Vegetable cultivation in the conflict of plant, environment, and consumer demands

Dietmar Schwarz
Hans-Peter Kläring
Rita Grosch
Saskia Welter

Leibniz Institute for Vegetable and Ornamental Crops, Germany

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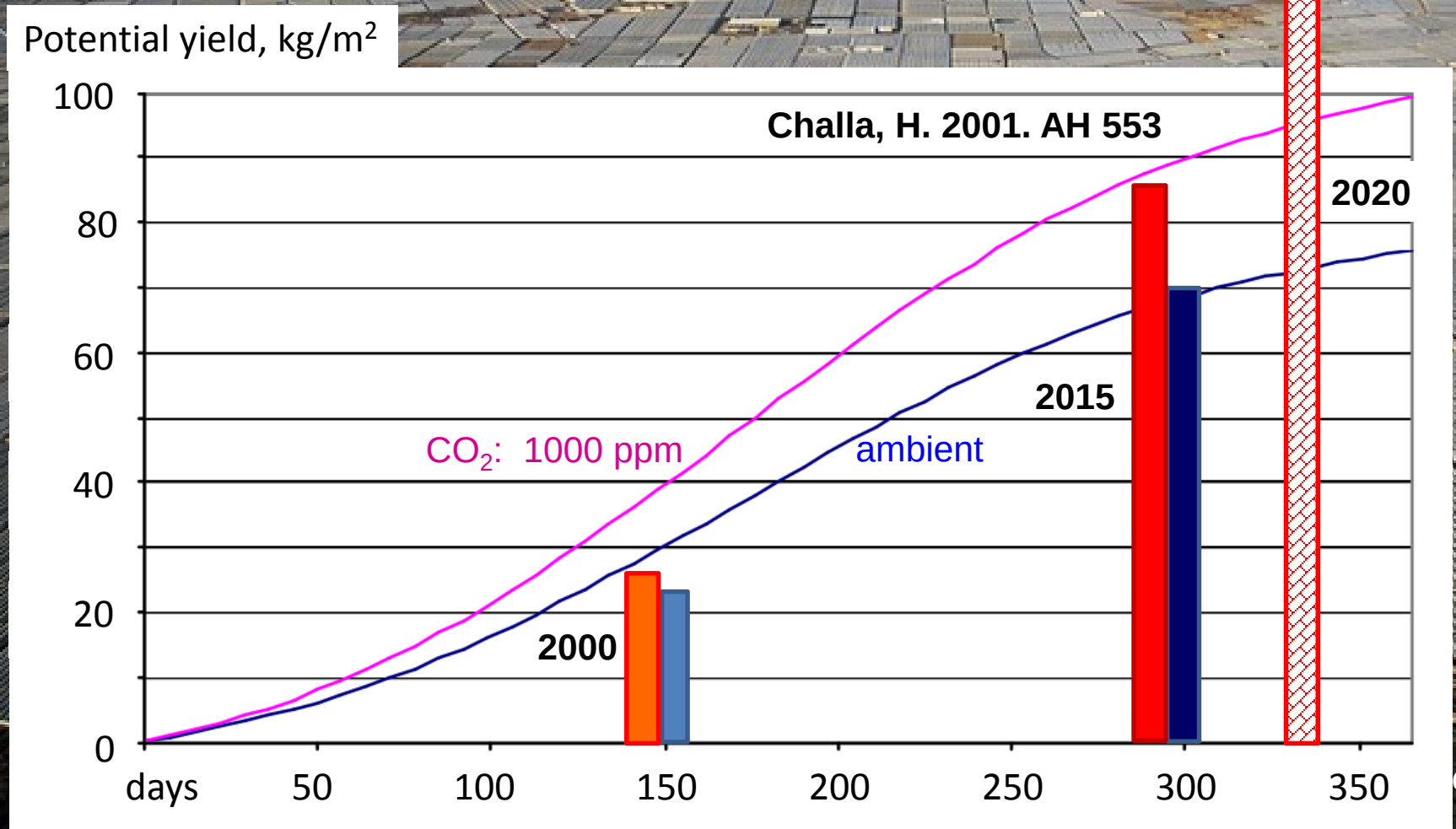
I am from….

Leibniz Institute of Vegetable and Ornamental Crops

What I want to talk about

1. Cultivation of vegetables
   - 1.1. Achievements
   - 1.2. Bottlenecks
2. Environmental claims
   - 2.1. Biocontrol
   - 2.2. Grafting
   - 2.3. Reduction in energy (windmills) and CO_2 emission
   - 2.4. Organic production
3. Consumer claims
   - 3.1. Quality issues
   - 3.2. Healthy product - allergic potential
   - 3.3. Transgenic tomato
4. Conclusions

1.1 Achievements in cultivation



modern and powerful machines

broad spectrum of cultivars

Top technologies available - field

www.maehlmann-gemuesebau.de

precision farming

www.ikeswelding.com

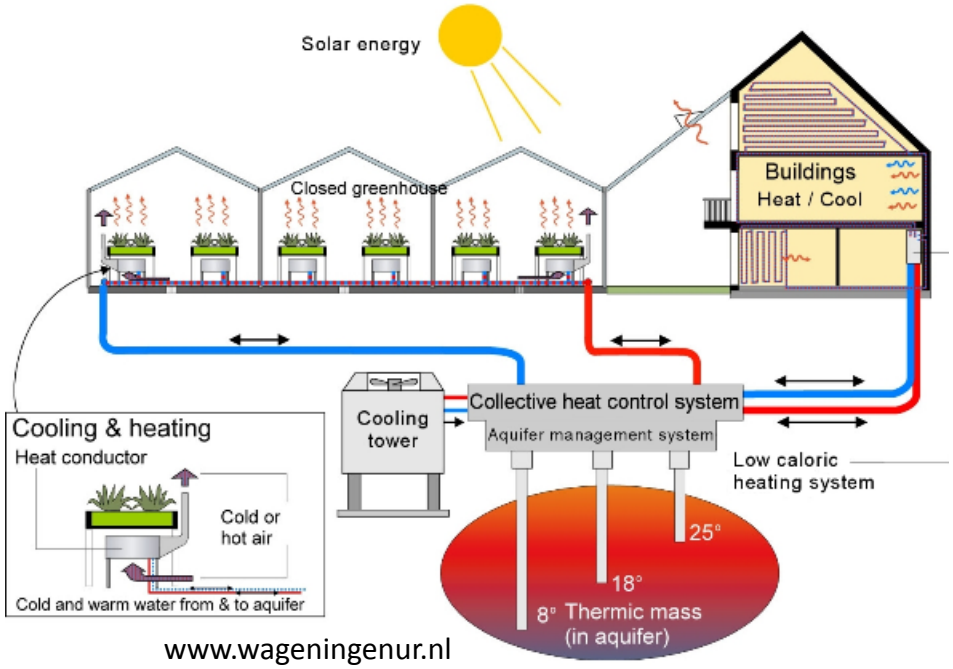
asparagus harvester

expo21xx.com

Top technologies available - protected cultivation

Growers get a close look at Rijk Zwaan Demo Facility for suitable tomato (Kwintsheul, NL)

Automatic tomato harvesting robot

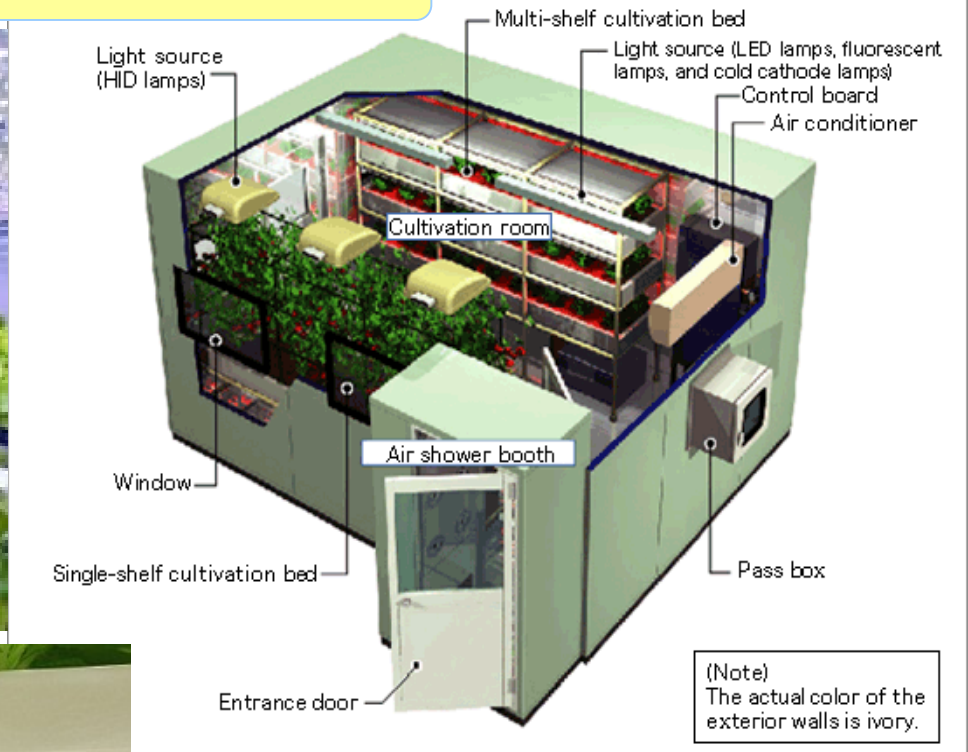


www.wageningenur.nl

The closed greenhouse concept

Greenhouse "Watergy

Top technologies available – plant factories



Top quality available

About Honeytomatoes®

HONINGtomaten®
de zoete verleiding

Honeytomatoes® are thé tastiest tomatoes on the market right now. Consumer tests consistently confirm this. Their velvety smooth, honey-sweet flavour is mouth-wateringly delicious. Once you've tasted Honeytomatoes® you'll never want any others!

Honeytomatoes® are perfect for nibbling on between meals, as an appetizer or as a healthy snack. For adults and children alike! Our Honeytomatoes® have inspired chefs who have come up with some delicious new recipes for Honeytomatoes®.

Want to try Honeytomatoes® for yourself? Then click on 'Where to buy' to find a Honeytomato® stockist near you.

Ecological sound

Making electricity from tomato waste

Making biogas from horticultural waste

tomato crop green waste (<60 t·ha^{-1}) turning to biochar

Dunlop et al. 2015. HortScience 50, 1572-1581.

Solid board made from tomato plants

e.g. Tomato Inspiration Awards

TOMATO INSPIRATION EVENT

2016

- A tomato farm 20 (5) ha controlled greenhouses
- on an open salt flat using a desalination plant
- a leader in the use of renewable energy: a solar field with a 115 m tower and > 23,000 mirrors reflecting the sun's energy
- natural pest management
- 17,000 t of tomatoes annually (85 kg/m^2)

Production problems seem to be solved

Problems left – for science ?

Zukunftsstrategie Gartenbau

Abschlussbericht zum Zukunftskongress Gartenbau am 11./12. September 2013 in Berlin

Problems left – for science ?

Yes - they are !

www.bmel.d

Future strategies
Horticulture 2020
Report 2013 Berlin

- market chances
- bio production
- generations
- attitude of life
- creativity
- nature conservation
- family farms
- sustainability
- quality
- vitality
- cooperation
- tradition
- automatision
- ……

1.2 Bottlenecks to face

- **Diseases** and **abiotic stresses** **SOI**
  the microbiome, biocontrol, biostimulants…
- **Soil problems** (i.e. deficiencies, toxicities, salinity) **SOI**
- **Energy consumption and efficiency** **SOI**
- Production of **bioenergy** **SOI**
- Increase of relevant **climate gases**
  (i.e. CO_2, methane, N-oxides)
- Demands on the **environment** **SOI**
- Ban of **transgenic crops** in Europe
- Mixed **production systems** (e.g. aquaponics)
- Conventional vs. **organic growing**
- Organic vs. **novel production system** **Inv.L.**
  short marketing chain, agro-tourism…
- Consumer demands on **quality** (i.e. taste and health) **SOI**
- …..

1.2 Bottlenecks to face

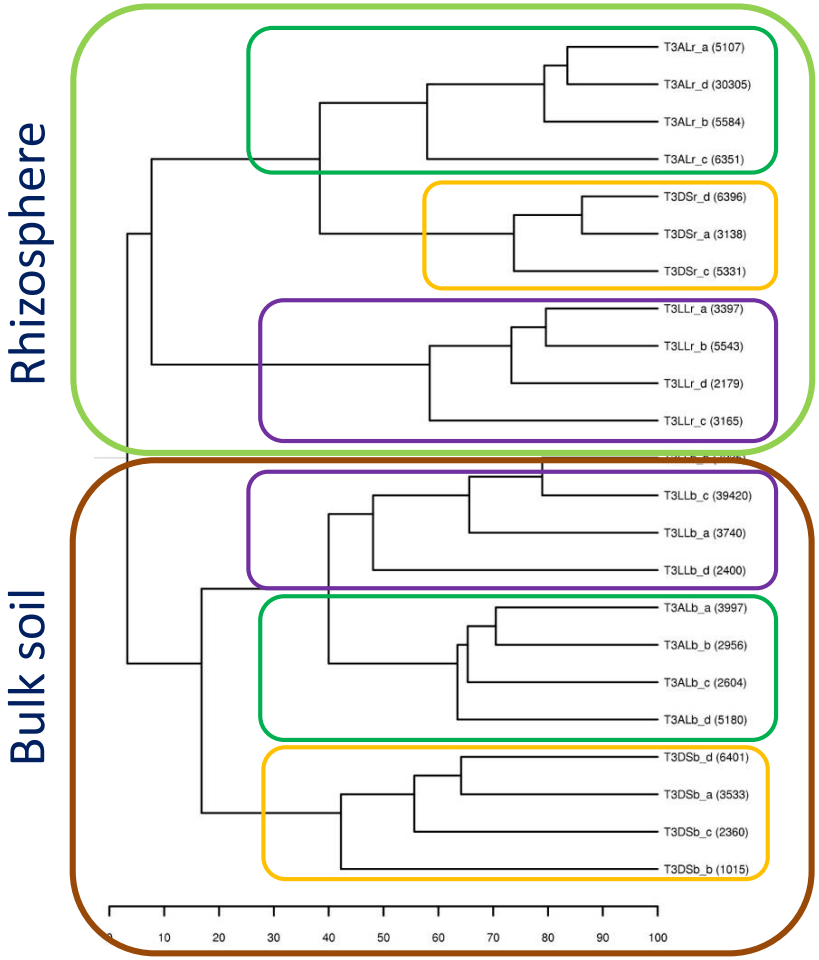
- Diseases and **abiotic stresses**
  microbiome, biocontrol, and biostimulants
- Soil problems (i.e. deficiencies, toxicities, salinity)
- **Energy consumption**
- Production of bioenergy
- Increase of relevant climate gases
  (i.e. CO_2, methane, N-oxides)
- **Consumer demands on the environment**
- **Ban of transgenic crops in Europe**
- Mixed production systems (e.g. aquaponics)
- Conventional vs. organic growing
- Organic vs. novel production system
- **Consumer demands on a healthy product**
- …..

Possible solutions:

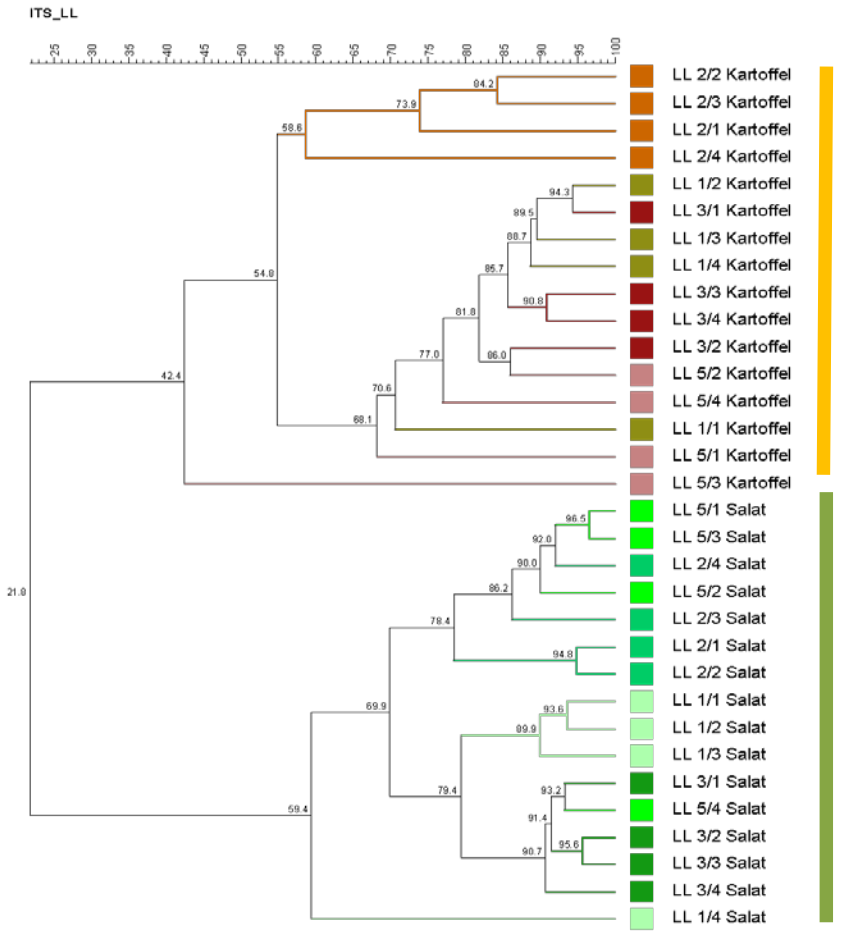
2 Environmental claims

2.1 The microbiome and biocontrol

Bacterial community in lettuce



Fungal community in the rhizosphere



Pyrosequencing (249,983 sequences)

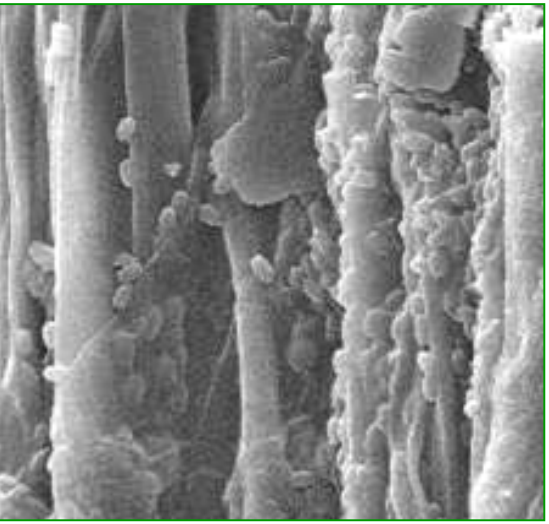
Microbial community affected

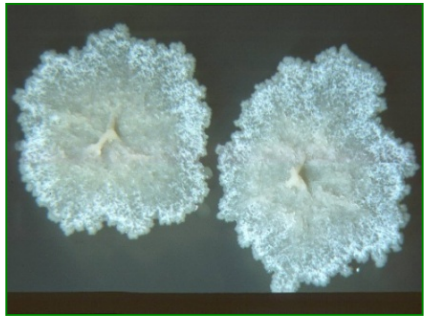
Average D-level	Plant	>	Soil type	>	Treatment
Bacteria	16.9		9.0		0.6
Fungi	42.0		4.1		-0.2

- Bacterial and fungal rhizosphere community structure were pronounced affected by the plant species.
- The bacterial community was significantly stronger influenced by the soil type than the fungal community.

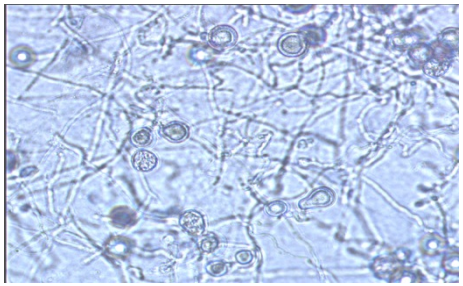
Plant associated micro-organism used in biocontrol

Disease suppression effects against different, particularly soil-borne pathogens were shown mainly by bacteria living in association with plants such as:





- *Bacillus amyloliquefaciens* FZB42
- *Serratia plymuthica* 3Re4-18
- *Pseudomonas jessenii* RU47
- *Kosakonia radicincitans*
- *Pririformospora indica*



2.2 Grafting

combines the advantages of two cultivars
alleviates or even counteracts the negative effects of (a)biotic stresses

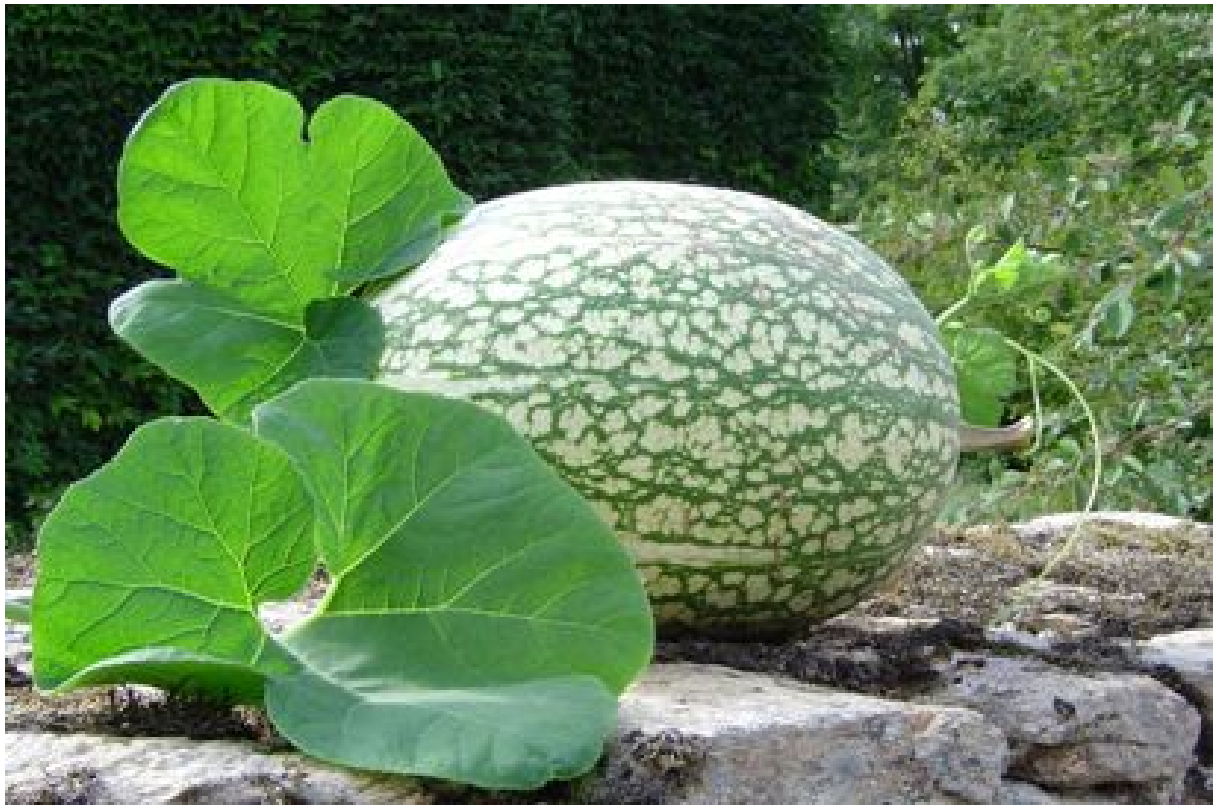
- reduce the incidence of soil borne diseases (Fusarium, Verticillium, etc.) alternative for chemical soil disinfection
- increase the vitality of plants
- save and enhance yield
- enhance tolerance against non-optimal conditions (temperature, salinity, etc.)
- improves taste and health related characteristics

Vegetable GRAFTING

cost
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

Grafting an advantage at low temperature

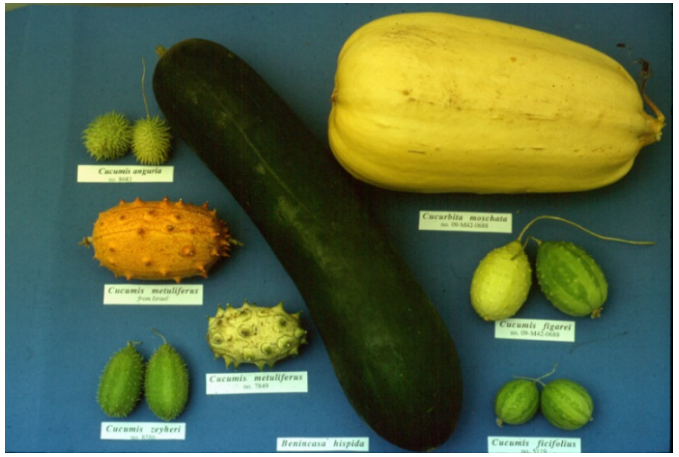
The tolerance is known for cucurbitaceae



<u>Figleaf gourd</u>
(*Cucurbita ficifolia*)

Bur cucumber
(*Sicos angulatus*)

Squash
(*Cucurbita moschata*)



Advantages at sub-optimal T:
- prolonged growing period
- early production

in protected cultivation:
- save fuel costs (7% per 1 °C)
- reduce CO_2- emission (100 t/ha)

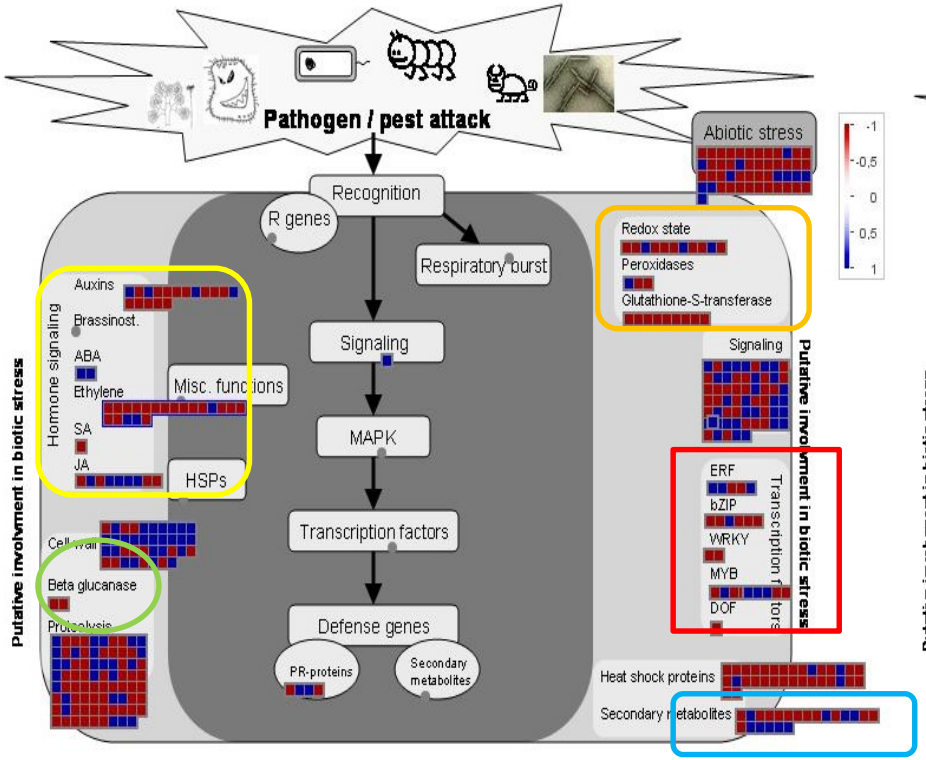
not clear and must be tested for solanaceae (tomato)

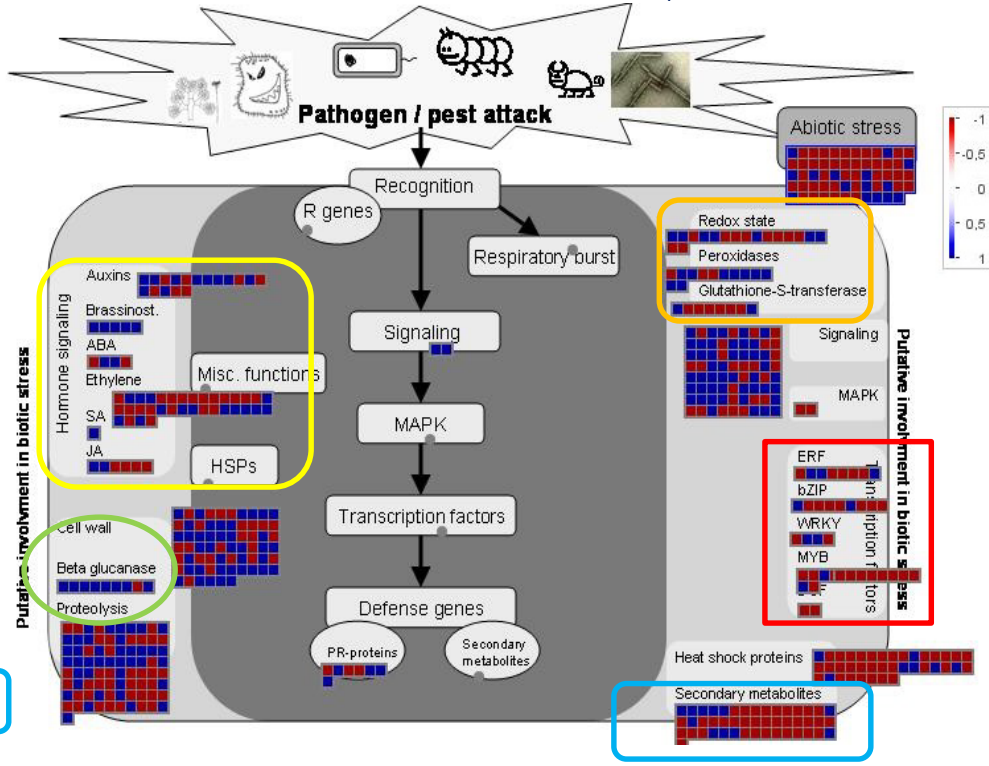
Untargeted approach

LA 1777- cold tolerant

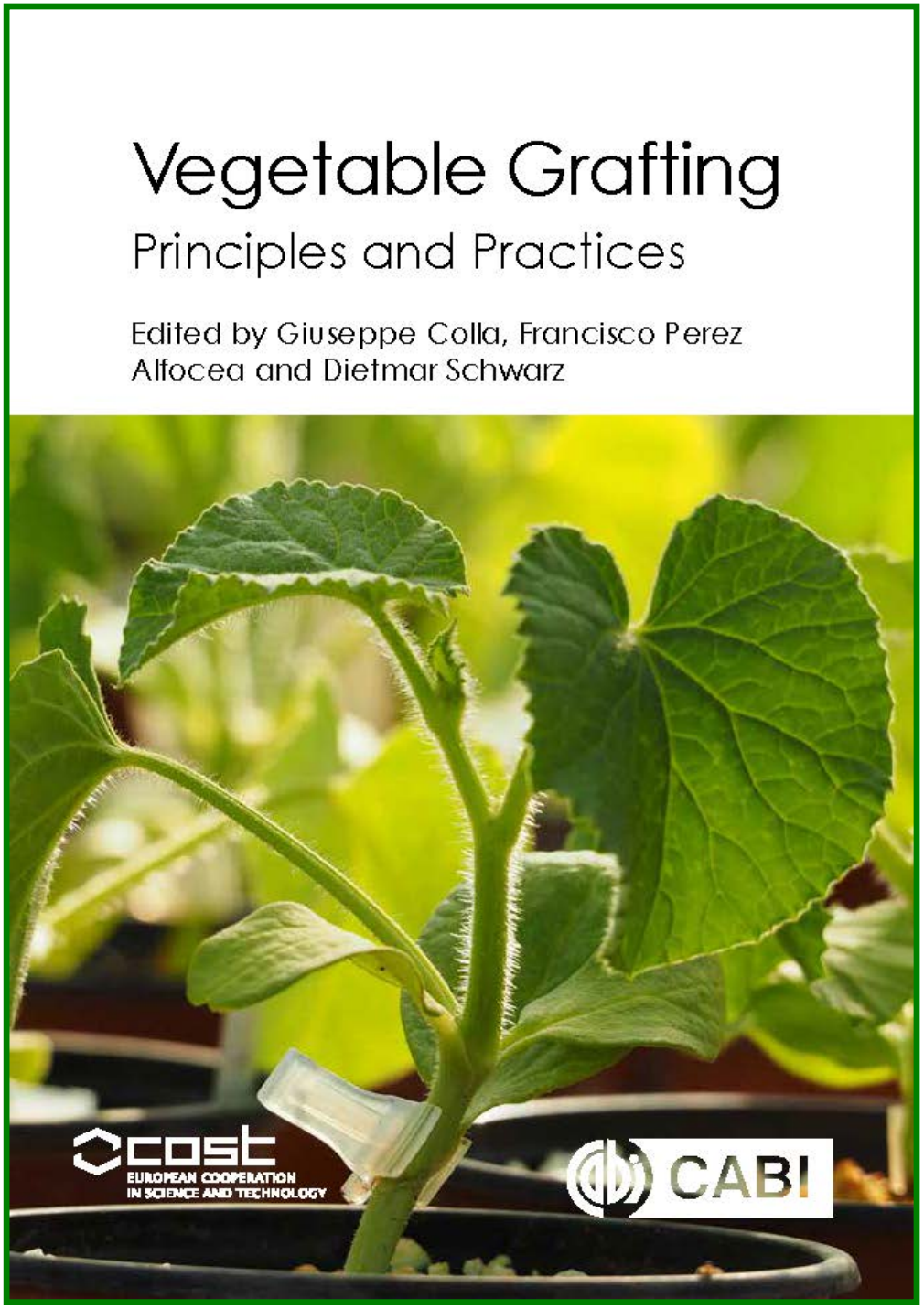
Moneymaker- cold sensitive

Ntatsi et al., 2014. Env. Exp. Bot .
Ntatsi et al., 2016. Frontiers.





Goal: Discover genes, processes related to sub-optimal temperature tolerance und mechanisms.



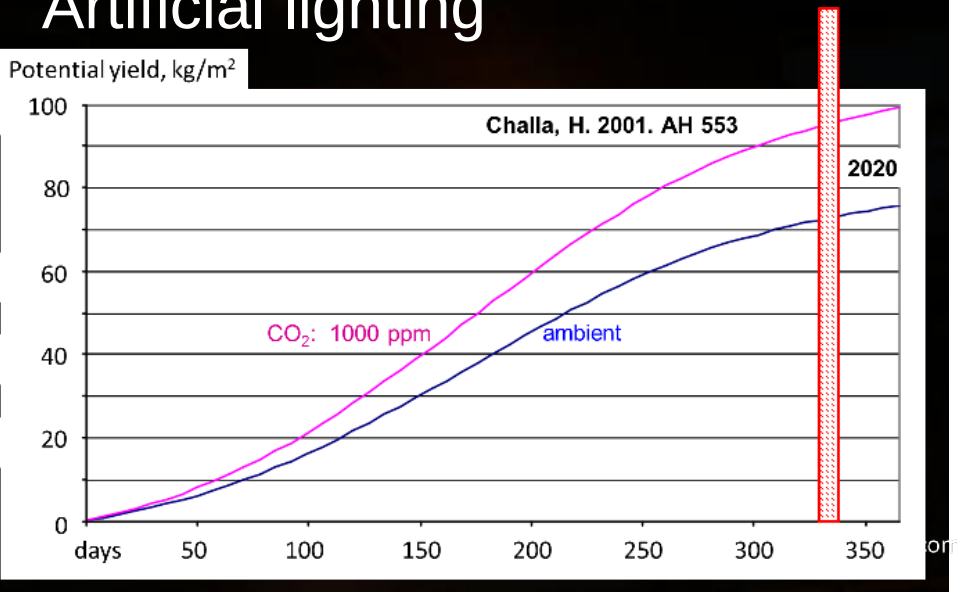
- publishing in January 2017
- hard copy
- about 300 pages
- price of about 110 € (85 £) per book
- open access in 2019

Content

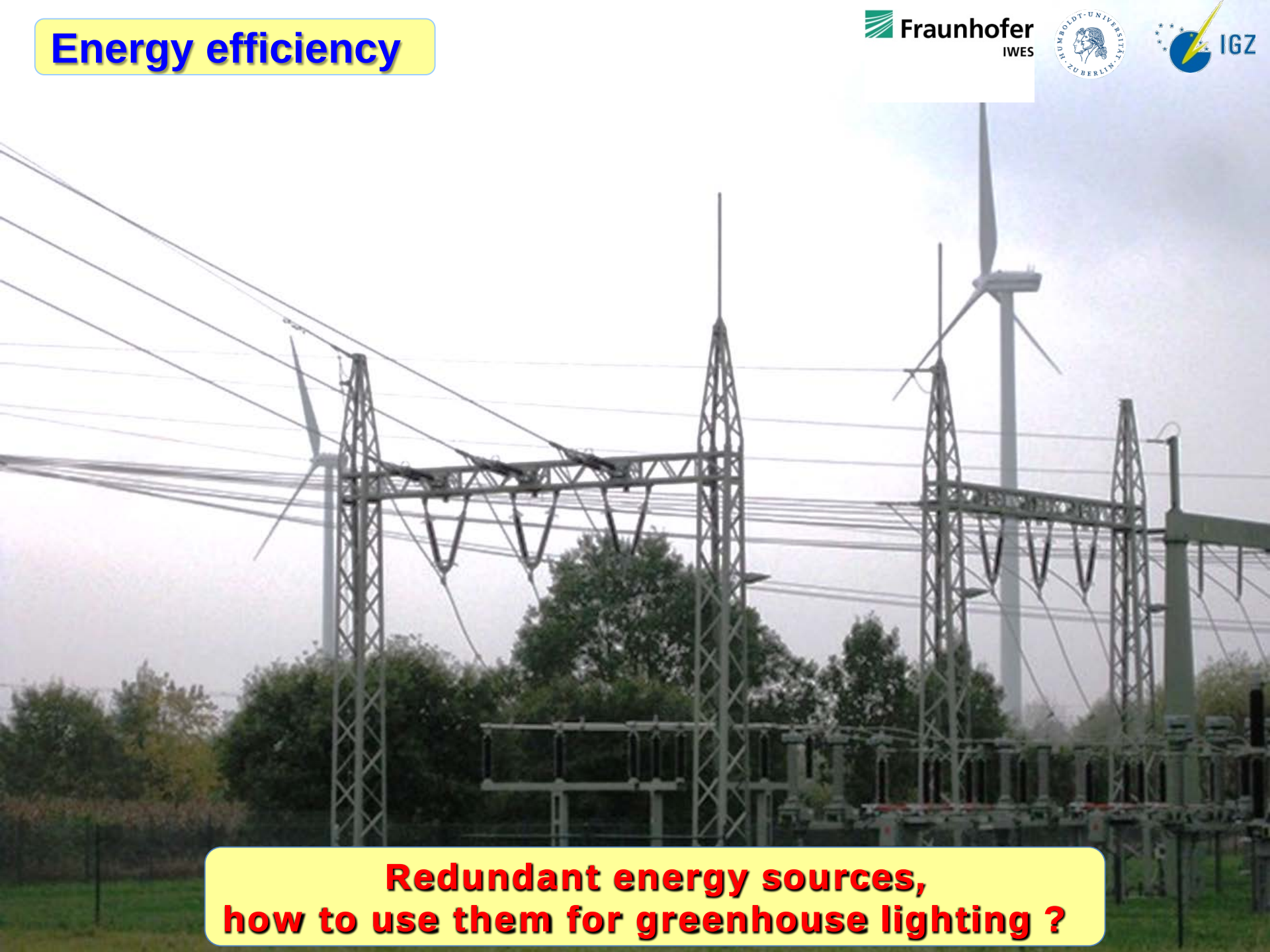
1. **Introduction to vegetable grafting**
   Zhilong Bie et al.
2. **Genetic resources for rootstock breeding**
   Maria Belen Pico et.al.
3. **Rootstock breeding: current practices and future technologies**
   Andrew J. Thompson et al.
4. **Rootstock-scion signalling: key factors mediating scion performance**
   Jan Henk Venema et al.
5. **Physiological and molecular mechanisms underlying graft compatibility**
   Ana Pina et al.
6. **Grafting as agro-technology for reducing diseases**
   Roni Cohen et al.
7. **Grafting as a tool to tolerate abiotic stress**
   Youssef Rouphael et al.
8. **Quality of grafted vegetables**
   Cherubino Leonardi et al.
9. **Practical applications and speciality crops**
   Amnon Koren et al.

2.3 Energy saving and less CO_2 release

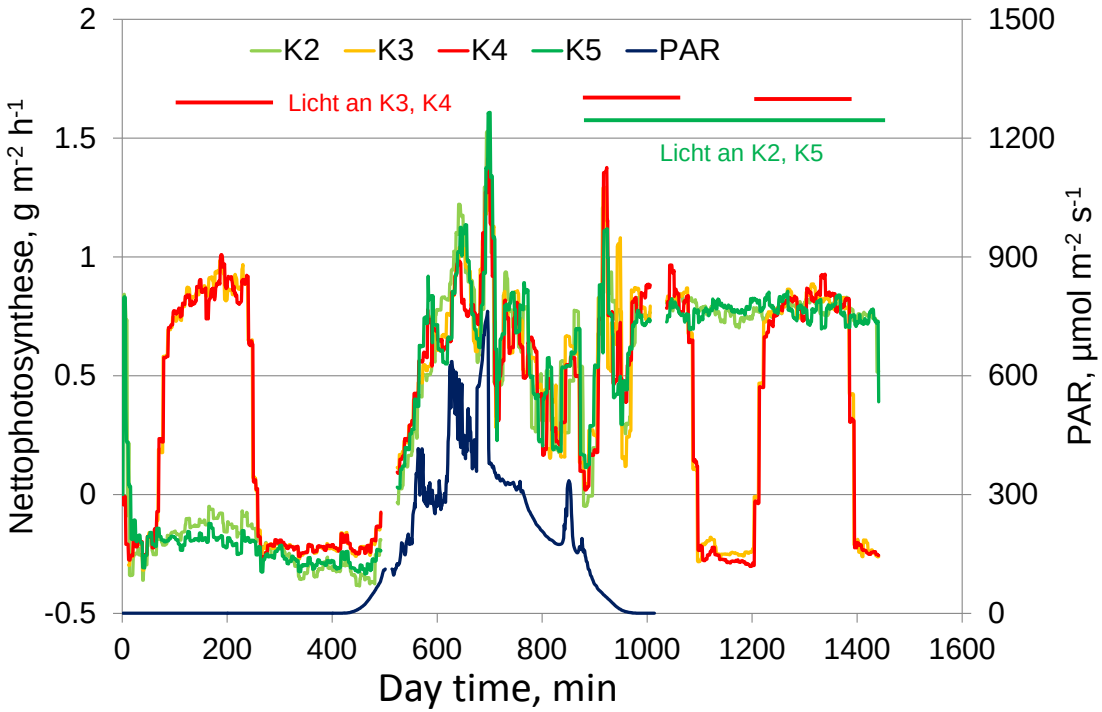
Artificial lighting



Energy efficiency



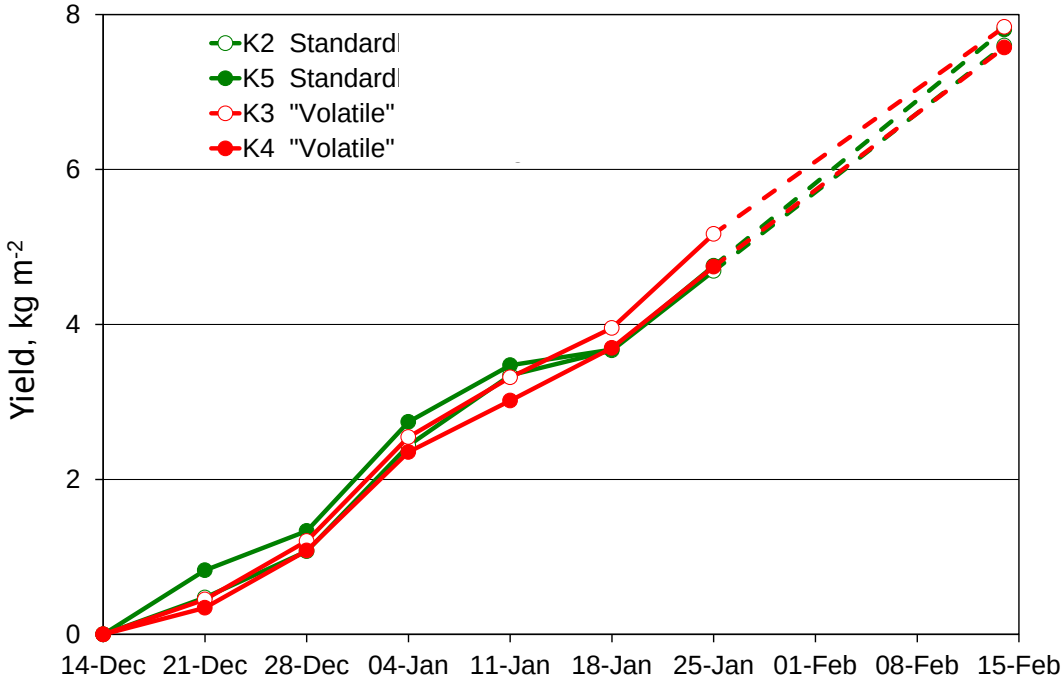
Redundant energy sources,
how to use them for greenhouse lighting ?



First results:

- photosynthesis responded with delay (< 10 min) - insignificant
- necessary dark period (6 h) - could be split
- split period of 9 h artificial lighting does not reduce yield

Volatile lighting seems possible, thus, energy surplus can be used !



2.4 Organic production


Alternative pepper grower (Westland, NL)


old fashion preparation of the soil
Demeter farm (Rotterdam, NL)

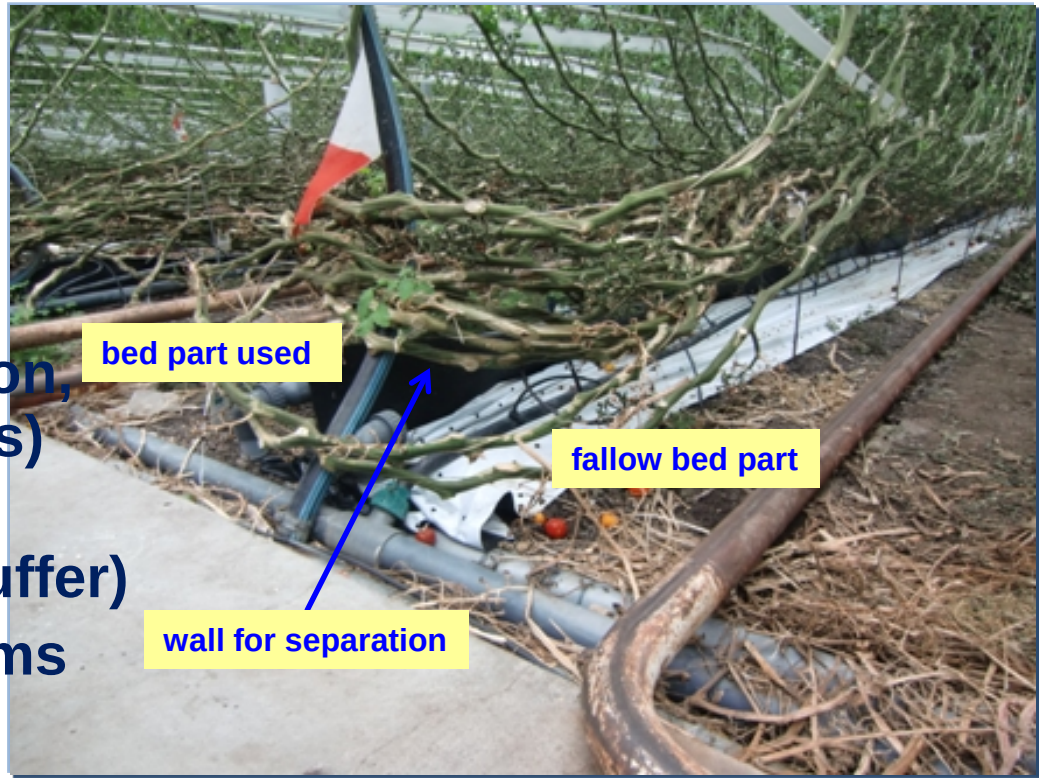
modern production with bioenergy unit
(Westland, NL)


Herb cultivation (Papenburg, GER)

Organic production

Bottlenecks:

- Fertilization bears potential constraints
- Risks are related to irrigation, climate (growing conditions)
- Particular excess of P supply (relation to soil buffer)
- High risk of salinity problems



Actions:

- Synchronized fertilization + “smart” side-dressing
- Smart irrigation (synchronized with evapo-transpiration)
- Compost supply with organic certification
- Variety of “plant” source fertilizers (low in Na, Cl, SO_4)
- Application of biostimulants
- Application of “new” cultural practises

Alternatives – e.g. urban farming

Concept A. attract people to come to the plants

www.ecf-farmsystems.com

Concept B. take the plants to the consumer

www.infarm.de

3 Consumer claims

3.1 Quality issues

Cibus Tec.

How the vegetable consumption is changing.

Production, processing, distribution industries show their ansv

Vegetable consumption is evolving:

healthy and ethical trends push the consumption in different ways.

Nowadays a difficult challenge is to meet both retailers' and consumers' needs. This is surely a way to grow motivations to make better and better.

Quality definition

Outer appearance

- colour
- size, shape
- disorders
- decay

Texture

- dry matter
- firmness
- rind thickness

Undesired compounds

- pesticides
- heavy metals
- aroma volatiles
- **allergens**
- **….**

Sensory properties

55 attributes,

- mouthfeel.
- aftertaste
- …

Health-promoting compounds (nutraceutical)

- minerals
- vitamins (ascorbic acid)
- antioxidants
- carotenoids
- flavonoids
- polyphenols
- ….

Flavour compounds (organoleptic)

taste {
- titratable acids
- sugars
- aroma volatiles

3.2 Healthy product vs. allergenic potential

Example tomato allergies

widespread allergy in Europe, more in south EU
Northern Europe: 1.5 %; Italy: 16 %

pollen associated
sensitization to different pollen
reaction to different allergens in the same fruit

e.g. in Italy: heat stable protein LTP (= Lyc e3)
reaction also to cooked tomato

Plant food allergens

- rather small proteins
- often resistant to proteolysis
- sometimes heat resistant
- small amount of protein families:

IGZ
CHARITÉ
Fraunhofer IAP
Proteome Factory

structural proteins:
Profilin, Lyc e 1
Lipid transfer protein, Lyc e 3
acidic ribosomal protein 60S
Expansin
Cyclophilin

PR/defense proteins:
TSI 1, Lyc e 4
Chitinase
Beta-1,3-Glucanase
Thaumatin-like protein NP24
cytosolic ascorbat Peroxidase
anionic Peroxidase
Hsc 70
Superoxid dismutase

developmentally regulated/ metabolism proteins:
Beta- Fructofuranosidase, Lyc e 2
Polygalacturonase 2A
Pectinesterase
Pectinmethylesterase
Mannosidase

seed storage proteins:
Vicilin
Miraculin
Legumin, 11S Globulin

Is it possible to reduce allergenic potential by cultivation ?
Can we develop hypo-allergenic tomato?
A suitable and simple test system for sensitive people.

Investigations on tomato allergenicity

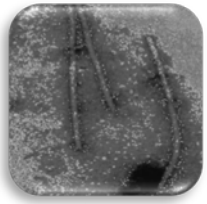
Objective: Is it possible to reduce the allergenic potential of vegetables using cultivation methods?

environmental conditions (light, N-nutrition, temperature) → no real effect

(Dölle *et al*. 2011)

Mycorrhiza → expression of genes

(Schwarz *et al.* 2010)



PepMV → expression of genes and defense proteins

(Welter et al. 2013, 2014)

cultivars →

(Dölle *et al.* 2011, 2012)

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Tomato cultivars

Objective: to discover a low allergenic cultivar

old landraces:

S. lycopersicum cv. Reisetomate LYC 1045/90

S. lycopersicum cv. Parvibaccatum LYC 457/02

selected for organic farming:

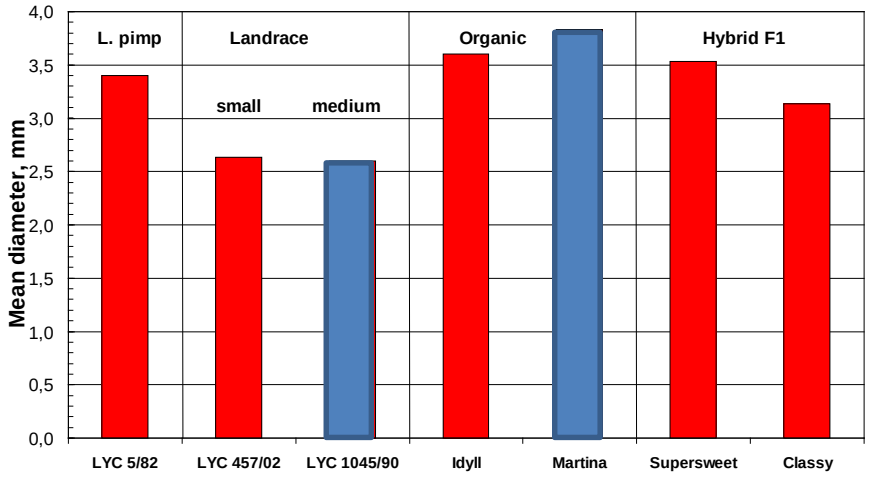
Matina

Idyll

modern hybrids:

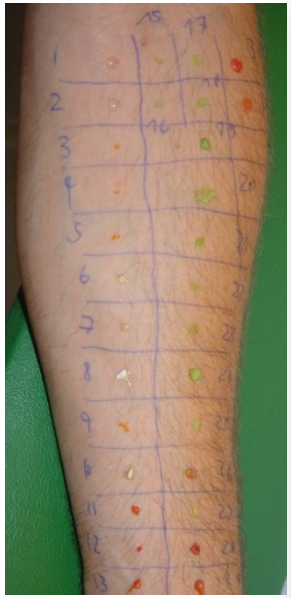
Supersweet (cherry type)

Classy (round type)

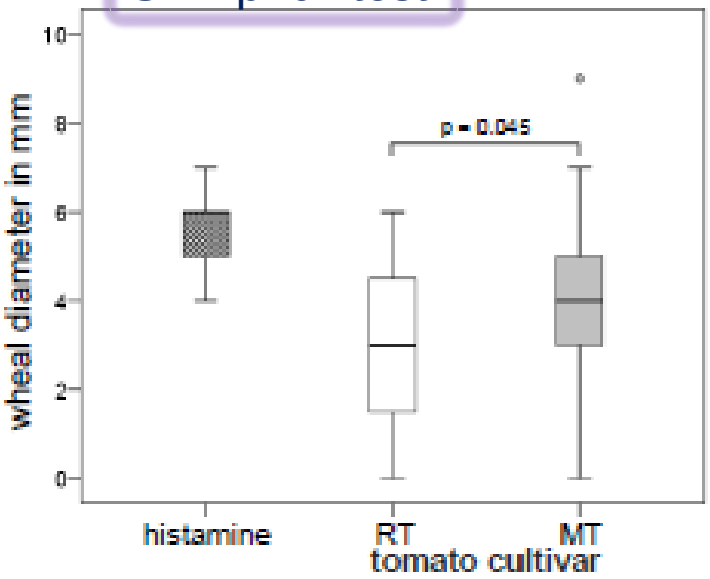


Highest difference in allergenic potential

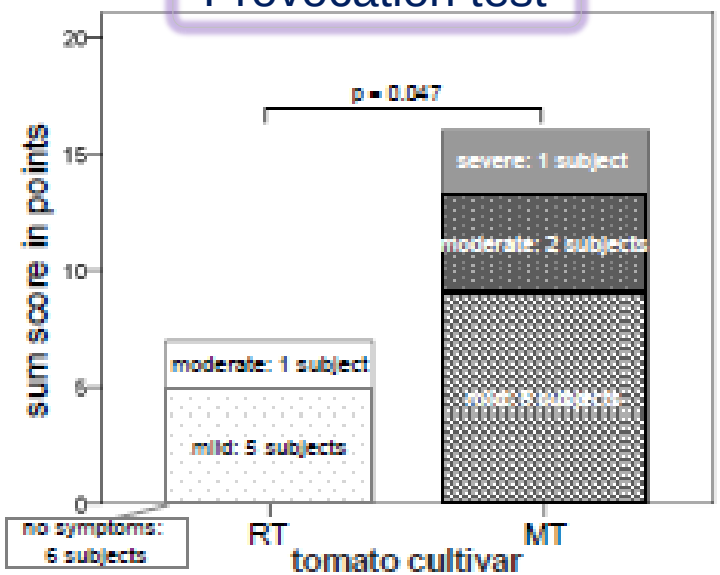
Tomato cultivars: ‘Reisetomate’ vs. ‘Matina’



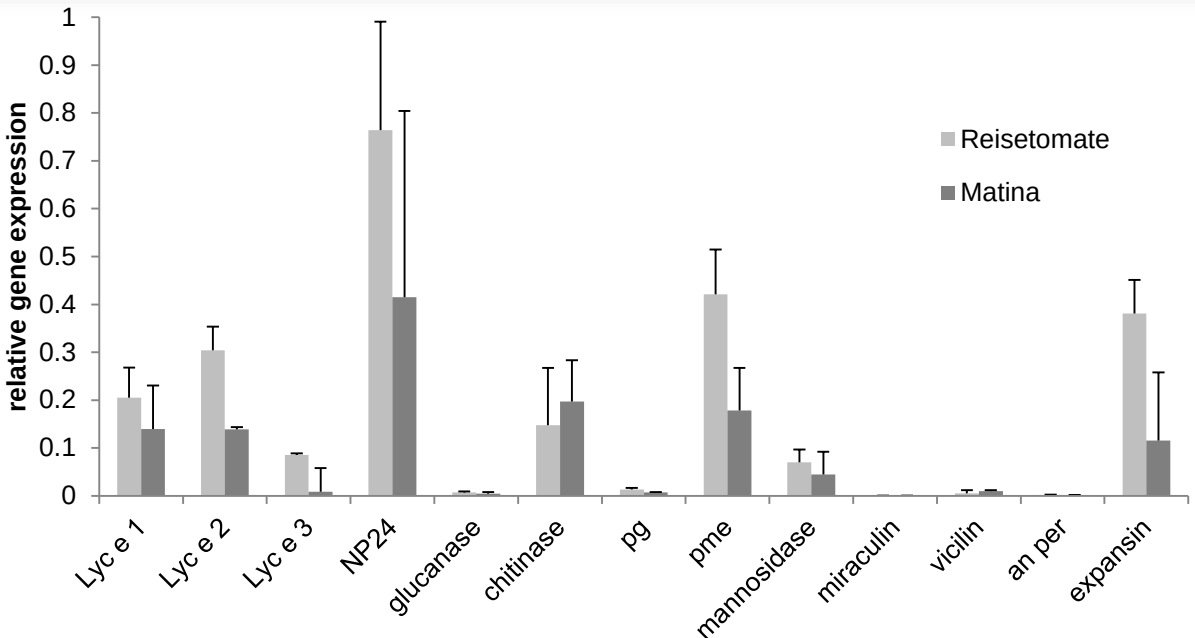
Skin prick test



Provocation test



RNA accumulation



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Proteome Factory

Tomato cultivars: ‘Reisetomato’ vs. ‘Matina’

What did we learn:

- Allergenicity of tomatoes differed significantly between experiments.
- Patient response differed: individual medicine ?
- RNA accumulation seems to be an indicator for tomato allergy.
- Available differences do not allow recommendation for a special cultivar.
- Discovered and verified novel allergens

Conclusions

1. **A hypo-allergenic tomato: difficult to find**
2. **Test-kit for patients: possible , basically developed**
3. **Reduced allergenicity: not really successful**

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3.3 Transgenic plants

Question: Can we sustain (in Europe) the ban of non GMO's (transgenic plants) from cultivation? (How long ?)
What about the introduction of new technologies (e.g. CRISP-CAS9)

Scientist Yvonne Lorenz gets Max Rubner-Preis:
„**Skin prick test reveals stable and heritable reduction of allergenic potency of gene silenced tomato fruits**" .

- blocked the translation of the LTP Lyc e3 initiating allergy, by RNAi-technology („gene silencing")
- New tomato could be confirmed as less allergenic also in the second generation:
  reduced basophil-histamin release
  significant lower skin pricks of allegic patients

???

Conclusions - SOI 2016

- Dedicated growers proof a successful (protected) cultivation awarded by society, science and consumers.
- Worldwide production levels and protection of the environment are very diverse.
- Thus, sustainability in horticultural production can be significantly improved by using the available knowledge.
- Cost benefit balances on the conflicting demands are needed: i.e. enhanced synchronization of demands.
- Consumer demands for a tasteful product are part of breeding programs of many companies but what about health related traits?
- Problems left are hardly solvable with conventional approaches. Use of new tools and technologies are under discussion and have to attract notice.


mille gracie per l’attenzione !
questiones ?