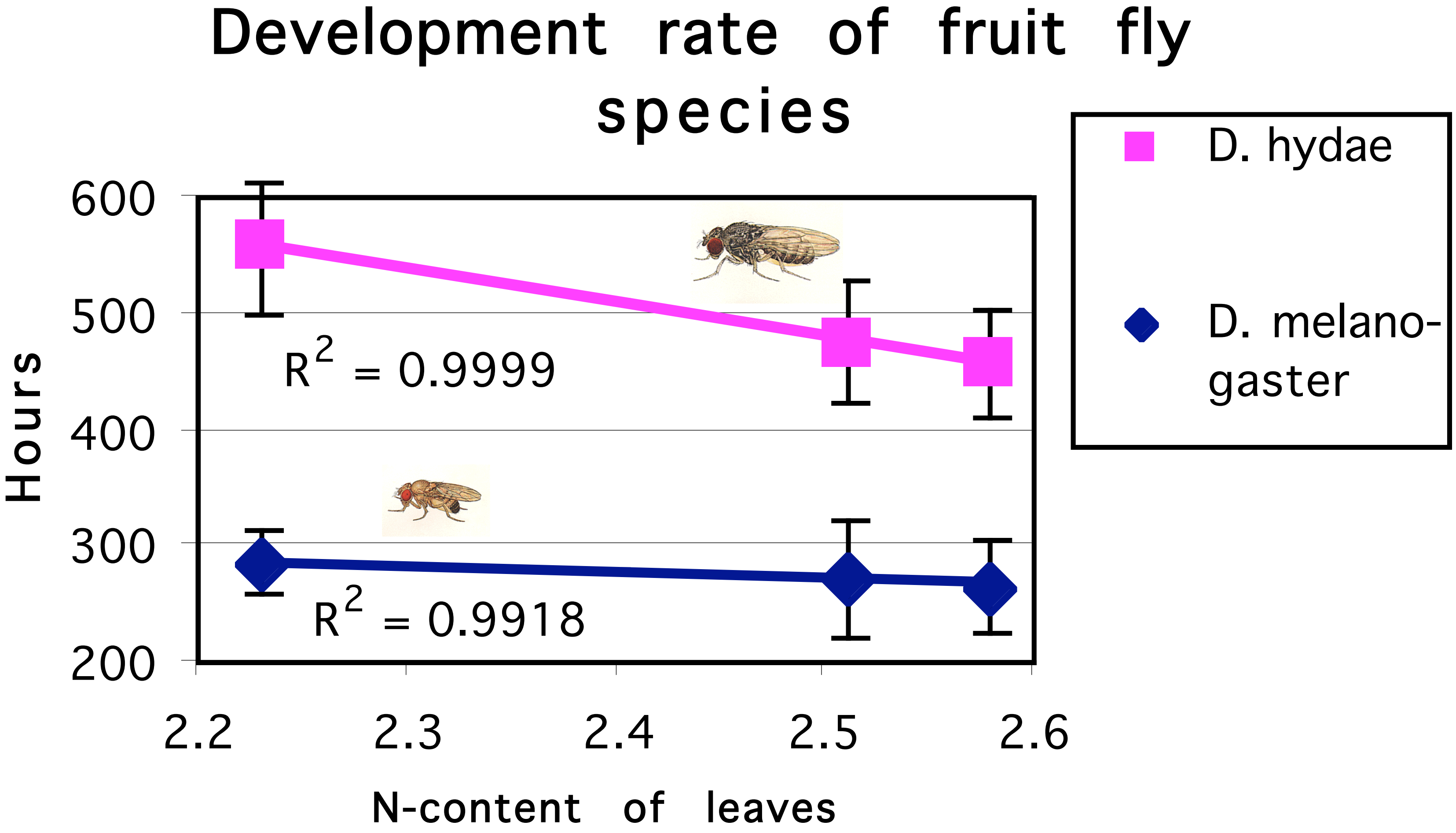
Effects of nutrient supply to apples on health of fruit flies

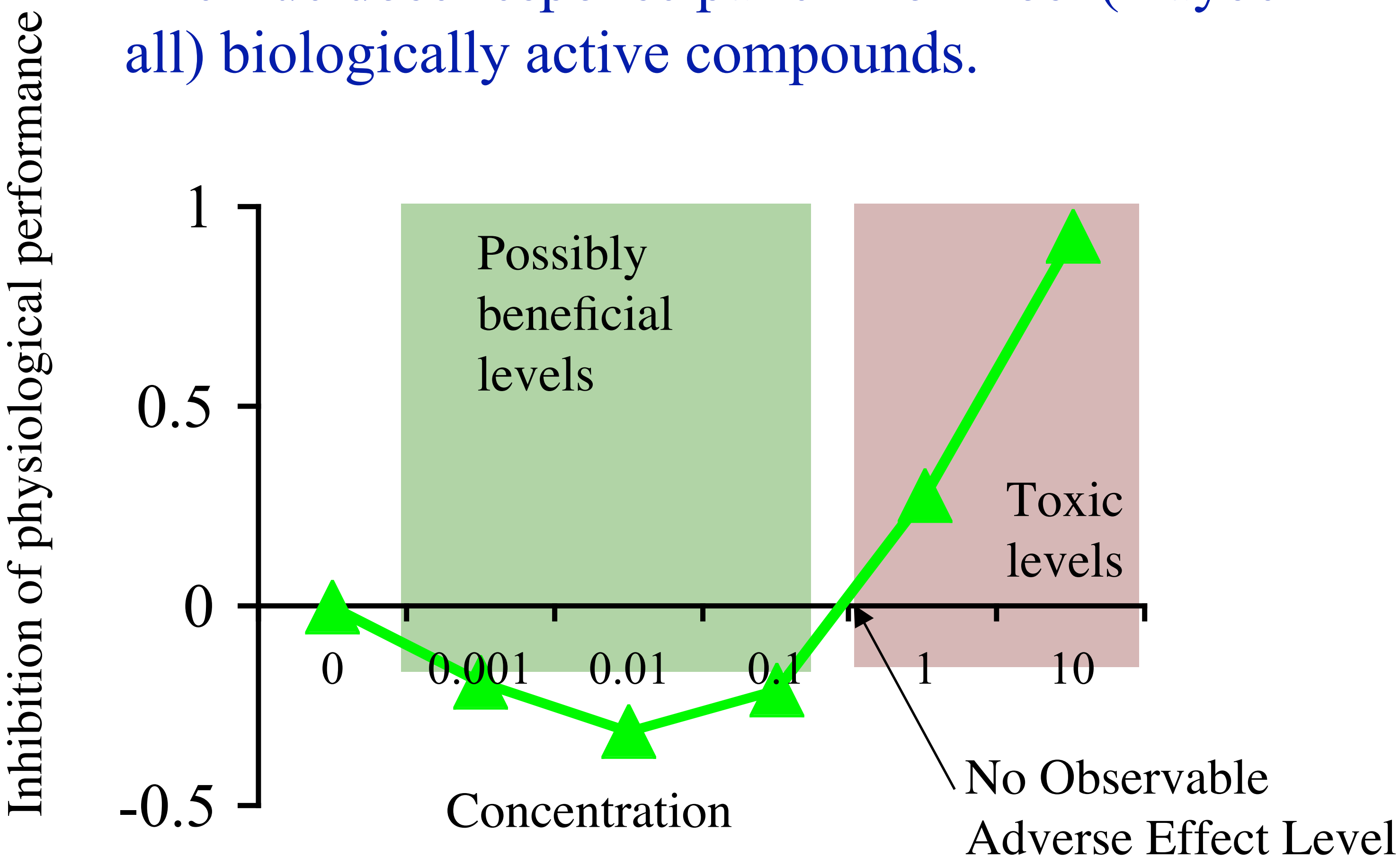


Negative effects on health?

- For some phytochemicals, a high concentration is toxic, e.g. glucosinolates or the potato glycoalkaloids
- Here we need to know the consequences of both too little and too much, in order to define the optimal level, and thus the optimal production strategy

Hormesis

“J-shaped” or biphasic curve.
The true dose response pattern for most (maybe all) biologically active compounds.



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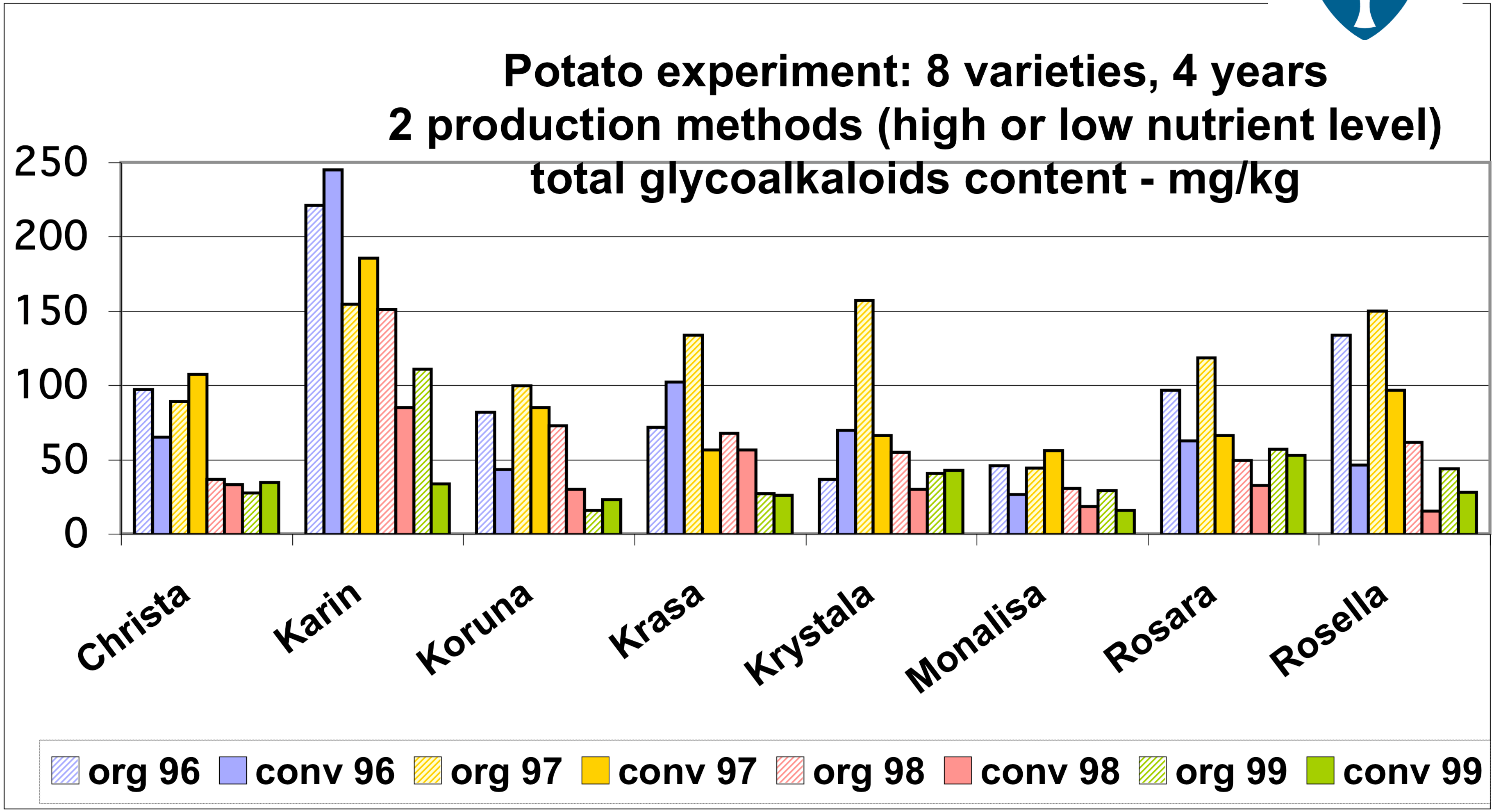

(Hajslova et al. 2005)

Model for toxicant accumulation

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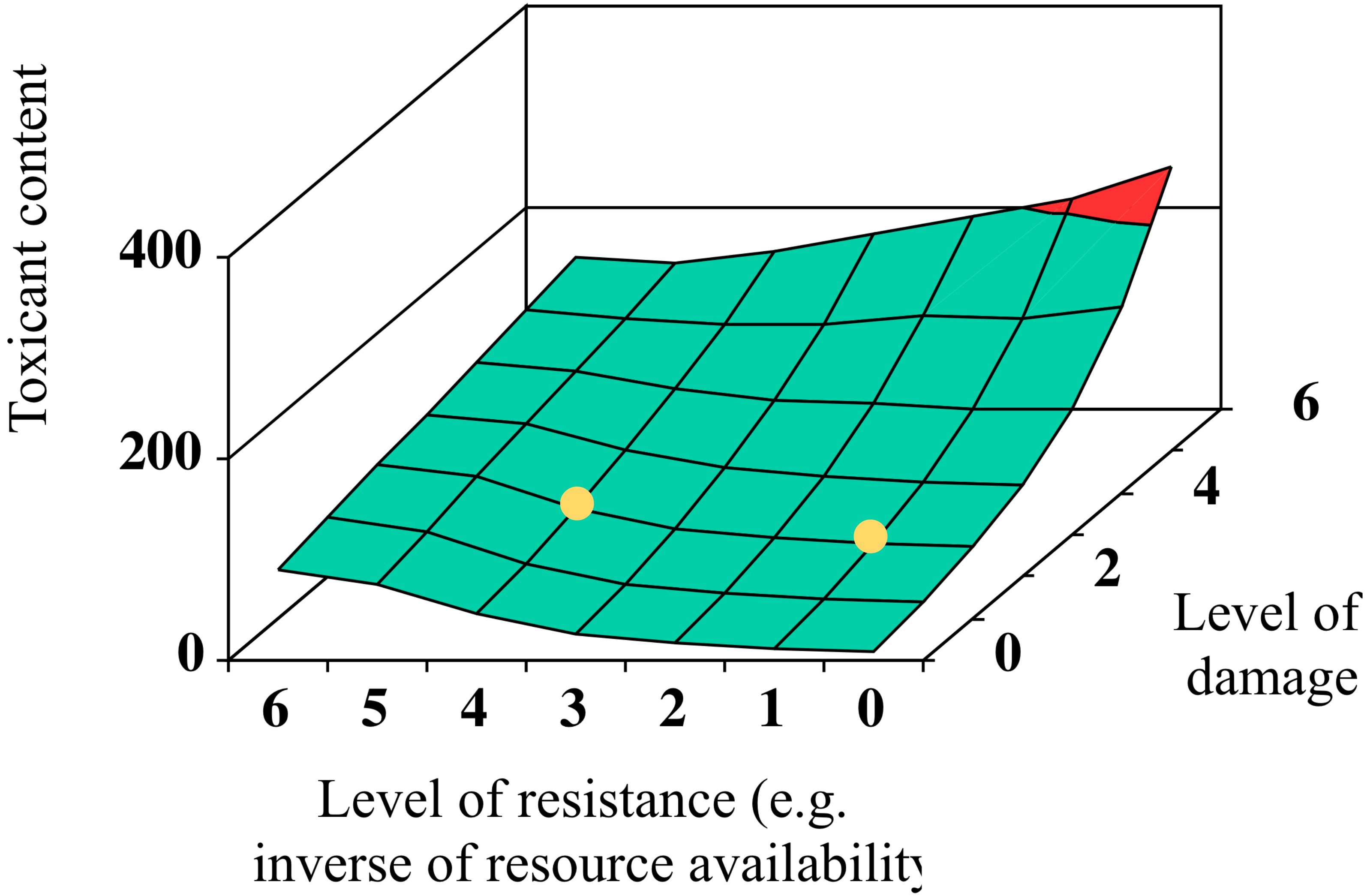

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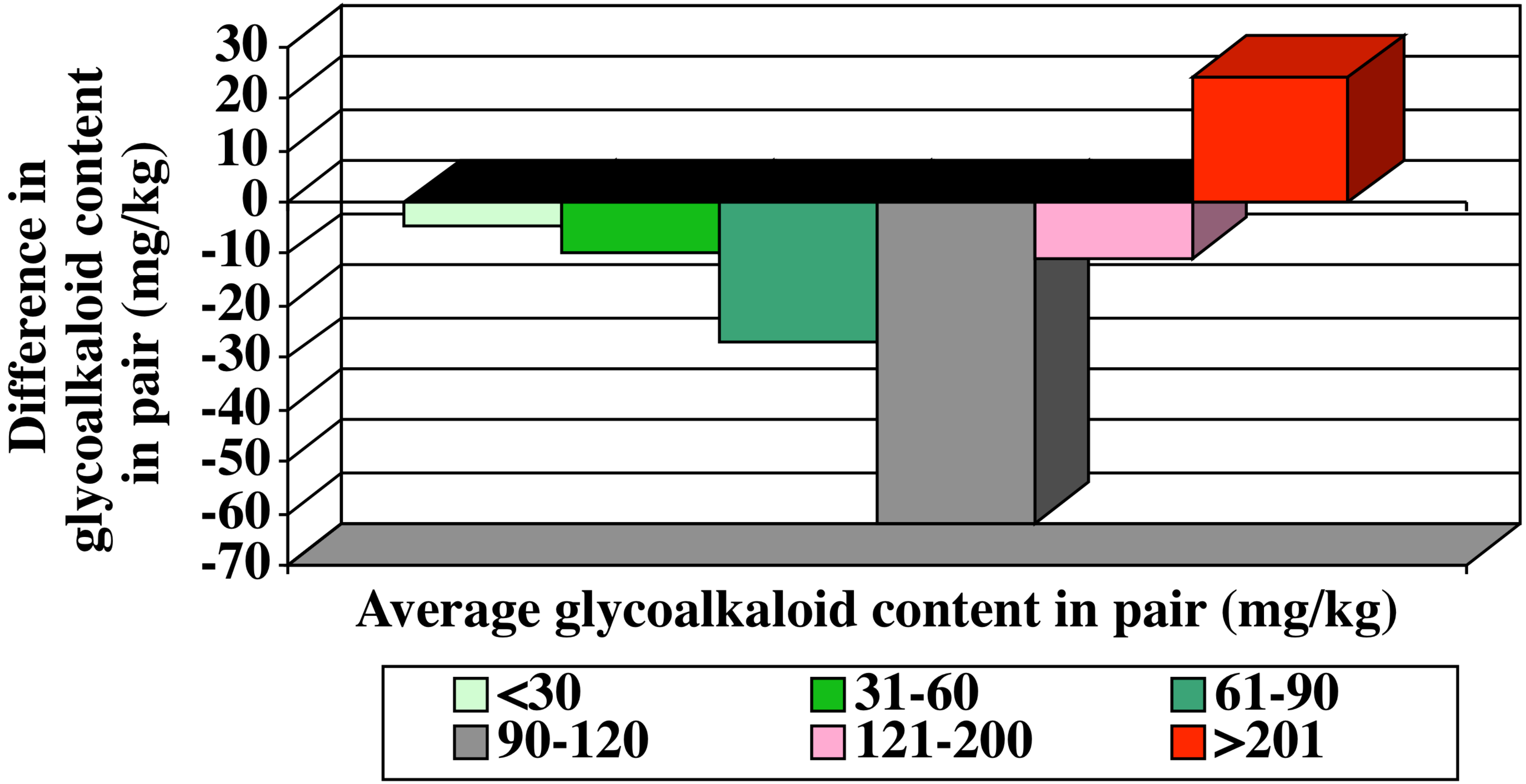
Effect of growth conditions on response to stress



Pair = same variety and year,

Difference = conventional value minus organic value.

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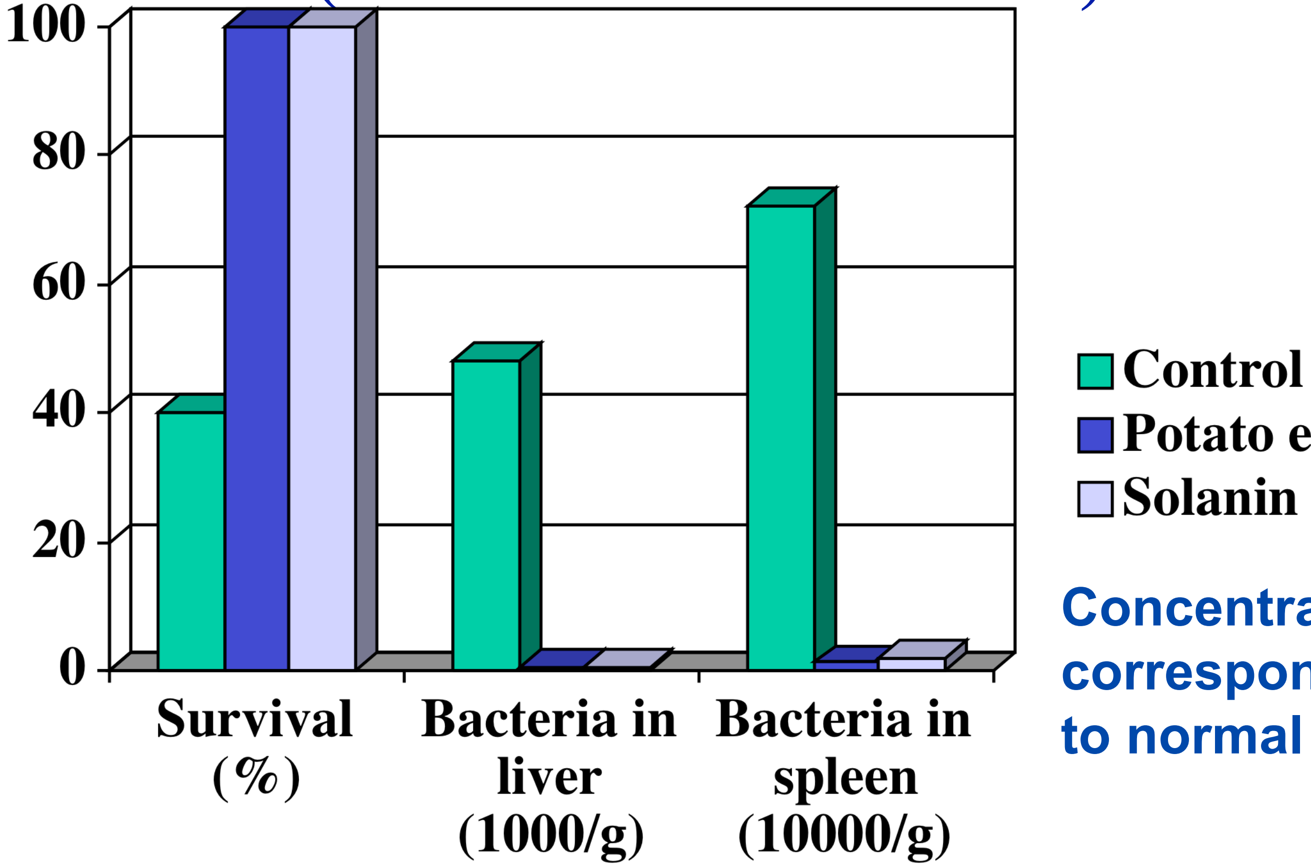
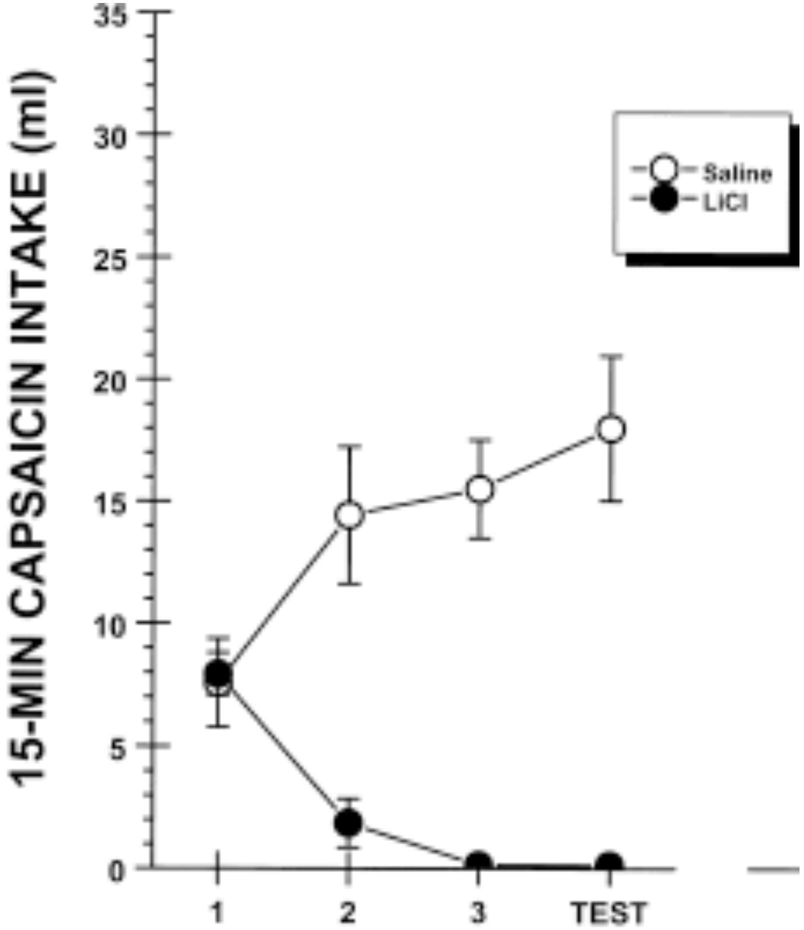
Effects of potato extract and glycoalkaloids on *Salmonella* infection in mice (control = “too little”)



Concentrations corresponding to normal food

(Gubarev et al. 1998)



Conditioned taste aversion:
If you get sick, the taste of the last food you ate before this becomes disgusting.

Example: If presented with flavoured water, and then injected with LiCl, a thirsty rat will not any more drink water with this flavour.

(Reilly & Trifunovic 2000)

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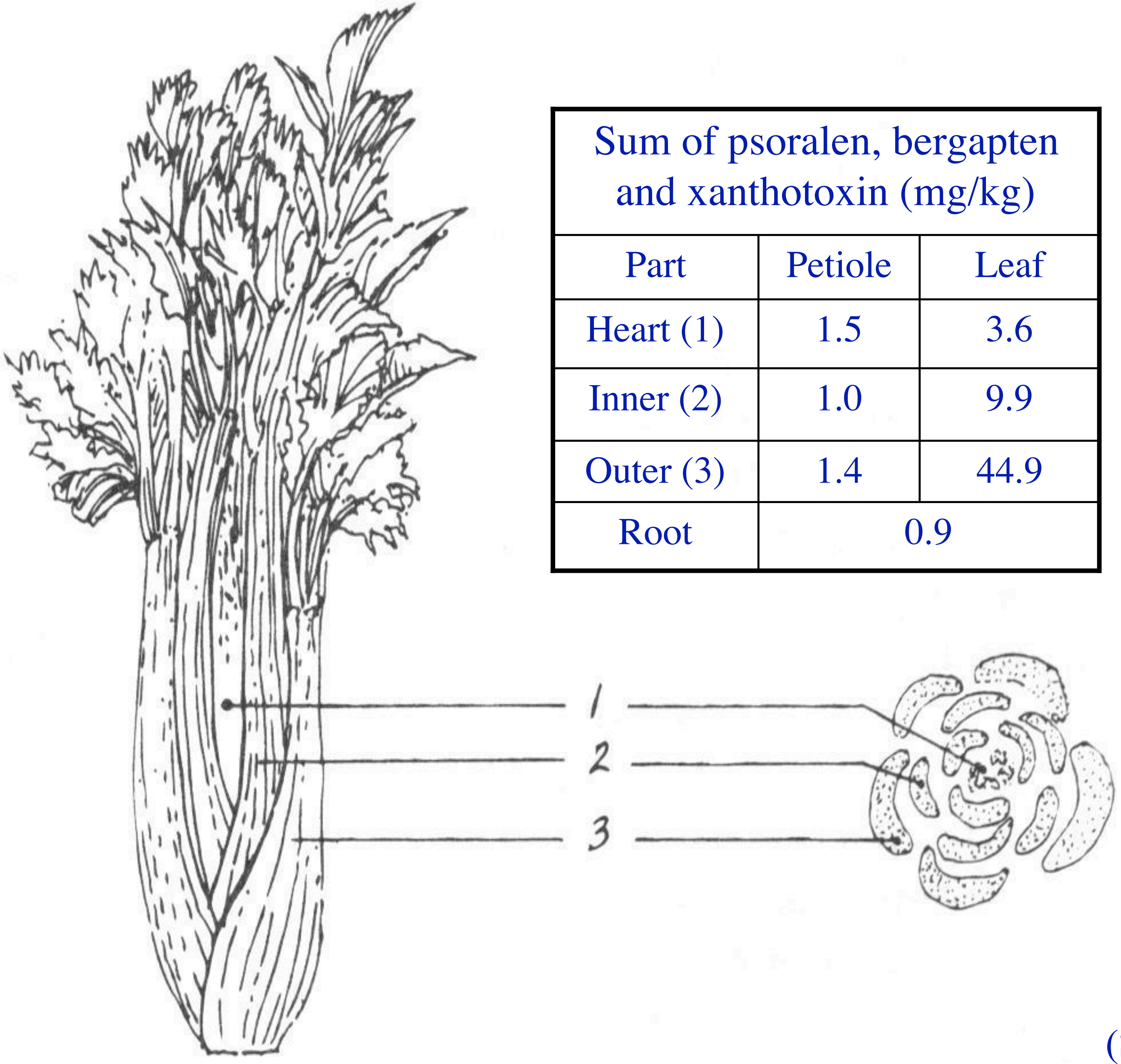

Sum of psoralen, bergapten and xanthotoxin (mg/kg)		
Part	Petiole	Leaf
Heart (1)	1.5	3.6
Inner (2)	1.0	9.9
Outer (3)	1.4	44.9
Root	0.9	

(Slanina et al. 2003)

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Cancer preventive compound(s)? in carrots.

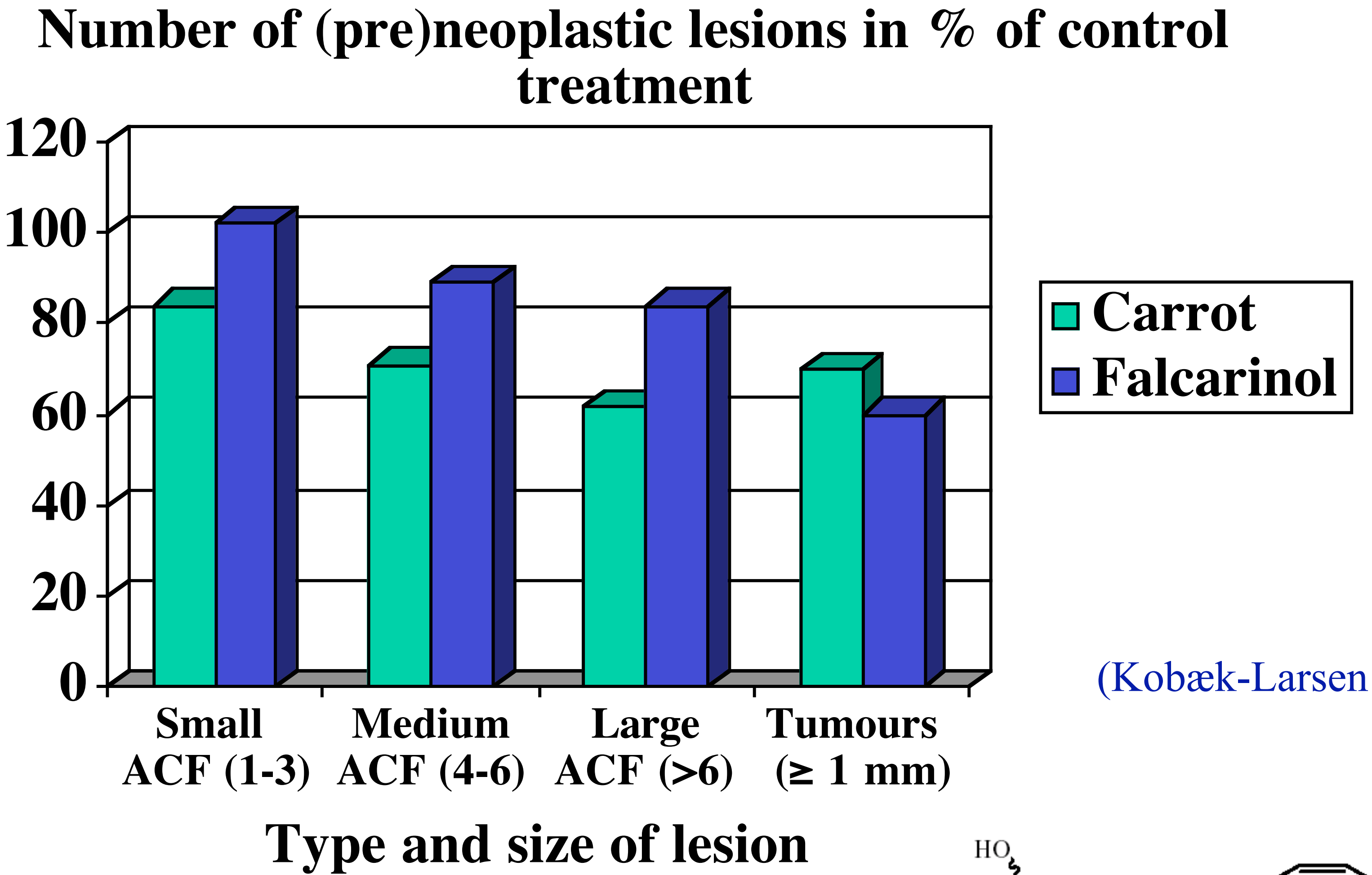
Epidemiology, carrots, cancer and β-carotene:

Risks of several cancers are negatively correlated with β-carotene content in human plasma.

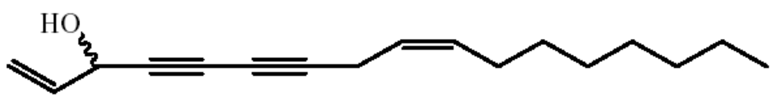
Carrots are a major contributor to intake of β-carotene.

Supplementation with β-carotene has no preventive effect on cancer

Effect on Azoxymethane induced colorectal cancer in rats



(Kobæk-Larsen et al. 2005)



Falcarinol

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Impact on health from agronomic optimisation

- Increase using existing best practice: 10-50% higher than common practice
- Impact on health from doubling of vegetable intake: 1.3 years for cancer (Gundgaard et al. 2003), approx. 1 year for CVD.
- Estimated impact of best practice: 1-12 months additional life expectancy

Summary/conclusions

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- Constitutive and induced levels of phytochemicals are affected by farming practice, in particular fertilisation and irrigation strategies
- Low input/organic methods tend to shift the balance towards higher resistance and less growth compared with high input, leading to increased and less variable levels of defence related phytochemicals
- If we make plant foods more "concentrated" by increasing the level of those phytochemicals that are most important for health, will it have substantial impact on public health
- We need to know which phytochemicals are important for human health and by how much, if we want more specific improvements than organic food

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Sponsors

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- Danish Research Council for Veterinary and Agricultural Sciences

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