Influence of Farming Systems on Plant Food Quality

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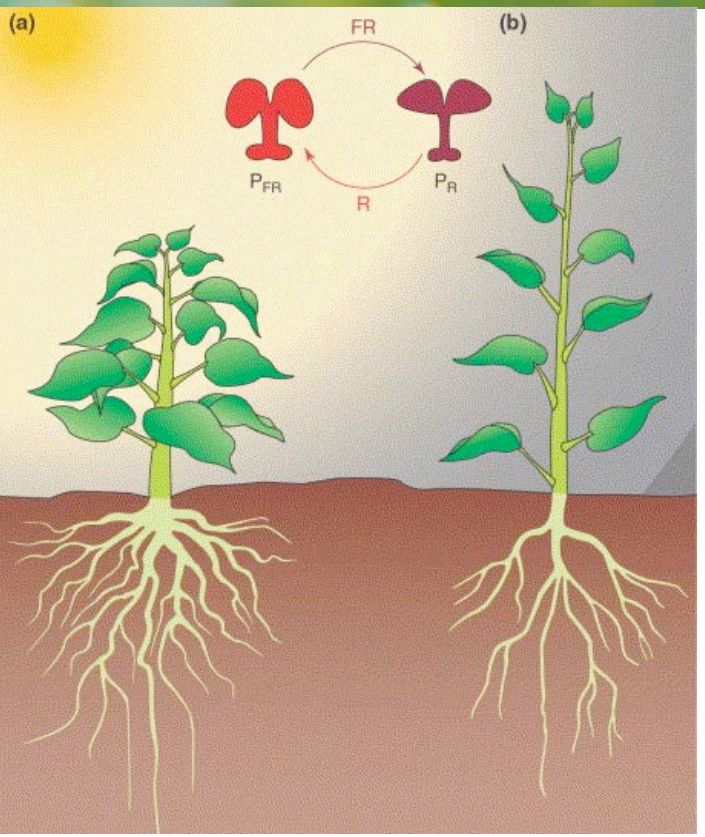
Influence of Farming Systems on Plant Food Quality

- Why environmental factors affect plant composition
  - Survival value of adaptation
- Adaptation to high or low growth rates ('stress')
  - Relations to different agricultural management systems
- How changes in plant composition can affect animal consumers (including humans)
  - Nutrients, non-nutrients and anti-nutrients
  - Nutrient-limited versus well-fed consumers
  - How to quantify the effects on composition (meta-analyses)
  - Results of meta-analyses
- Lessons learned and future work
  - Recommendations for future meta-analyses
  - Recommendations for design and reporting of experiments
  - What the information can be used for

Why environmental factors affect plant composition

- Environmental factors influence how much resources plants have available for growth and reproduction
  - Resources are light, temperature, water, CO_2, minerals (plant nutrients), O_2, anchorage
  - Any of these resources may be limiting, reducing the maximal growth rate (seed production) that the plant can achieve
- Survival value of adaptation
  - Plants can increase fitness by adjusting their development for optimal exploitations of the resources
  - This is well known regarding morphological adaptations
  - Most of these resources are objects of competition: Light, water, minerals
  - So one of the aims of adaptation is to optimise the plant's ability to compete for whichever resources limit growth
  - Growth can also be compromised by biotic factors (e.g. pests)

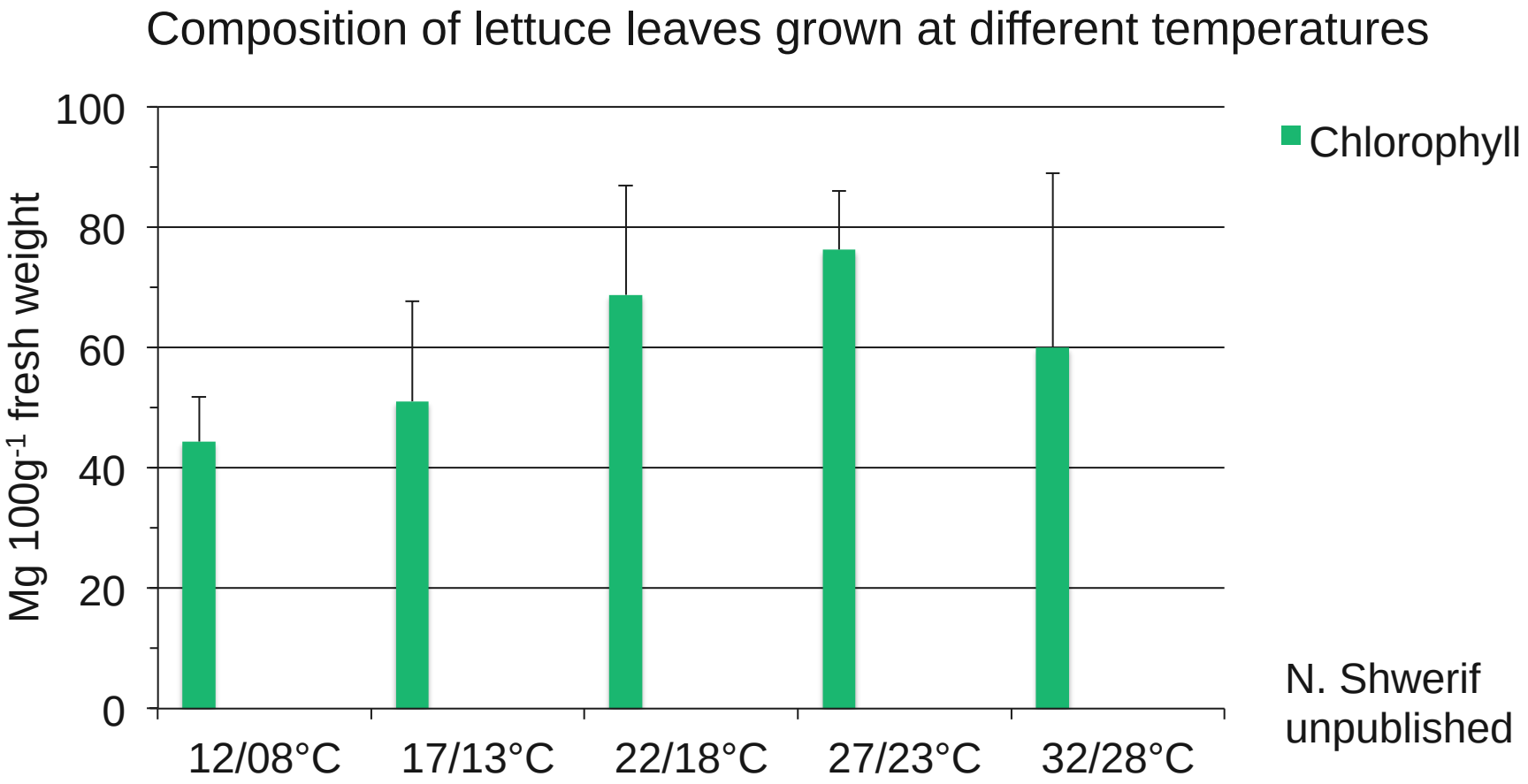
Adaptation to high or low growth rates ('stress')



Typical plant morphology when grown in sun (a) or shade (b)

- When 'stress' is absent
  - Light is the ultimate limiting resource
  - The number of photons per area limits the total biomass productivity of an area
  - Even if all other resources are sufficient or in excess
  - Under conditions where resources are plentiful, the fiercest competition among plants is for light: **Survival of the tallest!**
- When 'stress' is present
  - When growth is limited by another factor than light, other fitness aspects become more important, such as resistance to pests and diseases: **Survival of the toughest!**

Adaptation to high or low growth rates ('stress')



N. Shwerif unpublished

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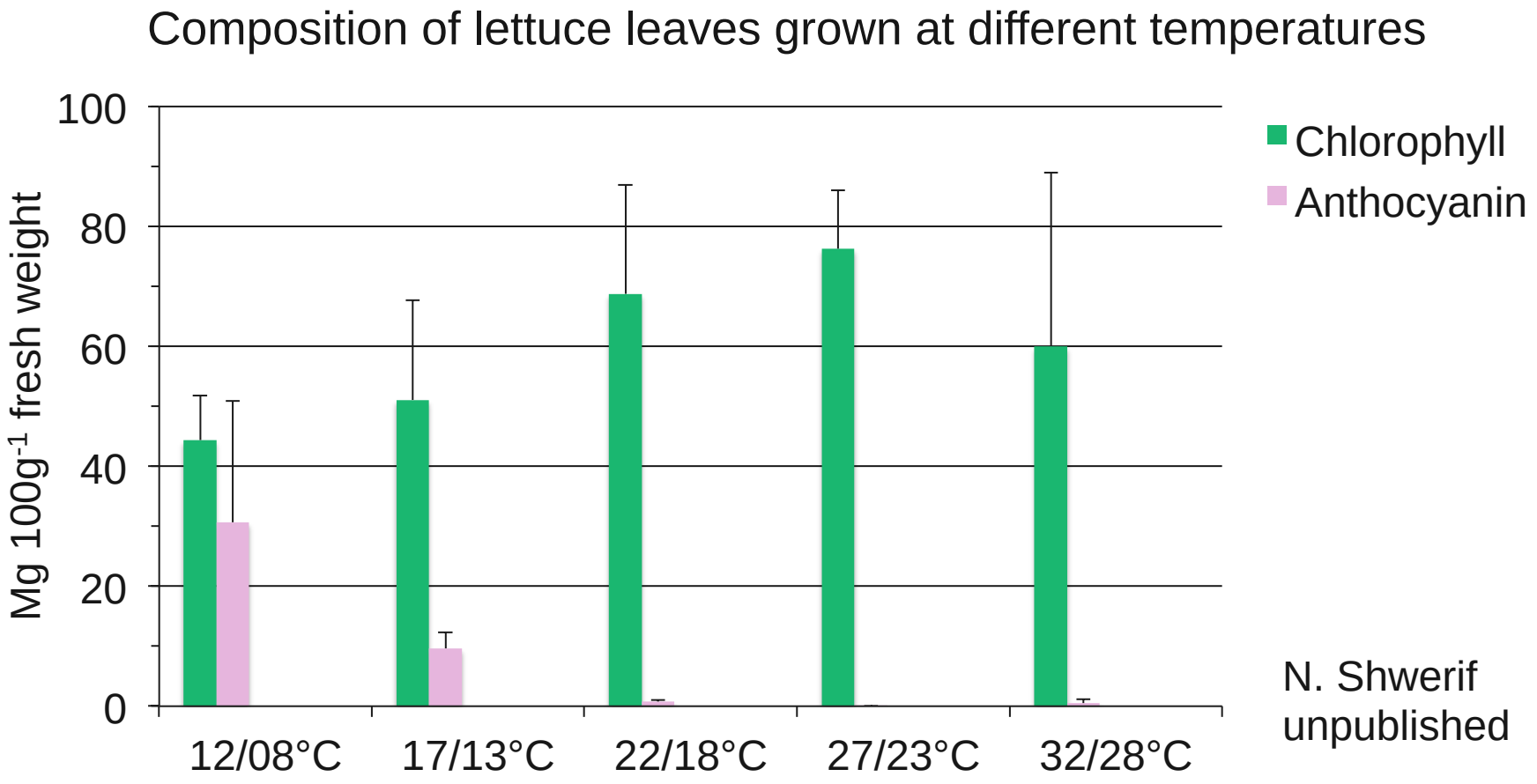

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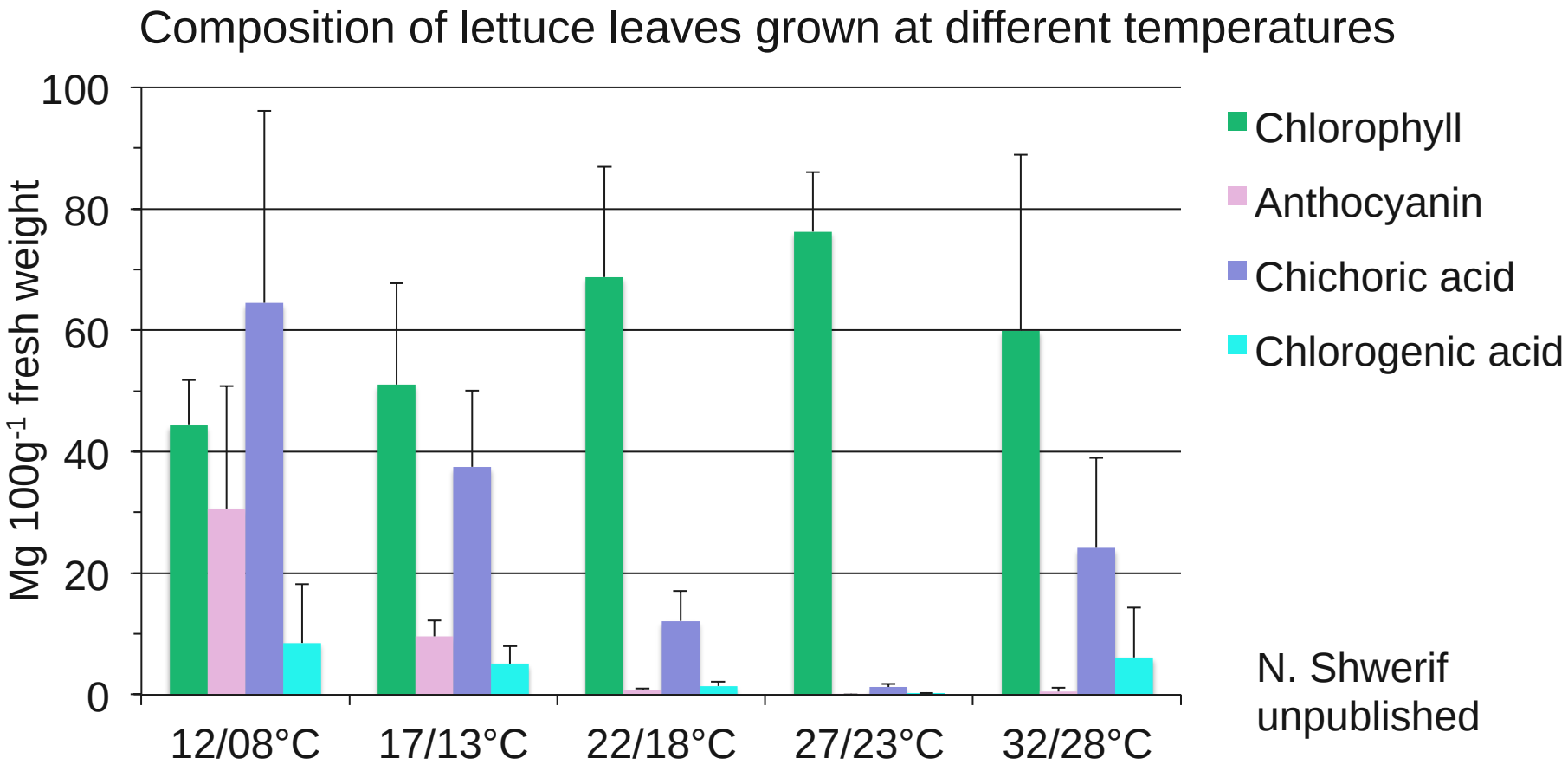

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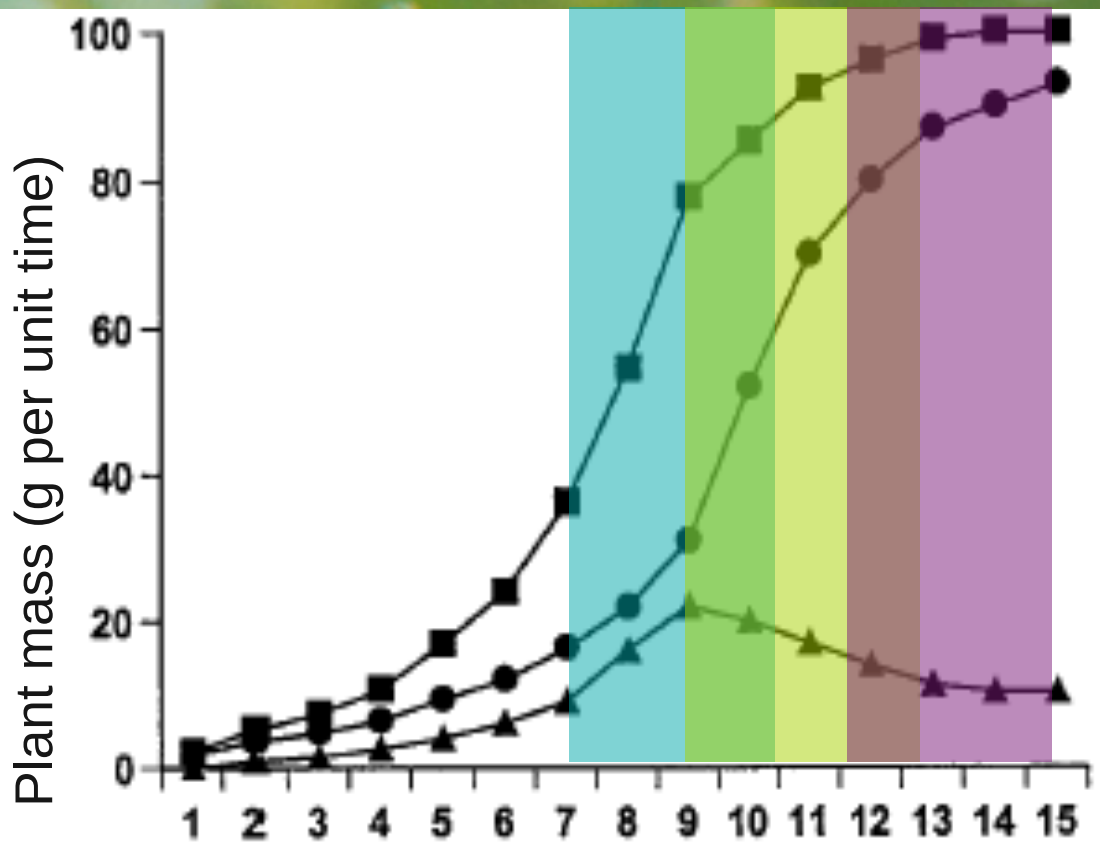
Relations to different agricultural management systems



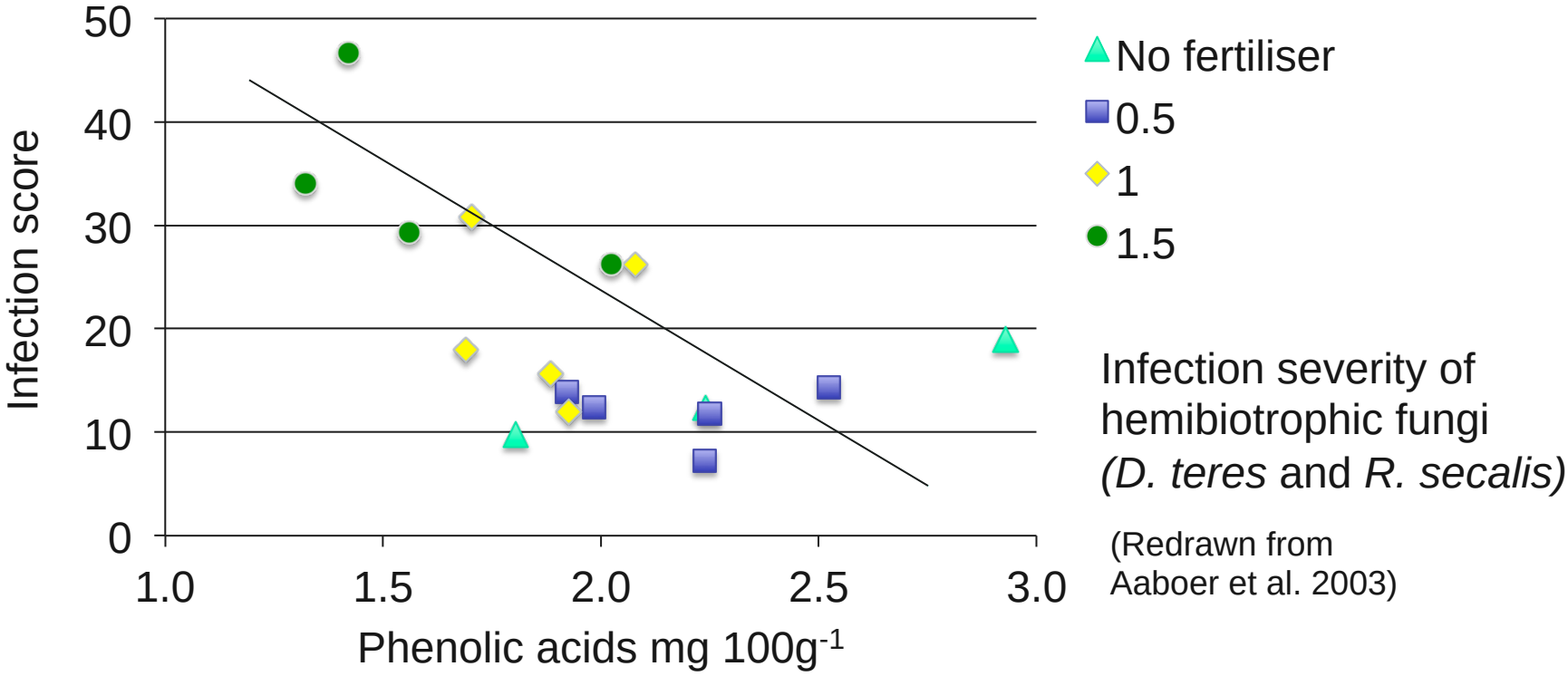
(graph from Stamp 2003)

- Plant mass
- Differentiated mass
- Secondary metabolites

- Subsistence farming
- Organic/low input
- Conventional/high input

Relations to different agricultural management systems

How fertiliser input affects phenolic acid concentrations and disease scores in barley leaves

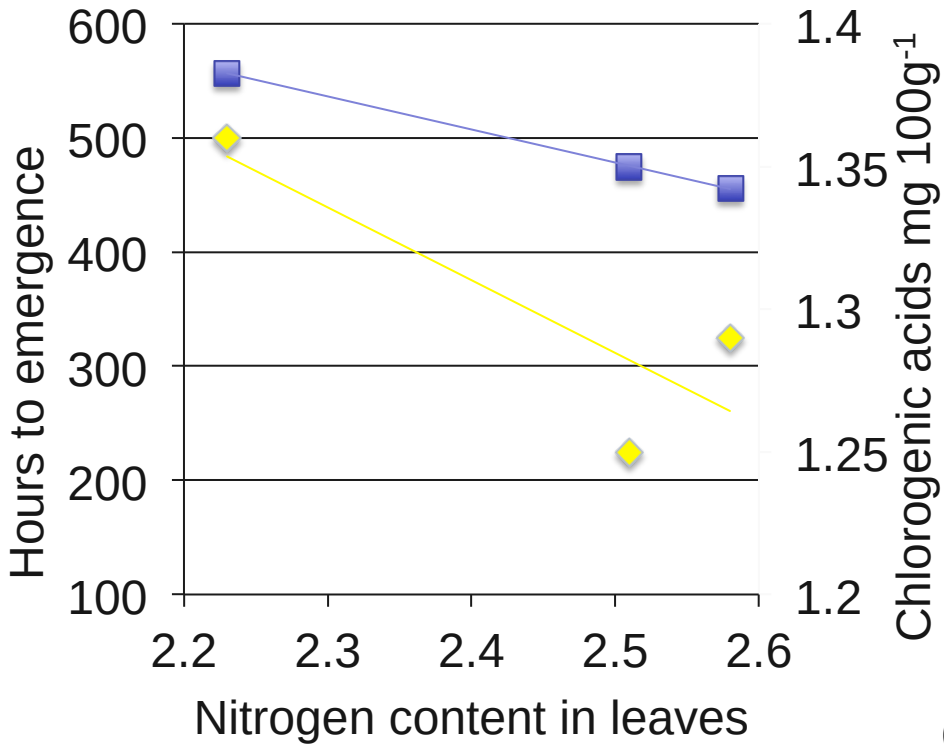


Infection severity of hemibiotrophic fungi (*D. teres* and *R. secalis*)

(Redrawn from Aaboer et al. 2003)

Relations to different agricultural management systems

How fertiliser status affects phenolic acid concentrations and development of fruit fly larvae



(Redrawn from Ejlersen et al. 2003)

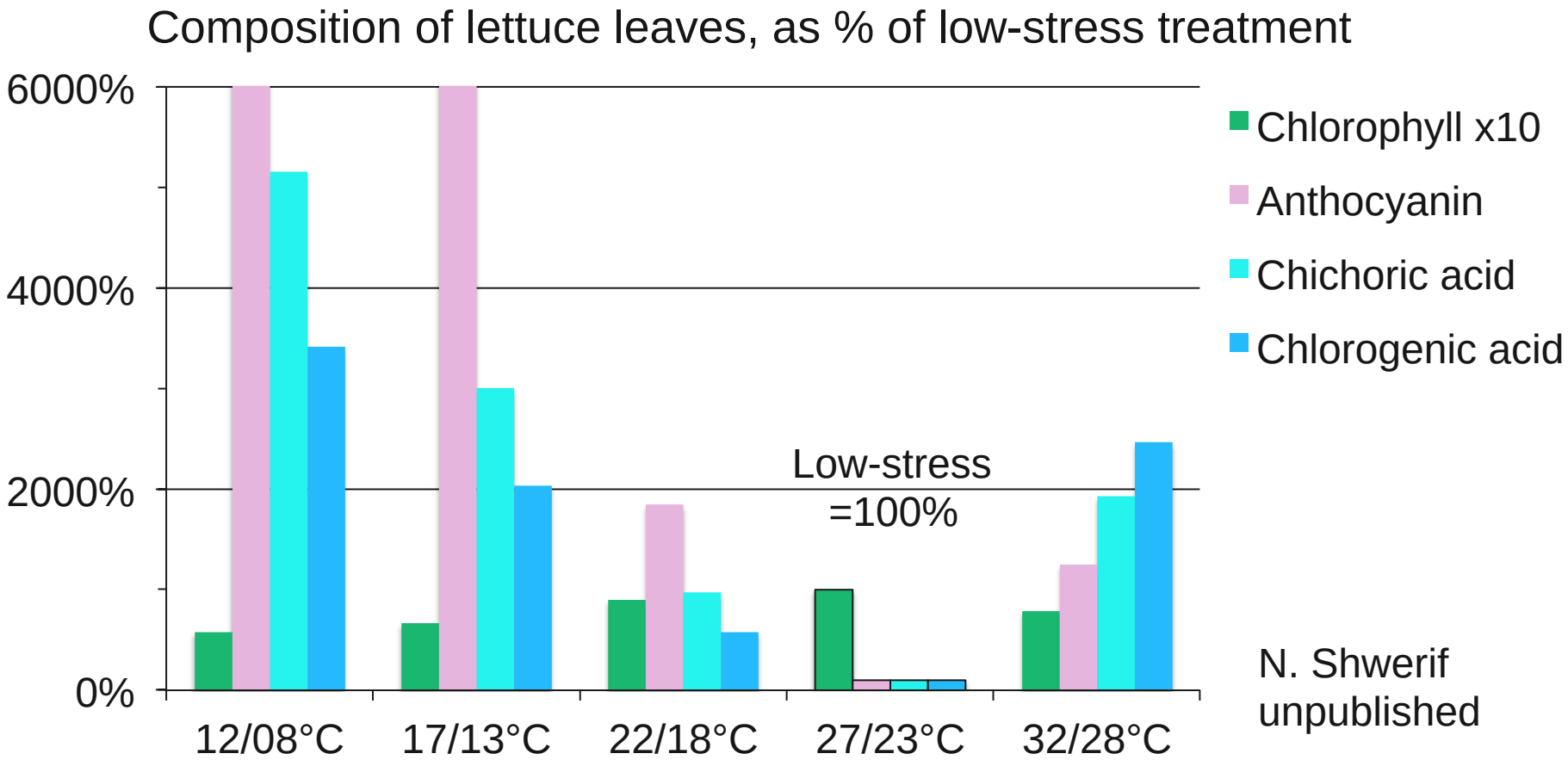
How changes in plant composition can affect animal consumers (including humans)

- Nutrients, non-nutrients and anti-nutrients
  - Secondary metabolites are usually toxicants (toxic at high concentrations), some interfere with digestive processes (anti-nutrients)
  - They reduce feed utilisation in animals, that's why breeders try to reduce their content, particularly in feed crops
  - Some cause off-taste in plant foods
  - Rapidly growing plants are easier to digest and provide more nutrients, except for vitamin C (which is used by the plants to protect against oxidative damage)

How changes in plant composition can affect animal consumers (including humans)

- Nutrient-limited versus well-fed consumers
  - If animals are hungry, they prefer feed with low content of secondary metabolites (conventional). They grow faster on this diet and gain more weight than on other diets.
  - If animals are well-fed, their feed choice is more varied, and closely reflects their physiological need (Forbes & Kyriazakis 1995).
  - Most animal species do not easily become obese, even if provided with unlimited access to appropriate feed.
  - Humans do not always choose food with the highest nutrient density, even if it is available.
  - High intake of fruits and vegetables benefits human health

How to quantify the effects on composition (meta-analyses)



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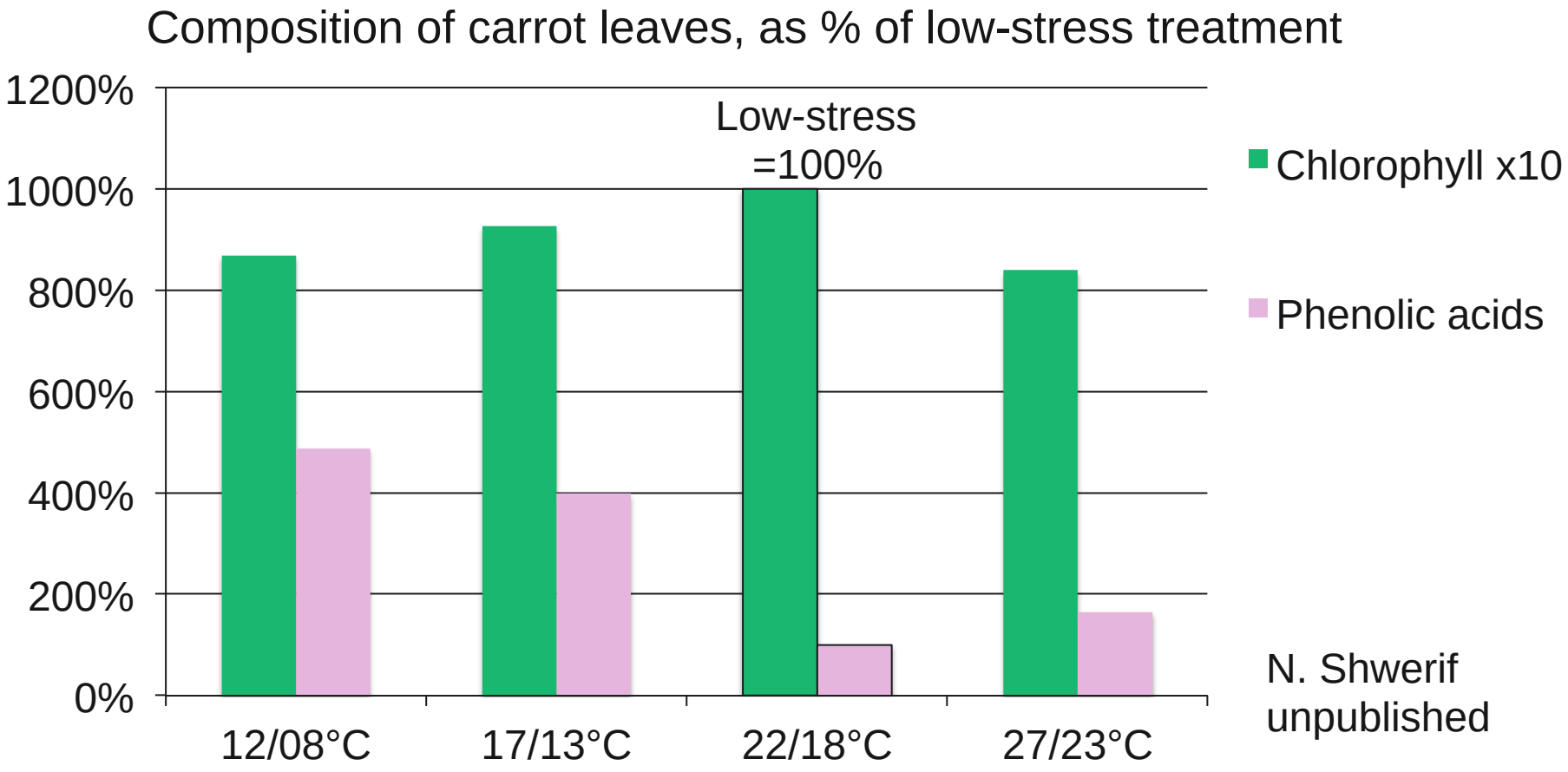
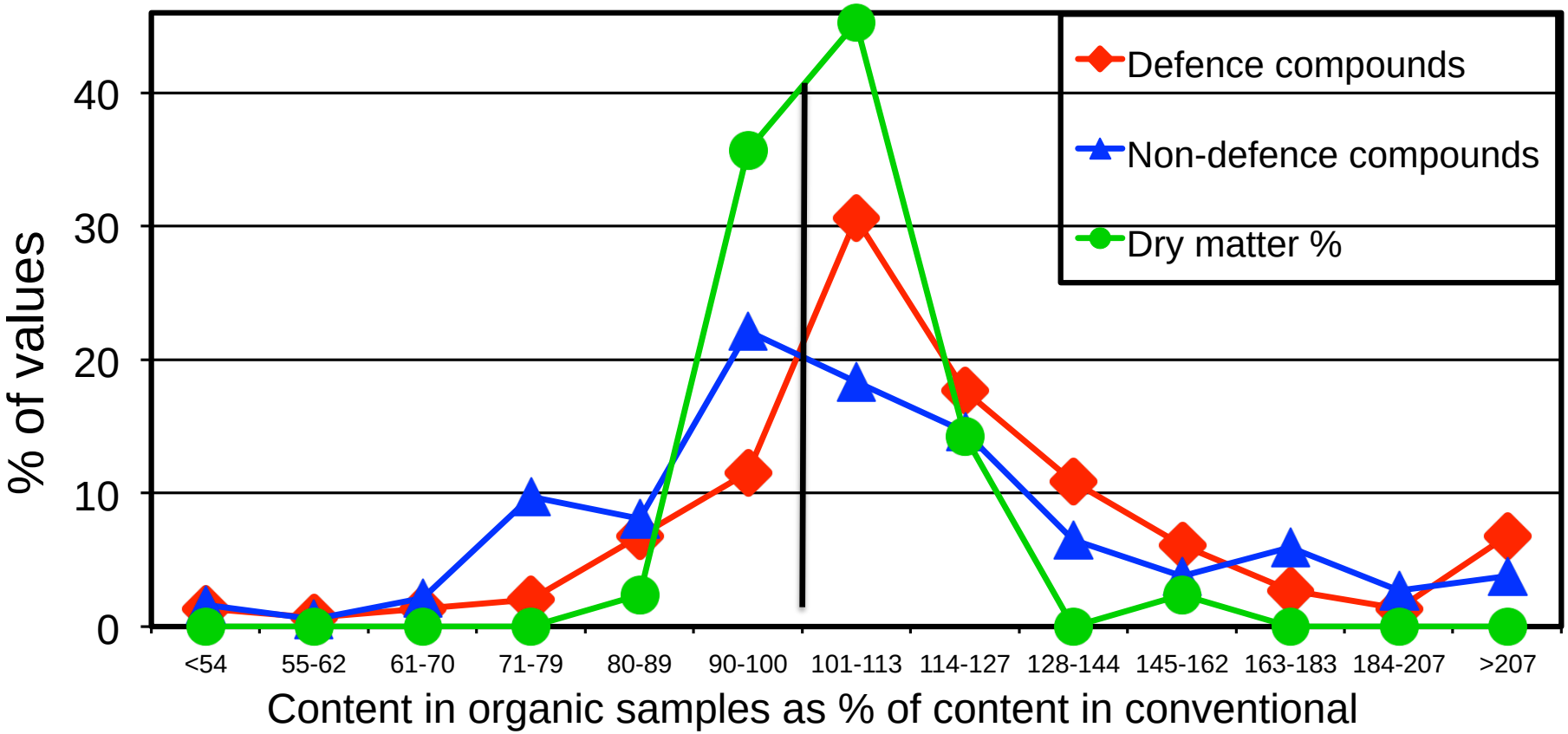


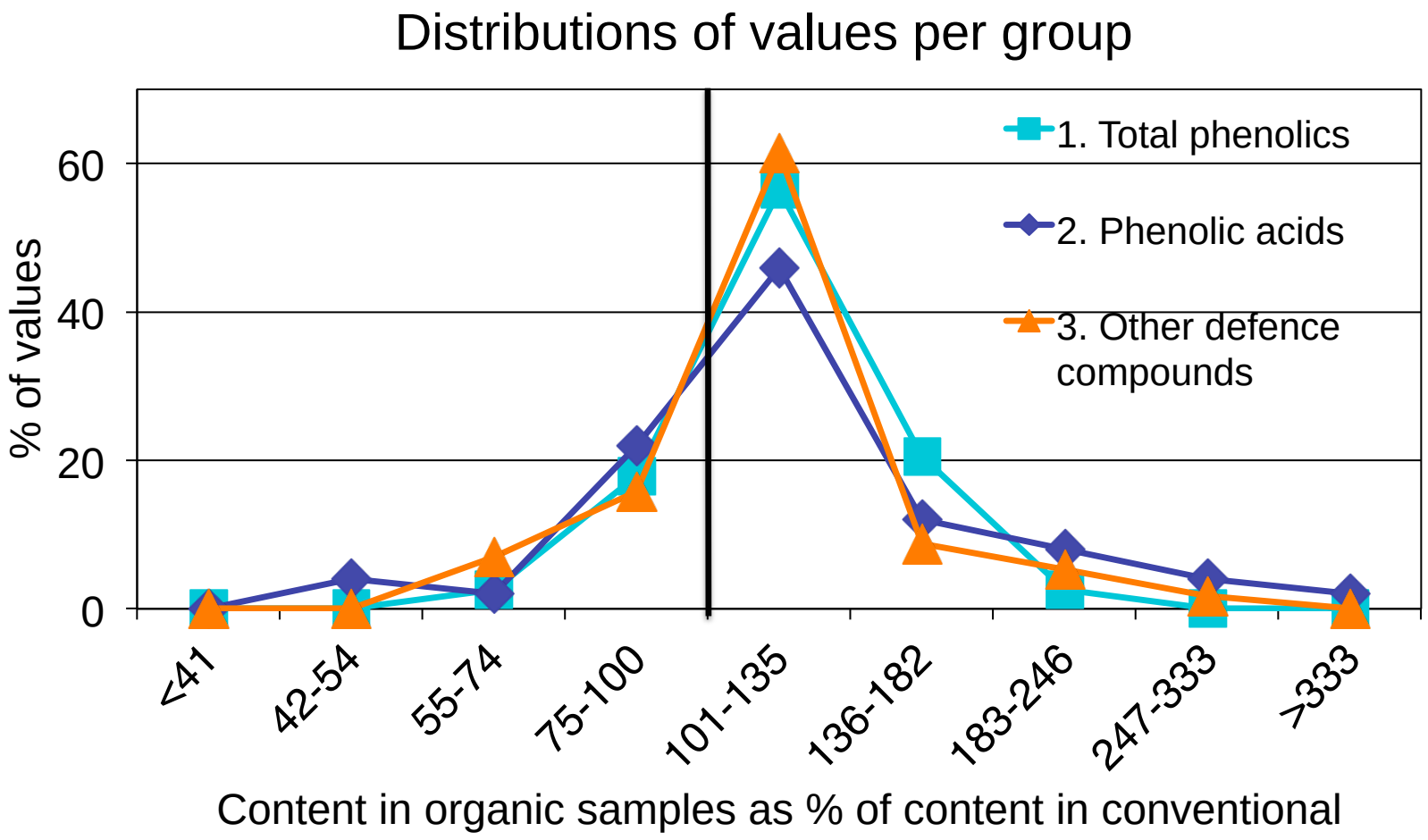
Results of meta-analyses Brandt et al. 2011



Average for defence compounds = 116%, P<0.0001
Average for non-defence compounds = 107%, P= 0.01

Average for dry matter content = 103%, P= 0.002
Average for all compounds = 112%, P<0.0001

Results of meta-analyses Brandt et al. 2011



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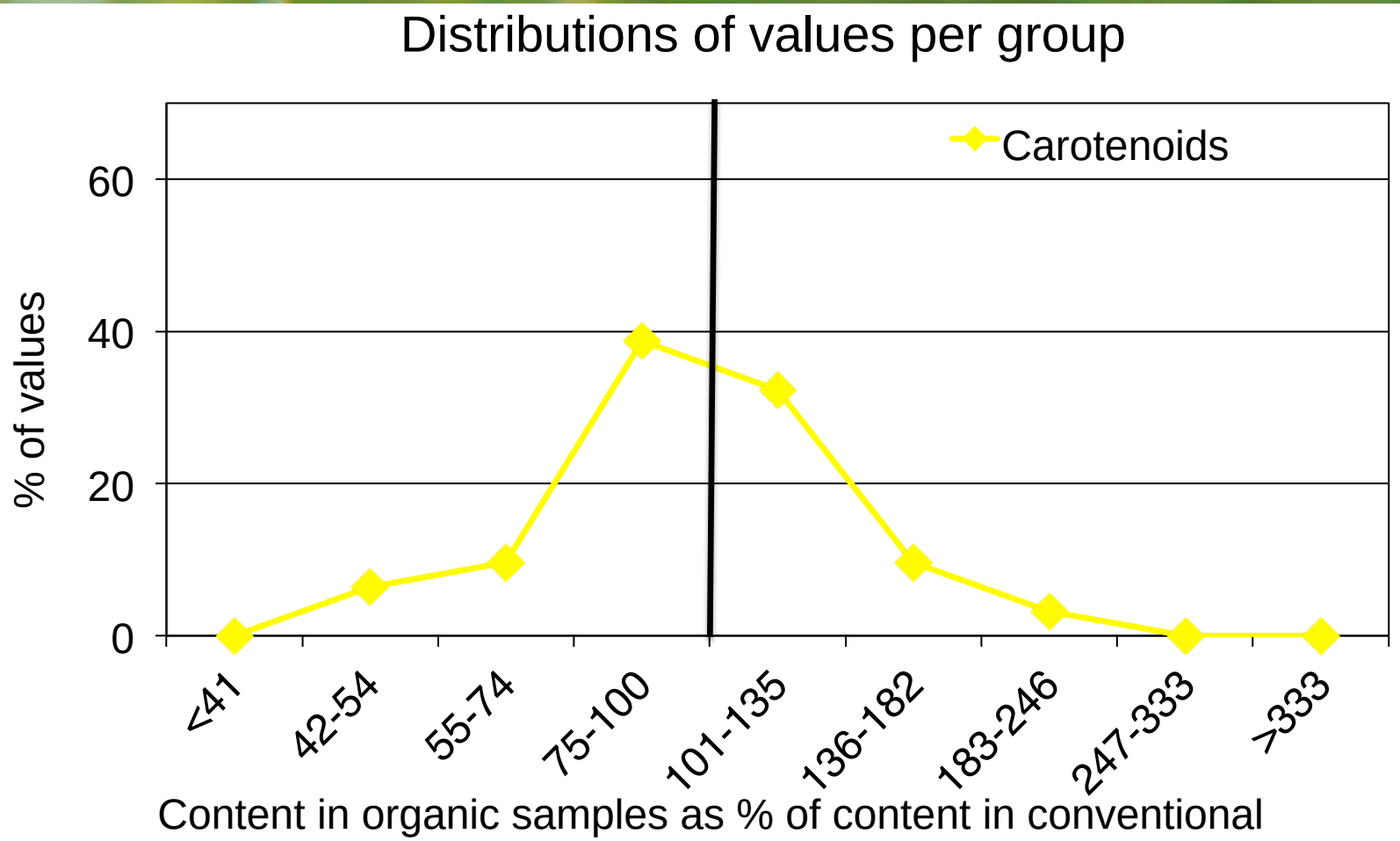


Methods for meta-analyses

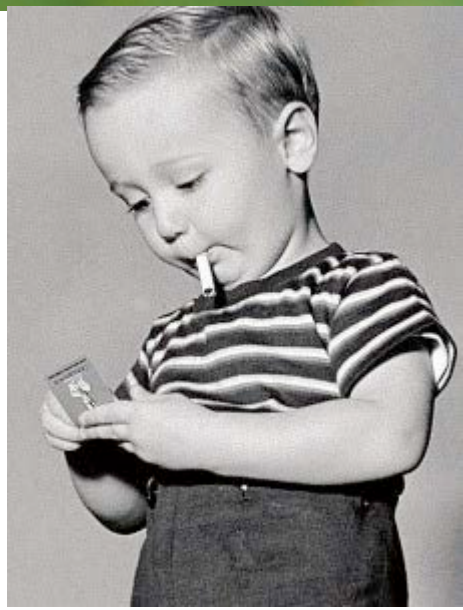
- Meta-analyses combine data from several studies.
- If data in the studies are comparable, the outcomes of studies can be analysed as if they were replications in an experiment.
- This works well if all studies have similar size and design.

– Most meta-analyses are done on data from Randomised Placebo-controlled Clinical Trials (RPCT).
  - When correctly designed, the main source of variation in an RPCT is the difference among individual humans (e.g. patients), and the only way to increase power is to increase the number of individuals.
  - In standard software for meta-analyses, trials are routinely assigned weight according to their variance.
  - So better studies with more patients influence the outcome more than small or ill-designed studies.

Methods for meta-analyses Brandt et al. 2011

- This meta-analysis was done without variance-based weighting
- Instead correlation within studies was controlled by averaging all factors other than species and harvest year
- So for studies using multiple varieties or field replications the outcome data for each compound were included as a single data point, while studies reporting data for multiple years were included as separate data points.
- This was due to a qualitative observation that several varieties in the same year tended to show very similar effects.
- Similarly, multiple forms of the same compound were pooled as single data points.

Results of meta-analyses Brandt et al. 2011



- The difference in composition is highly significant, but small in absolute terms.
- Increasing the content of biologically active compounds in fruits and vegetables by 12% could be equivalent to increasing the intake of fruits and vegetables by the same 12%.
- Using data from epidemiological studies to estimate the effect of increasing F&V intake (Veerman et al. 2006), 12% higher intake corresponds to increasing life expectancy by 3 weeks, or prevention of 17 cases of CVD or cancer annually per 100000 people. Similar to effects of breast cancer screening.
- The uncertainty is mainly on the risk reduction data, not on the composition data.
- However, a health effect of this size is far too small to measure directly using existing scientific methods.

Veerman et al. 2006. The European Common Agricultural Policy on fruits and vegetables: exploring potential health gain from reform. Eur. J. Pub. Health 16: 31–35.

Results of other meta-analyses

Examples of other meta-analyses comparing contents of vitamins, minerals and plant secondary metabolites and their results:

- Benbrook et al. 2008, The Organic Center: Study selection based on agronomic quality and reporting quality. Concluded that most studies favoured organic, no quantitative summary statistics.

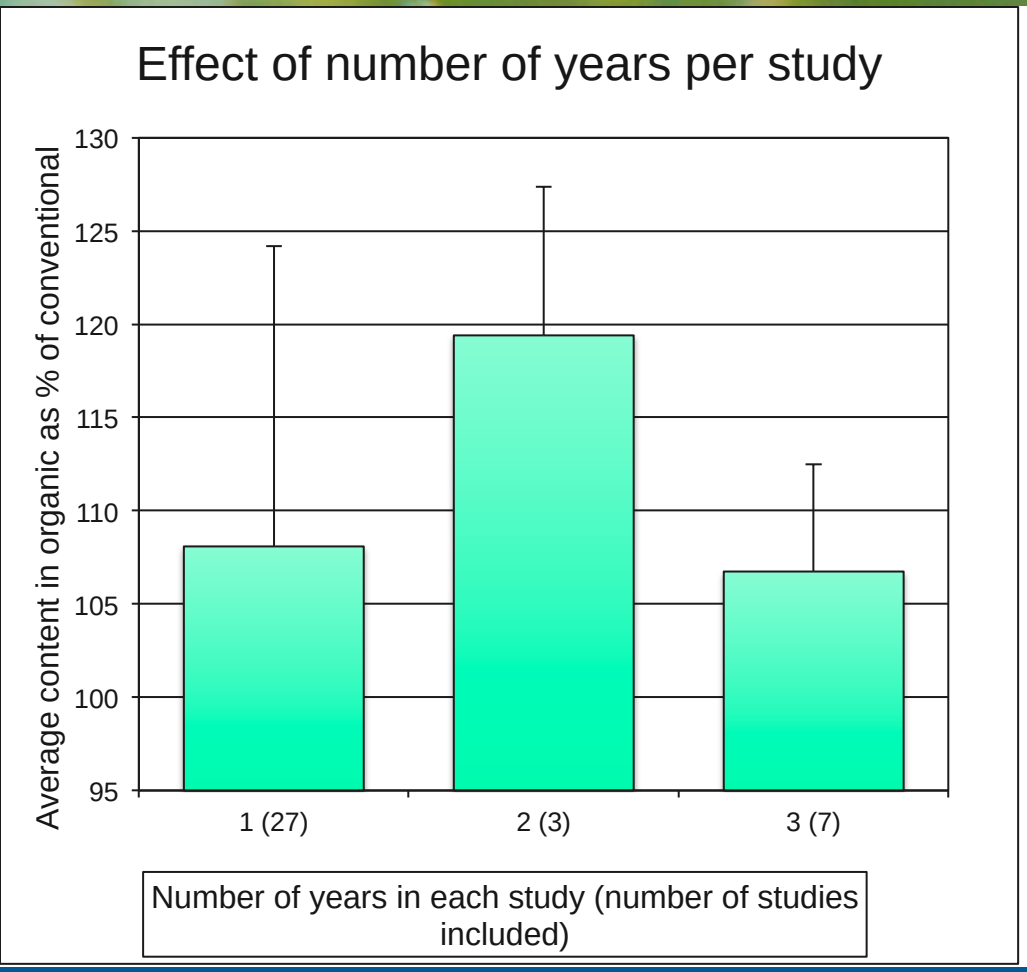
- Dangour et al. 2009, Am. J. Clin. Nutr. 90: 680–685: Study selection based on reporting quality, no assessment of agronomic quality. Compared all available data points without weighting. Found significant differences for 3 groups of compounds out of 11 analysed.
- Smith-Spangler et al. 2012, Ann. Int. Med. 157: 348-366: Study selection based on reporting quality, no assessment of agronomic quality. Compared all available data points, and used weighting, but did not distinguish between replications and repetitions. Found significant differences for 2 groups out of 13 analysed.

Different results of different meta-analyses

- Clearly at present the methodology for these meta-analyses is not sufficiently well developed to give reproducible results
- Which method should we choose to analyse this type of data?
  - Is it just about finding the method that gives us the results we want? no
  - Are there objective methods to determine which methods are best? yes
  - Are small (poorly funded and reported) studies affected by bias that over-emphasise the difference between organic and conventional food?
  - Are there design issues within some types of large studies, which systematically bias the difference (not reflecting the 'real world')?
- How to do it
  - For each choice regarding methods, sensitivity analyses can help to show the effect of each option
  - As and more data are published, the larger datasets provide more and more statistical power to answer these questions

Example of method development research:

Sensitivity test for number of years



Calculations based on data on 'total phenolics' from all studies used by either Dangour, Brandt or Smith-Spangler.

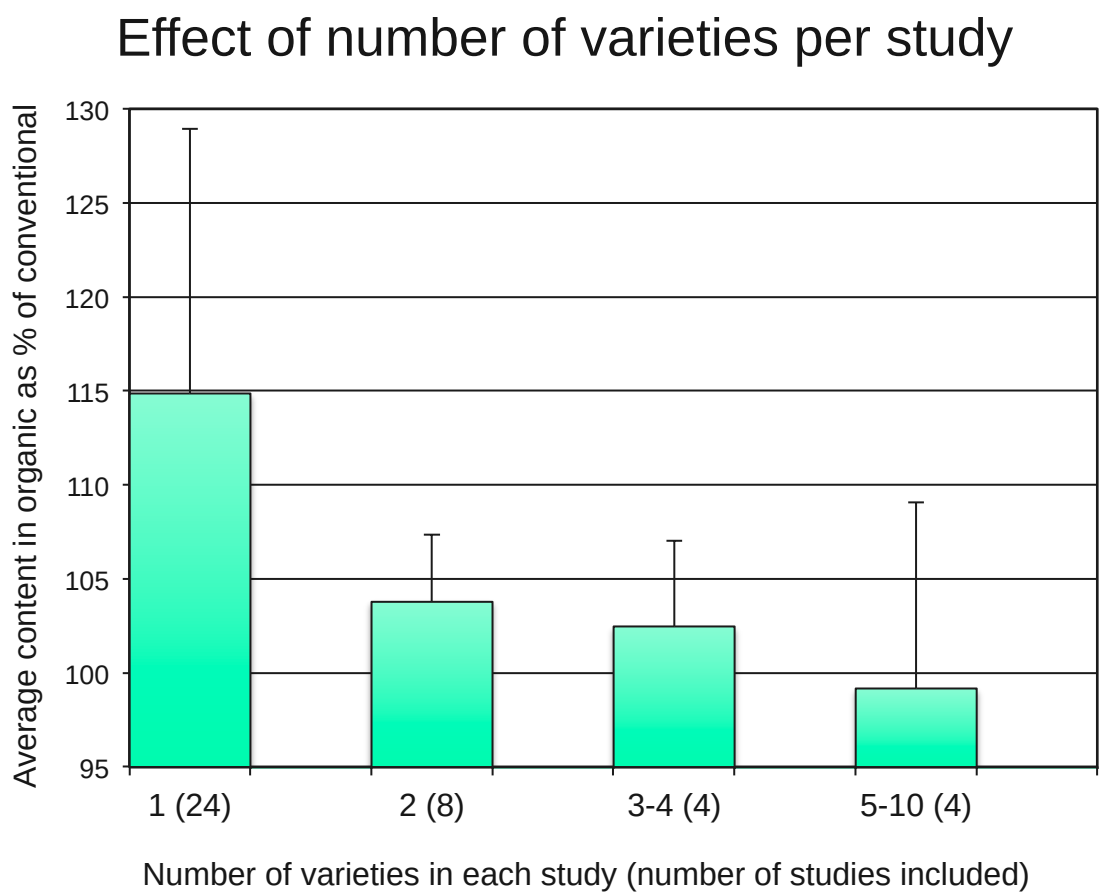
No effect of number of years on relative content of 'total phenolics', P=0.427.

Long-term studies would normally indicate higher quality than short-term studies.

These data do not indicate that smaller (cheaper) studies are inherently biased.

Example of method development research:

Sensitivity test for number of varieties



Organic plants in studies with many varieties have relatively lower content of 'total phenolics' (P=0.021), compared with studies using fewer varieties.

How does studies with many varieties differ from studies with many years?

Possibly that the more varieties are included in a trial, the more difficult it becomes to harvest each treatment in each variety at the optimal maturity?

Lessons learned and future work

- Recommendations for future meta-analyses
  - Don’t just assume that all publications are written with a meta-analysis in mind! Ask the authors, they are not (necessarily) trying to conceal anything!
  - Carry out extensive sensitivity tests to determine what data manipulations are appropriate to eliminate correlations among data, without unnecessarily reducing the statistical power.
  - Be particularly critical of the description of two aspects where systematic bias may inadvertently be introduced:
    - Pre-crop and soil fertility – are they relevant for commercial practice?
    - Sample collection/harvesting – are all samples at the same physiological maturity
  - Try as far as possible to use objective criteria for the choices that have to be made.

Lessons learned and future work

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Perspective

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Methods for Comparing Data across Differently Designed Agronomic Studies: Examples of Different Meta-analysis Methods Used To Compare Relative Composition of Plant Foods Grown Using Organic or Conventional Production Methods and a Protocol for a Systematic Review

Kirsten Brandt,*,† Dominika Średnicka-Tober,‡ Marcin Barański,‡ Roy Sanderson,# Carlo Leifert,‡ and Chris Seal†

Lessons learned and future work

- Recommendations for design and reporting of experiments
  - Have a meta-analysis in mind when you write your papers!
  - Include the relevant statistical details which will allow others to use your data in their analyses (standard deviation and N for each result).
  - Make effort to accommodate the interaction between variety and production system when determining dates for harvest and sowing etc.
- Be aware that as more data accumulate, researchers will try to mine them for ever more information. So don't delete any details about completed studies, you never know when someone comes asking for them!
- Even preliminary studies or projects that were not completed as intended can contain relevant data, which should be made available for meta-analysis studies. The important considerations are whether the data are representative for the products on the market and the comparisons valid.

Lessons learned and future work

- We will collect as much information as possible about comparisons of organic and conventional plant food constituents.
- After we have used it for the method optimisation, the data will be made available to everyone for research purposes.
- What the information can be used for
  - Optimise plant resistance to pests and diseases
  - Enhance awareness of correct statistics and detailed reporting of statistics and data
  - Improve input data for modelling of effects on human health (although the human data are already the main bottleneck)
  - New data will eventually provide a confirmation of the good methods compared with the not-so-good: The best method is the one that most precisely predicts the effect found in newly published studies!

Thank you very much for your attention!

Any questions?

Thank you to Mrs Najia Shwerif for data on temperature ‘stress’