USDA SCRI FUNDING# 2011-01397

Grafting Heirloom Tomatoes

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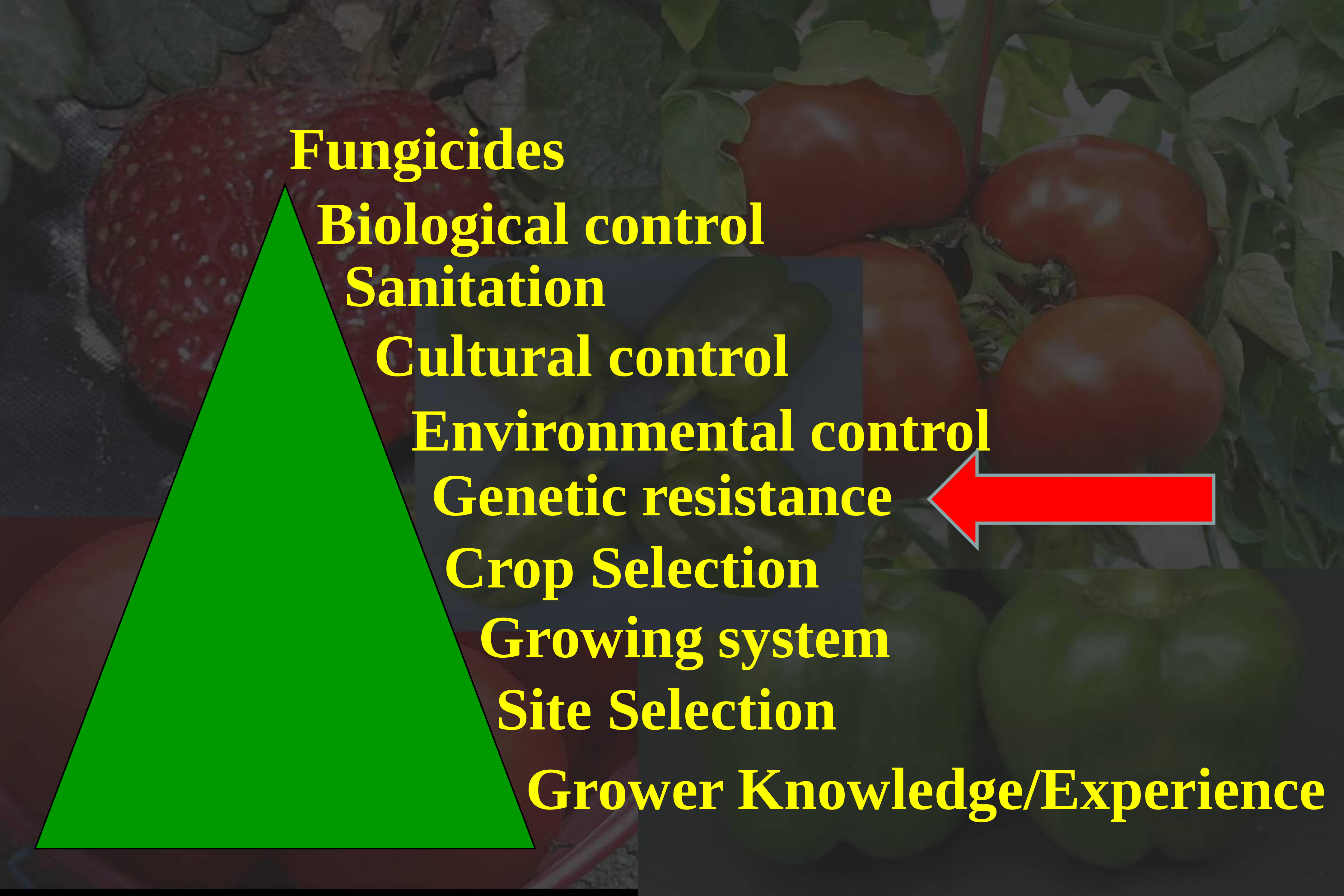
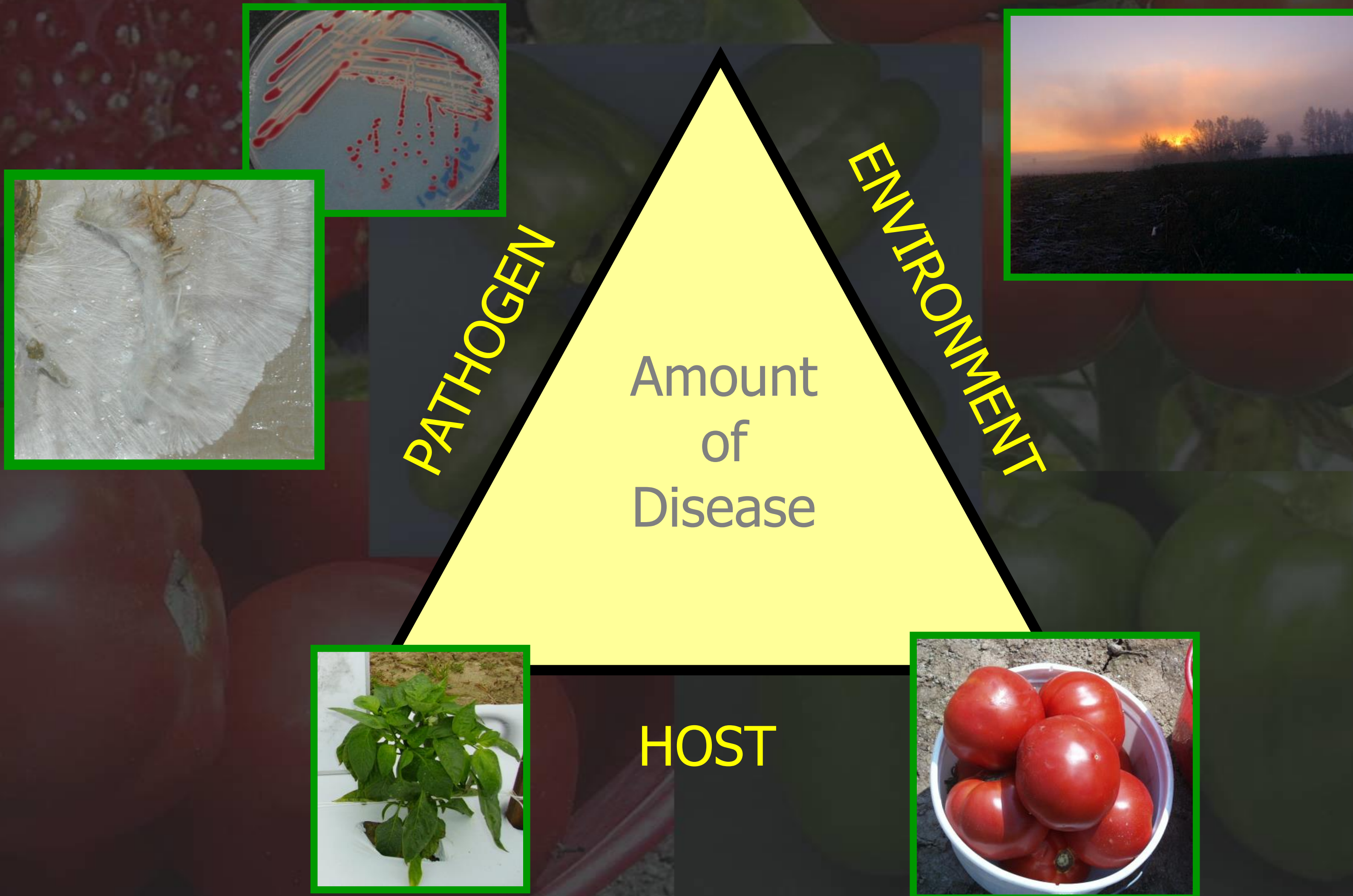

Fungicides
Biological control
Sanitation
Cultural control
Environmental control
Genetic resistance
Crop Selection
Growing system
Site Selection
Grower Knowledge/Experience

I A. Know Your Biology: The Disease Triangle



III DIAGNOSIS CAN BE DIFFICULT:

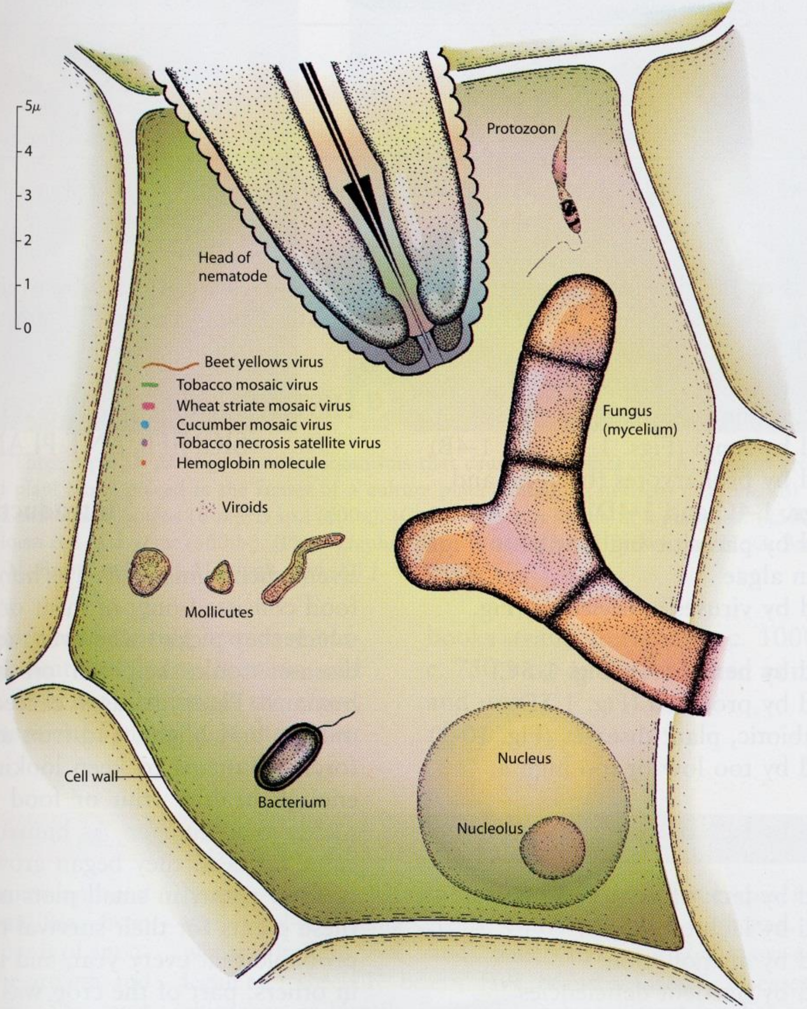


FIGURE 1-2 Schematic diagram of the shapes and sizes of certain plant pathogens in relation to a plant cell. Bacteria, mollicutes, and protozoa are not found in nucleated living plant cells.

From: G.N. Agrios. 2005. Plant Pathology. 5th edition. Elsevier AP.

Production Opportunities:

Heirloom vegetables

More fruits and vegetables
newenglandvfc.org

High tunnel production
Urban agriculture and local foods

Organic production

Introduction and Background

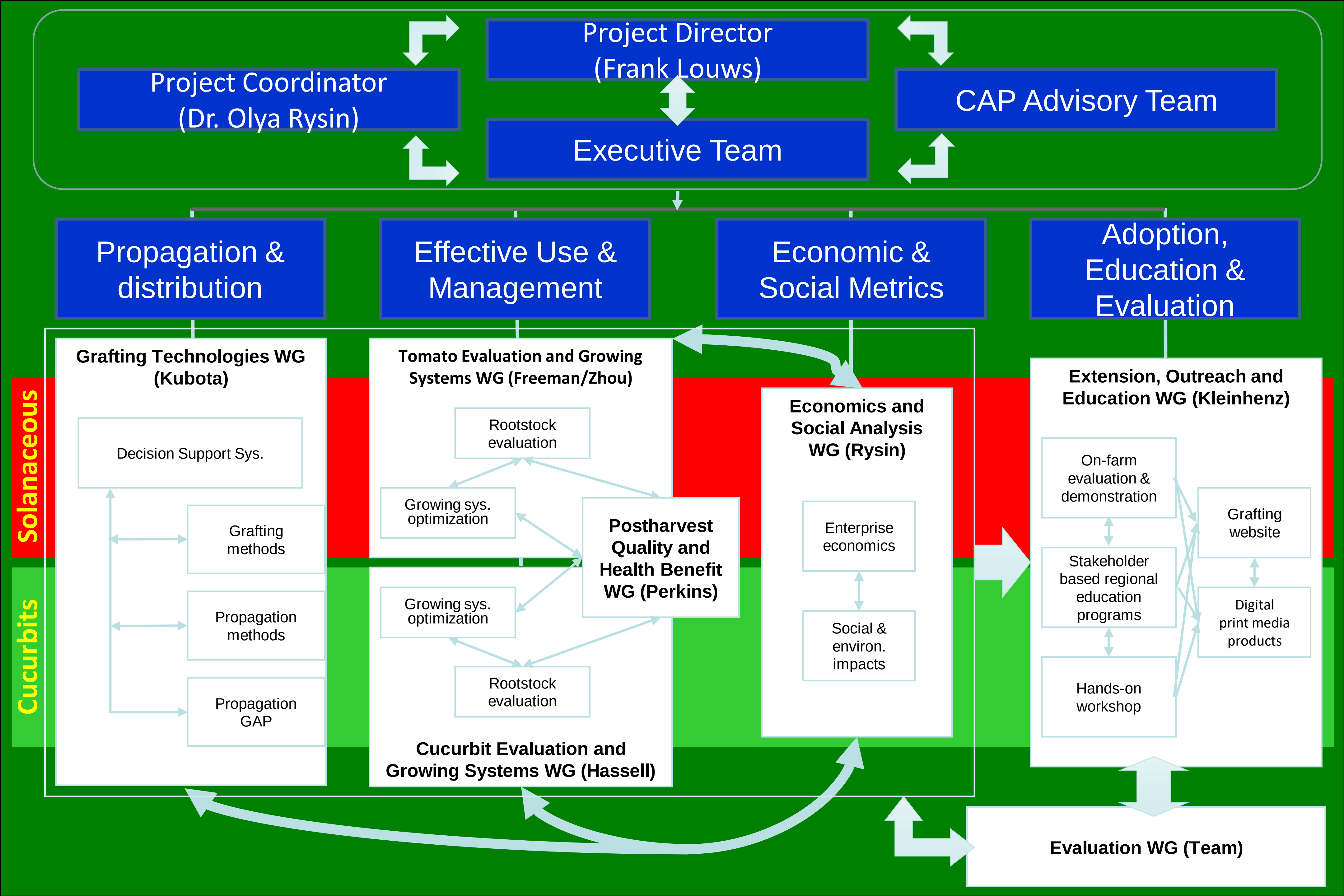
Production Limitations:

- biotic stress (diseases)
- abiotic stress (drought, salt, temperature)

- efficient use of water, nutrients, and land resources; decreased environmental impact

Factors that have led to the increased need to manage soilborne pathogens:

- Intensification; less rotation; increased pathogen inoculum
- reliance on susceptible cultivars to meet specific market demands (e.g. heirlooms)
- global movement & local invasion of novel pathogens
- transition to organics and high tunnels practices
- needs-based practices for resource-limited farmers
- loss of soil fumigants e.g. methyl bromide (MeBr)

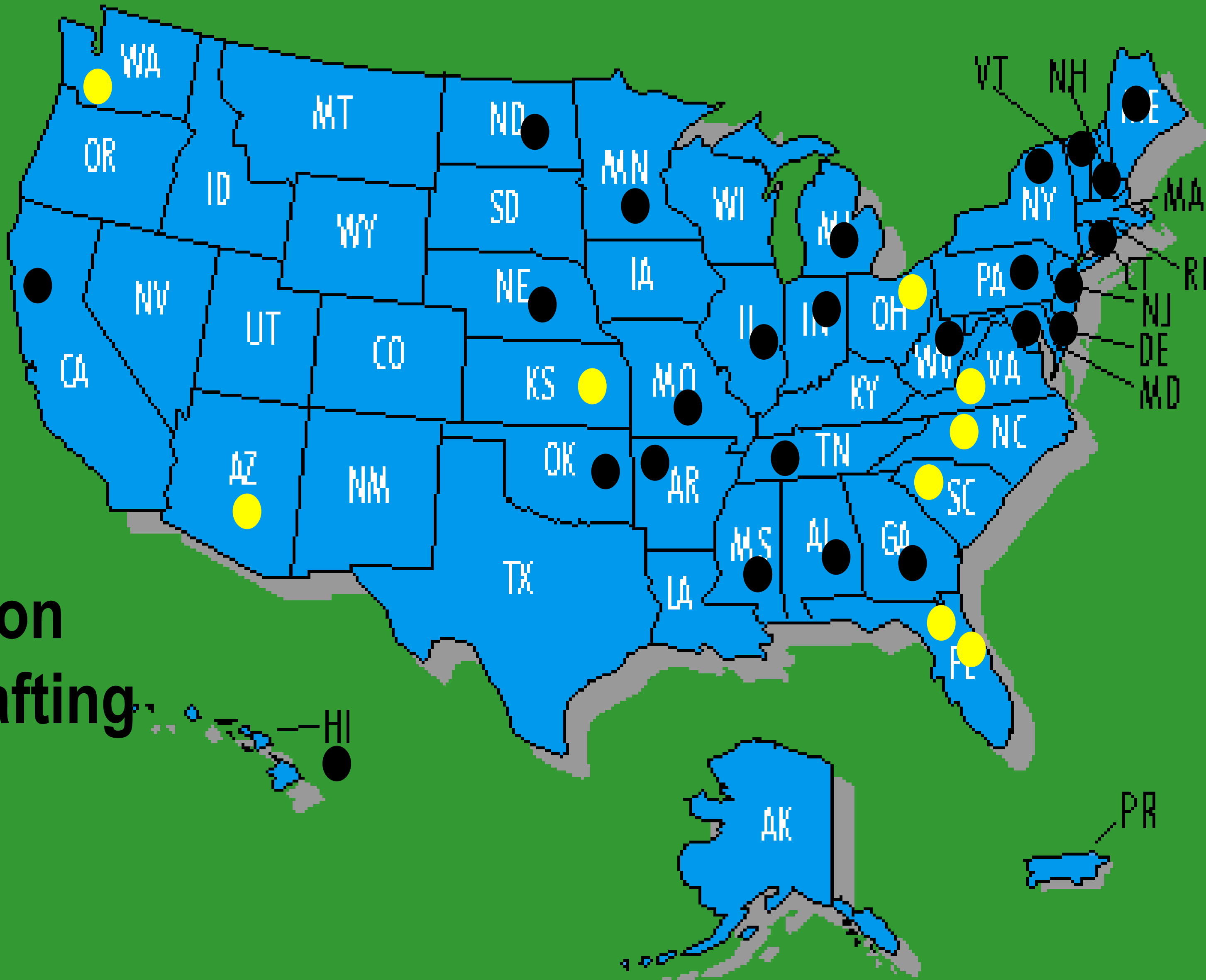

Project Director
(Frank Louws)
Project Coordinator
(Dr. Olya Rysin)
CAP Advisory Team
Executive Team
Propagation & distribution
Effective Use & Management
Economic & Social Metrics
Adoption, Education & Evaluation
Solanaceous
Cucurbits
Grafting Technologies WG (Kubota)
Decision Support Sys.
Grafting methods
Propagation methods
Propagation GAP
Tomato Evaluation and Growing Systems WG (Freeman/Zhou)
Rootstock evaluation
Growing sys. optimization
Postharvest Quality and Health Benefit WG (Perkins)
Growing sys. optimization
Rootstock evaluation
Cucurbit Evaluation and Growing Systems WG (Hassell)
Economics and Social Analysis WG (Rysin)
Enterprise economics
Social & environ. impacts
Extension, Outreach and Education WG (Kleinhenz)
On-farm evaluation & demonstration
Stakeholder based regional education programs
Hands-on workshop
Grafting website
Digital print media products
Evaluation WG (Team)

PROJECT GOAL: To amplify the ***productivity and profitability*** of U.S. fruiting vegetable enterprises by integrating grafting technologies as both sources of income and production tools.

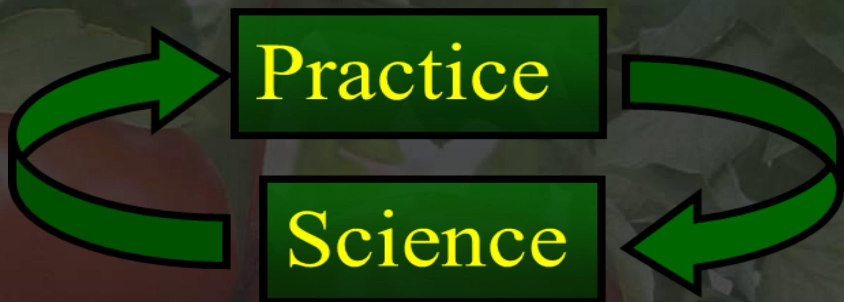
MECHANISM: Coordinated trans-disciplinary, stakeholder-based, and systems-oriented research, extension and education project that addressed all points on the grafting and crop production value chain.

Sites of U.S. Vegetable Grafting Research-Extension-Teaching Activity

- ● (yellow) **SCRI Team**
- ● (black) **other academic teams that have worked or now work on vegetable grafting**



USDA SCRI CONTACTS



Partners – (Third Party Match)

53 private partners representing the global diversity of the industry including:

- **Multiple farmers throughout the US (OFR)**
- **Grower Associations**
- **Automation/Robotics companies**
- **Seed companies (especially rootstock seeds)**
- **Propagators/transplant growers**
- **Consultants & other Stakeholders**

Expand or create profitable business opportunities

PRACTICE: Grafting of vegetable crops: Translating international knowledge and experience and adapting it to USA systems of production.

SCIENCE: Understanding the mechanisms –

- **population structure and dynamics of pathogens**
- **host genetics – QTL mapping**
- **plant physiology – cool storage**

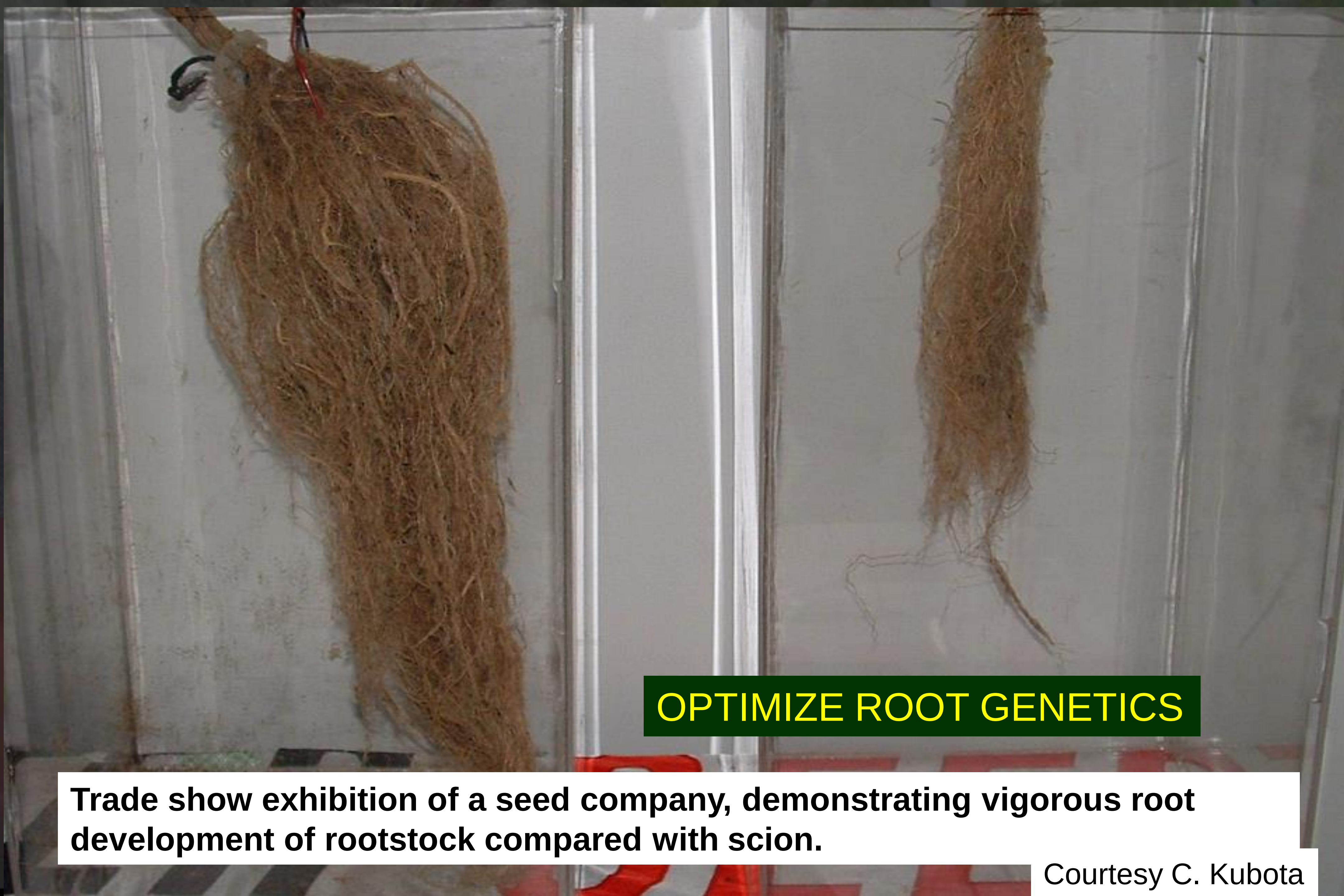
OUTCOMES HAVE: Direct and Indirect Benefits

The Practice can direct the Science and the Science can inform the Practice


AVRDC-The World Vegetable Center

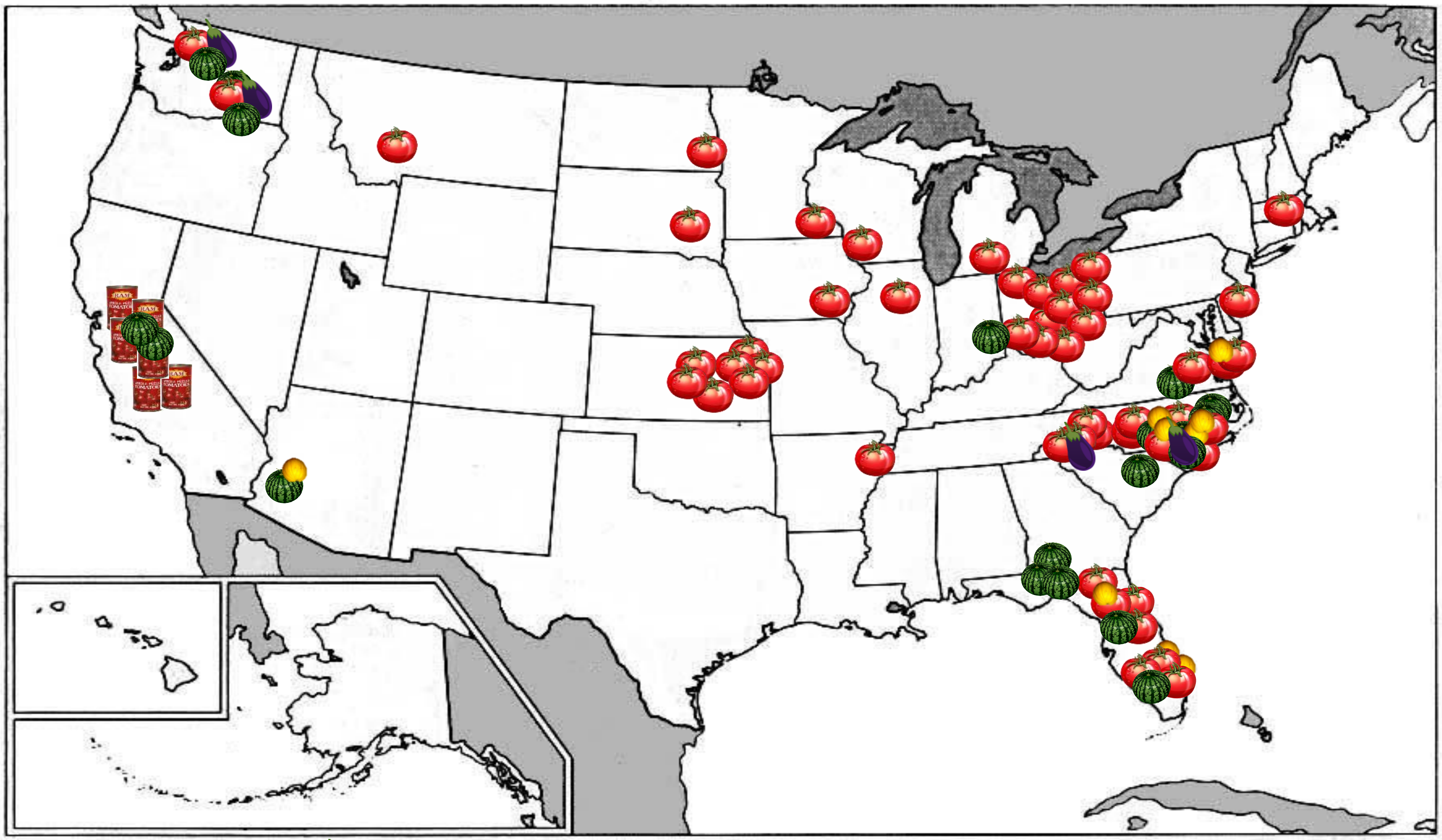
Tomatoes: Tactic Diversification

Grafting = RS x “YFT”



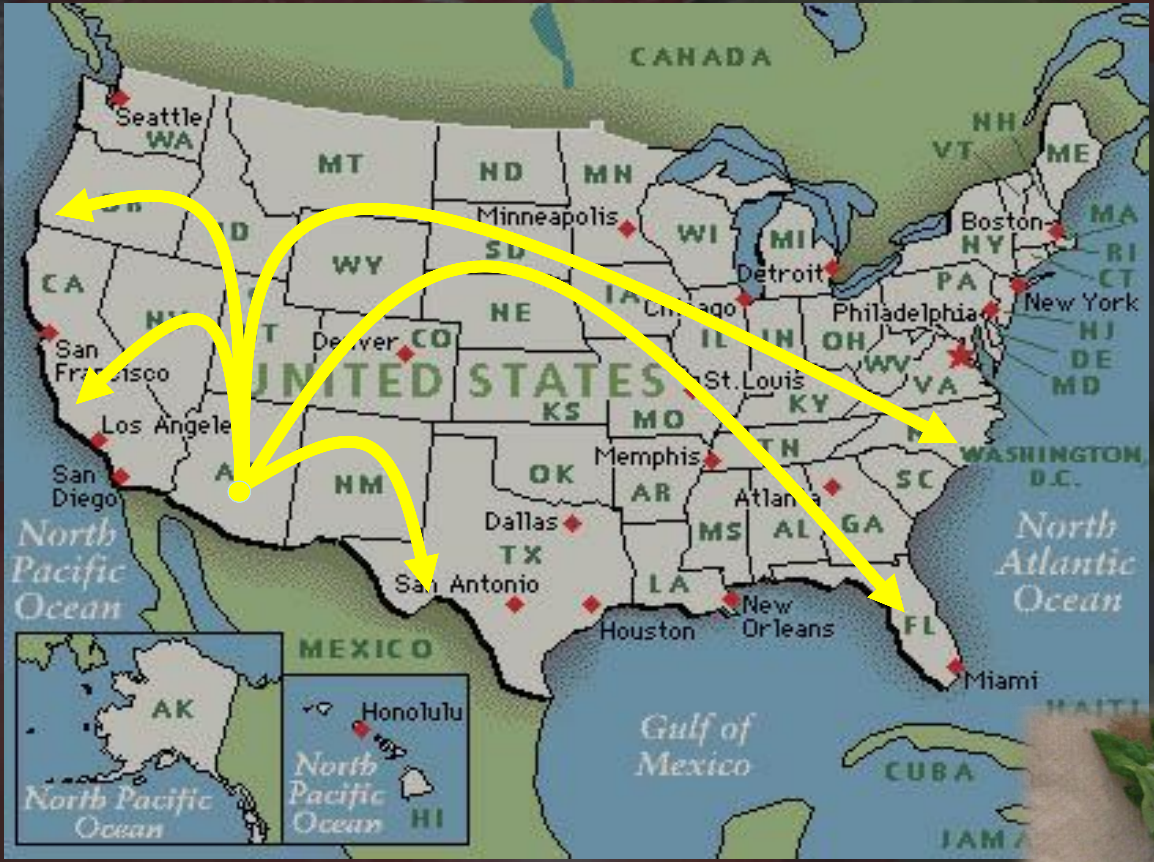
Trade show exhibition of a seed company, demonstrating vigorous root development of rootstock compared with scion.

Trial introduction of grafting to open-fields



Tomato (F) Eggplant Tomato (P) Watermelon Melon

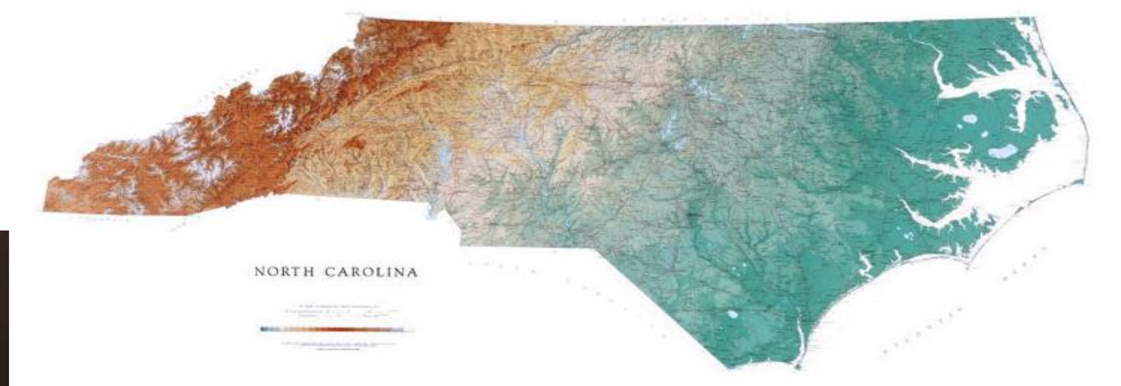
Use of Unrooted Grafted Vegetable Cuttings



PI: Chieri Kubota

Regional importance of various soilborne tomato pathogens in North Carolina

Pathogen	ECOLOGICAL ZONE			Graft Potential
	Coastal Plain	Piedmont	Mountains	
Verticillium dahliae race 1	----	*	***	****
Verticillium dahliae race 2	----	*	****	**
Fus. oxy. f.sp. *lycopersici race 0 or 1*	****	****	****	****
Fus. oxy. f.sp. *lycopersici race 2*	*	**	****	**
Ralstonia solanacearum (race 1)	****	***	*	****
Sclerotium rolfsii	****	**	----	***
Phytophthora capsici	***	***	***	*
Meloidogyne incognita	****	**	*	****



Louws et

On-farm trials

Alex Hitt
Peregrine Farm

Ken Dawson
Maple Spring Gardens

Stefan Hartmann
Black River Organic Farm

Practice

Science

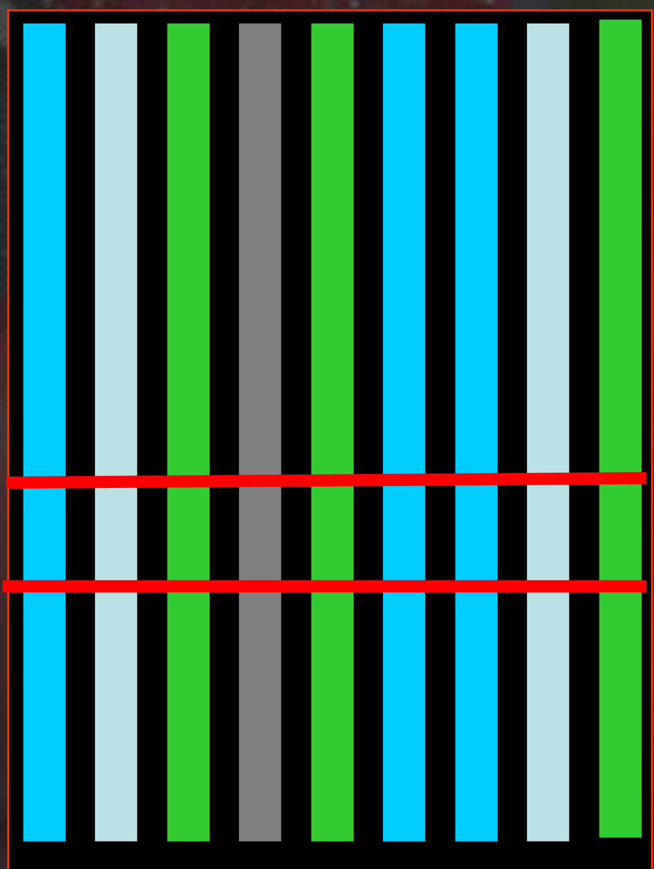
(Photos by Suzanne O'Connell, NCSU)

DOING AN ON-FARM RESEARCH

For example: 3 treatments

Planting different treatments….

randomize

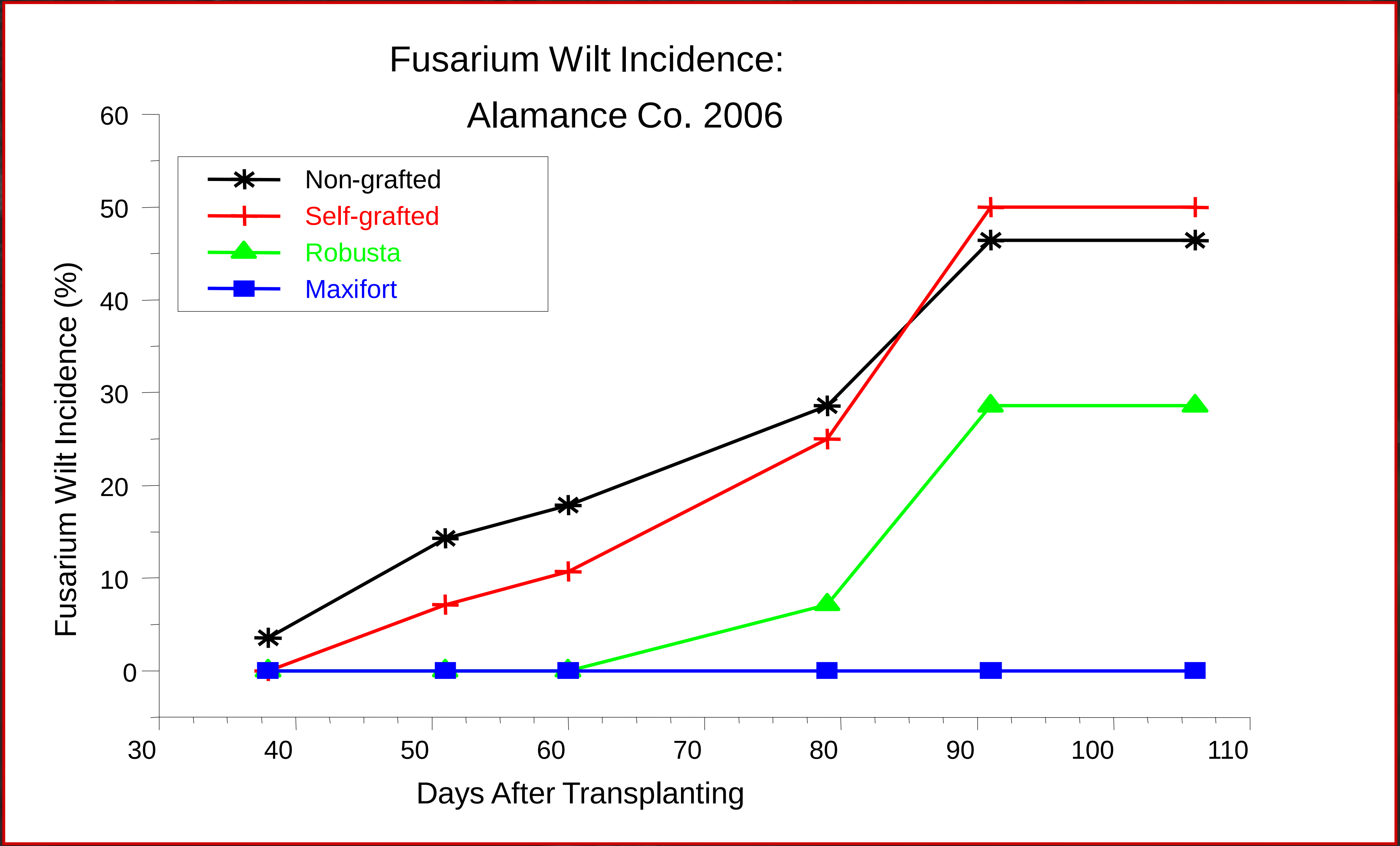


Harvest area

Low area?

- *Fusarium oxysporum* f. sp. *lycopersici*
  - Fusarium Wilt
  - Soil Inhabitant
  - Genetic Resistance

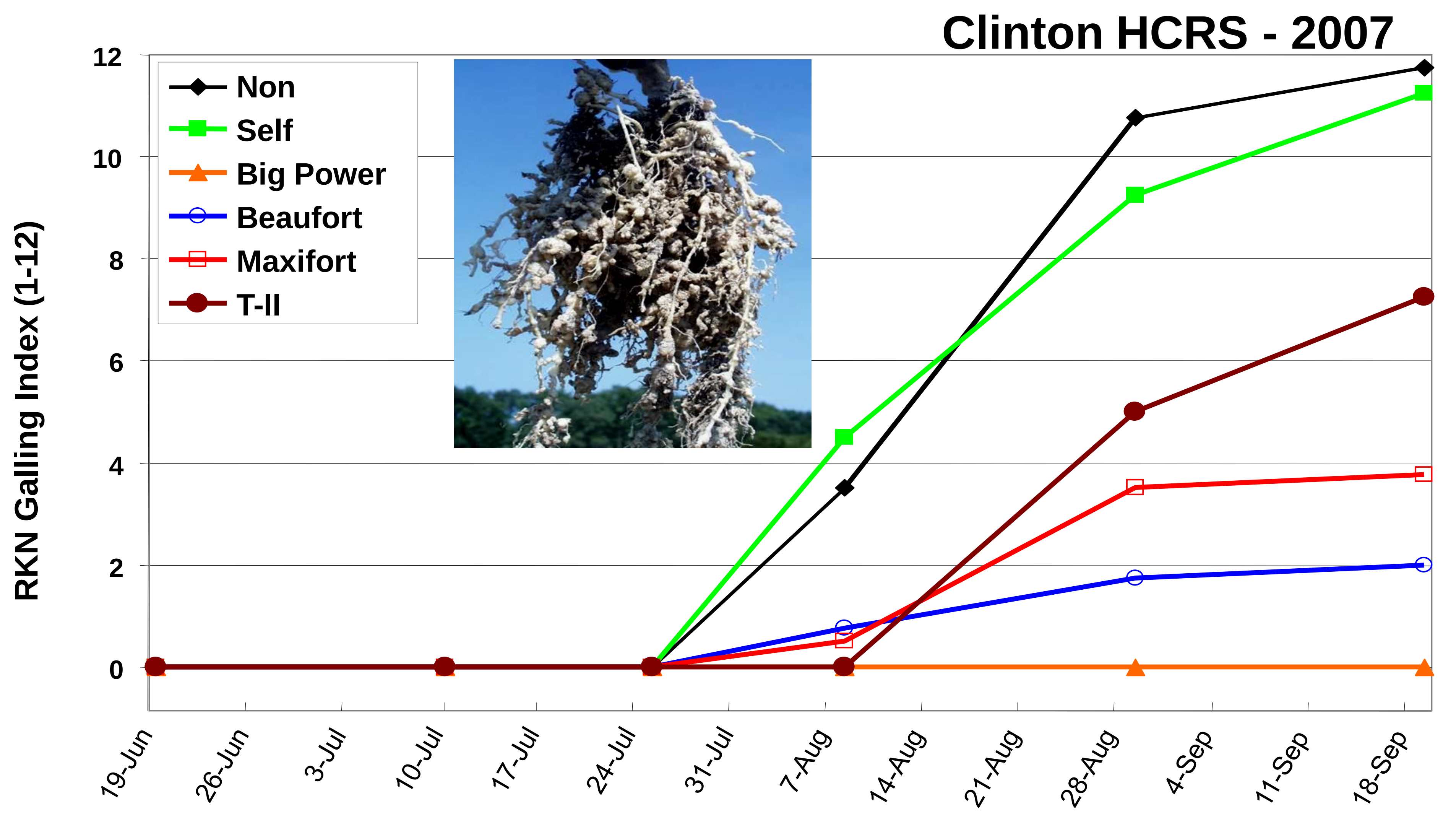
Results



Fusarium Wilt Incidence:
Alamance Co. 2006
Non-grafted
Self-grafted
Robusta
Maxifort
Fusarium Wilt Incidence (%)
0
10
20
30
40
50
60
30
40
50
60
70
80
90
100
110
Days After Transplanting

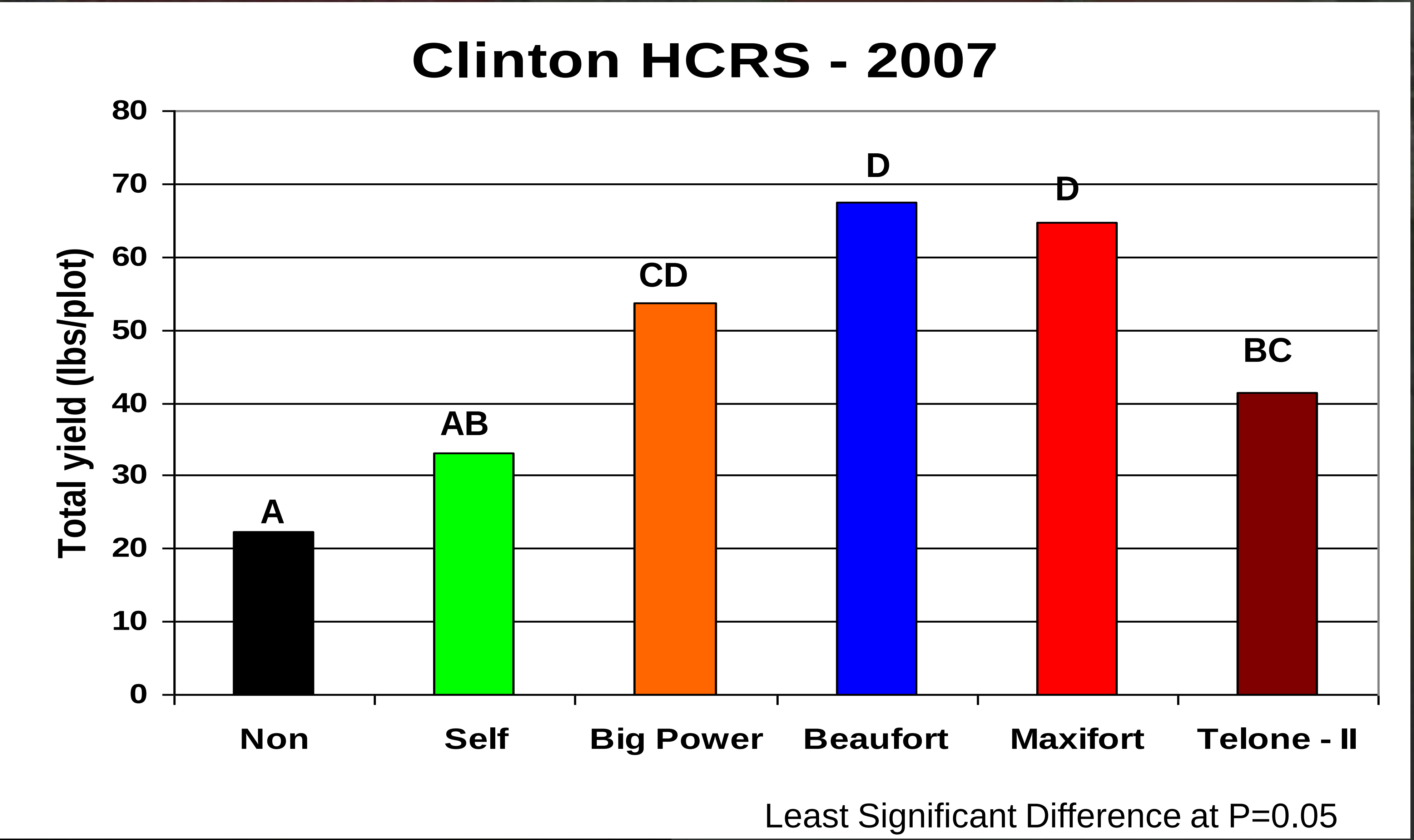
Root Knot Nematode

Meloidogyne incognita race 1



Root Knot Nematode

Meloidogyne incognita race 1



RKN Populations

Root-knot nematode soil populations / 500 cc soil		
	First Harvest	Terminal Harvest
Non-grafted	8357 D	1964 Y
Self-grafted	8751 D	1228 Y
Telone II	379 B	1260 Y
Big Power	77 A	40 Z
Beaufort	2680 C	2542 Y
Maxifort	3091 C	1251 Y

LSD based on P = 0.01

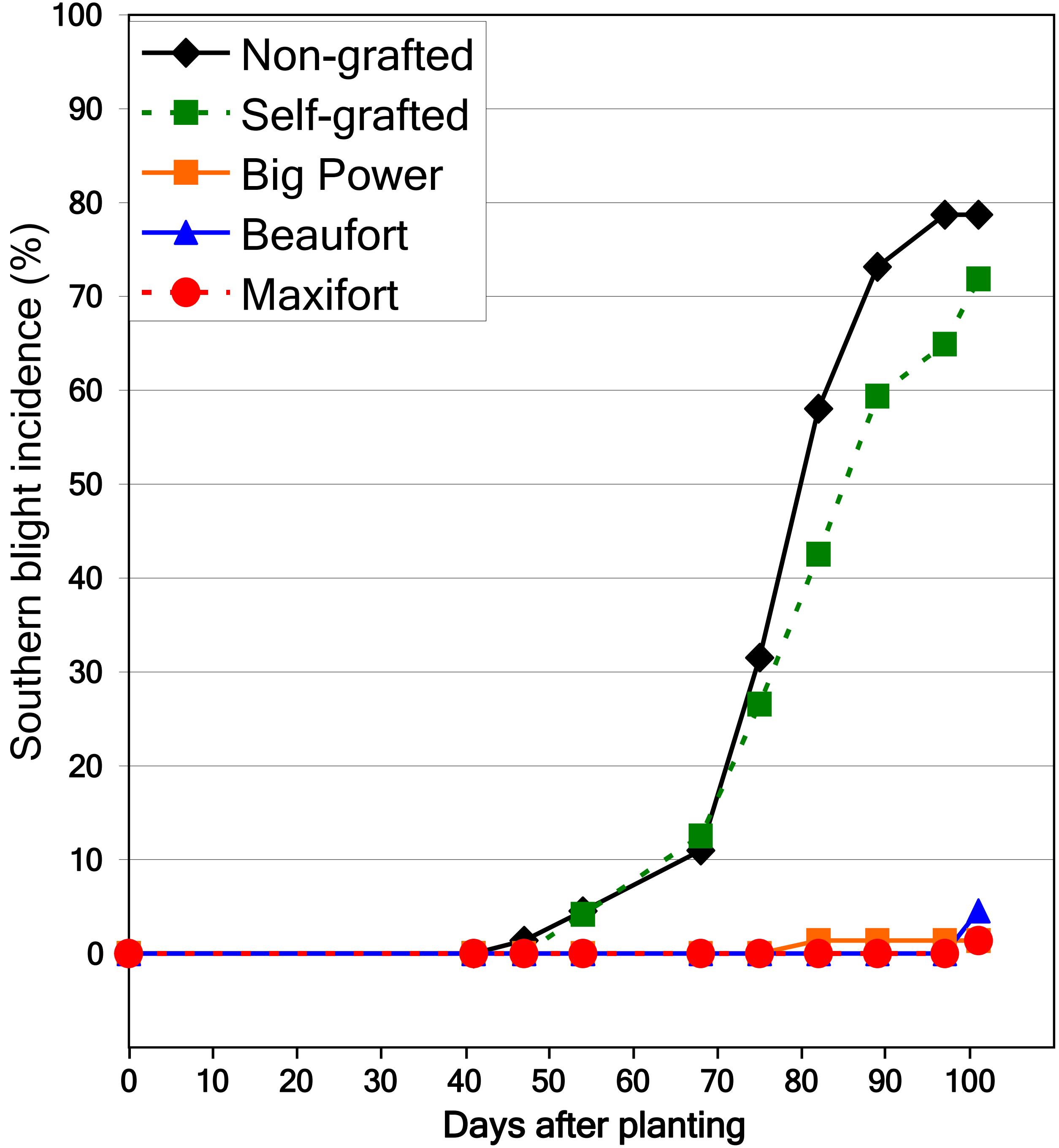
Mi gene reacted differentially: 'Big Power' rootstock appeared to confer complete resistance or was heat stable.

Southern Blight

Sclerotium rolfsii

- Wide host range
- Resistance in *L. pimpinellifolium*
  - (*Leeper, 1992*)

- No resistance in commercial cultivars

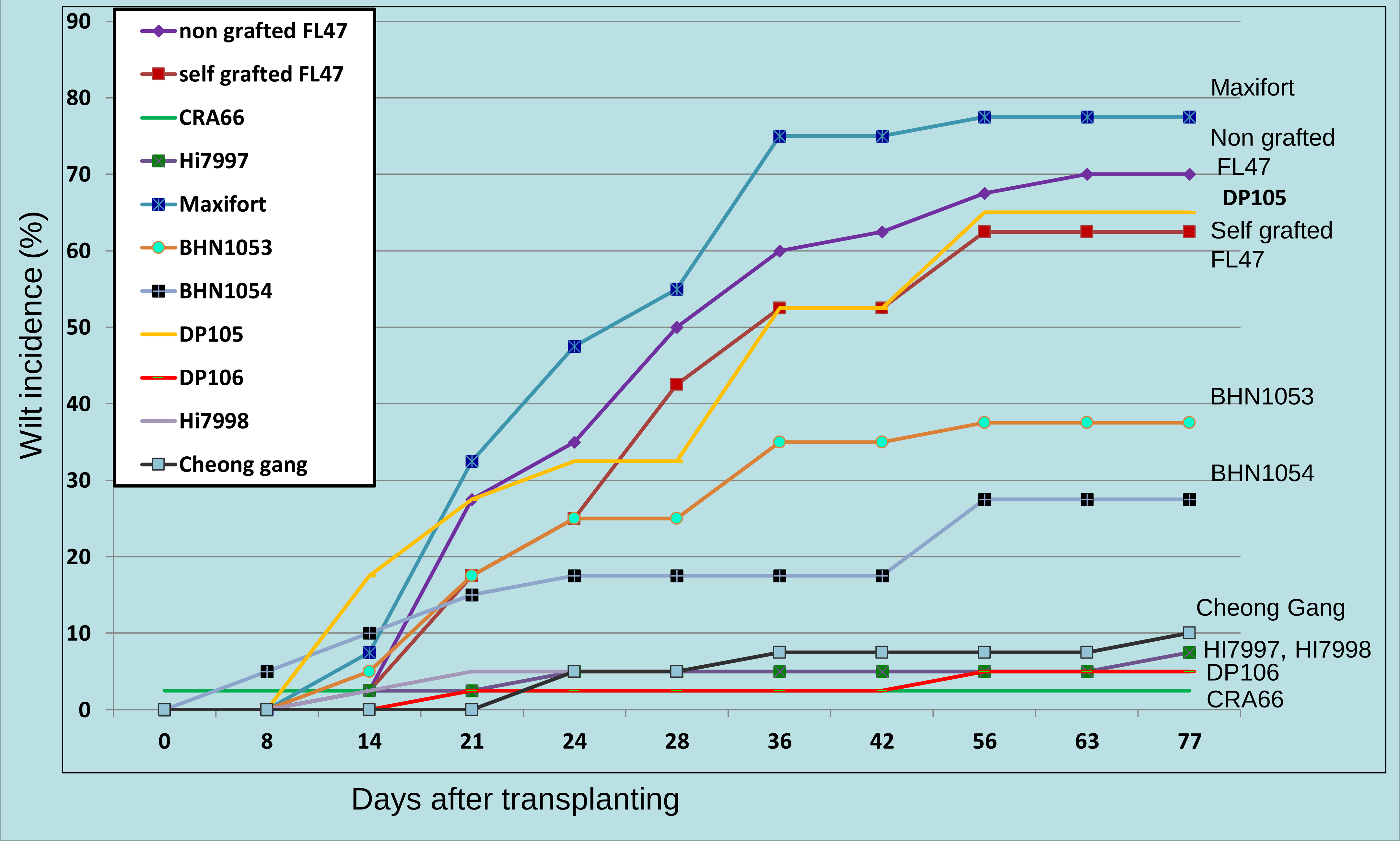


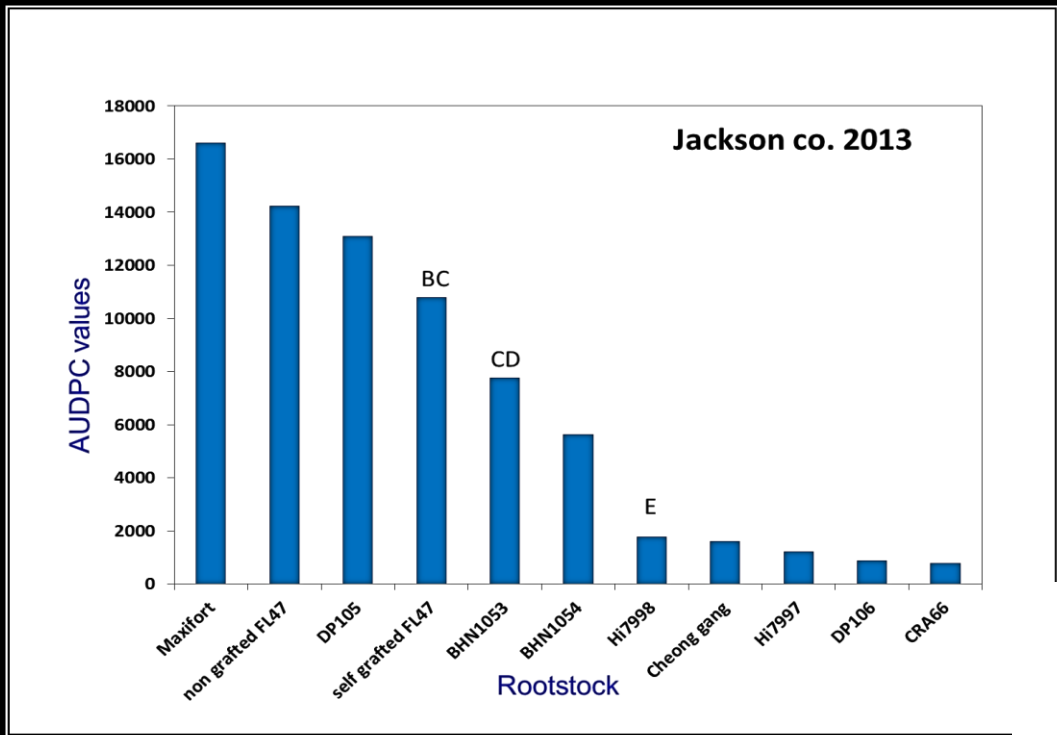
- Serendipitous finding
- Inter-specific rootstocks provided effective resistance to southern blight

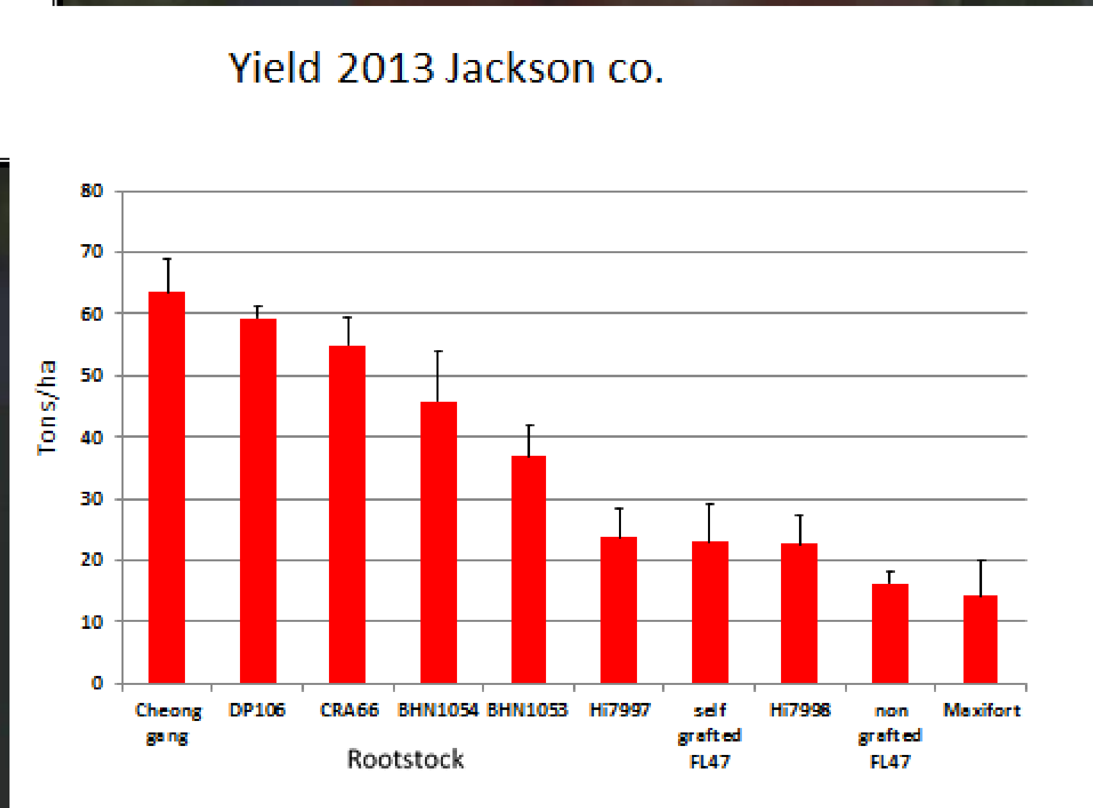
(Rivard et al., 2010)

- *Ralstonia solanacearum*
  - Southern Bacterial Wilt
  - Colonizes Vascular tissue
  - Tropical Environments
  - Soil Inhabitant
  - Wide host range

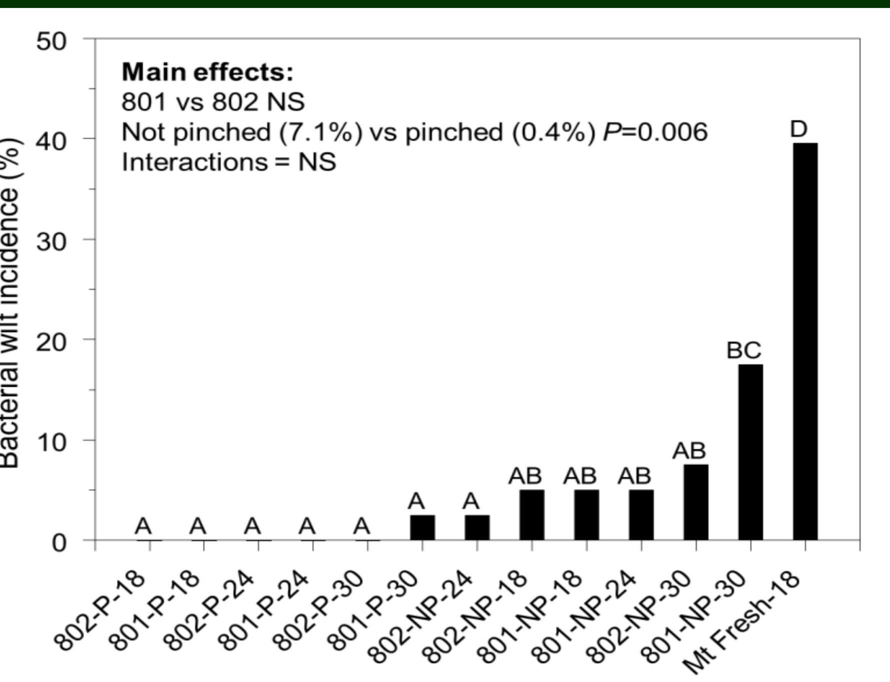
Disease Progress Curves Jackson Co. 2013




Jackson co. 2013
AUDPC values
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
BC
CD
E
Maxifort
non grafted FL47
DP105
self grafted FL47
BHN1053
BHN1054
Hi7998
Cheong gang
Hi7997
DP106
CRA66
Rootstock


Yield 2013 Jackson co.
Tons/ha
80
70
60
50
40
30
20
10
0
Cheong gang
DP106
CRA66
BHN1054
BHN1053
Hi7997
self grafted FL47
Hi7998
non grafted FL47
Maxifort
Rootstock

On Farm Research: Large scale grafting on 8.1 ha (101 ha tomato farm)



Grafting to Manage Bacterial Wilt

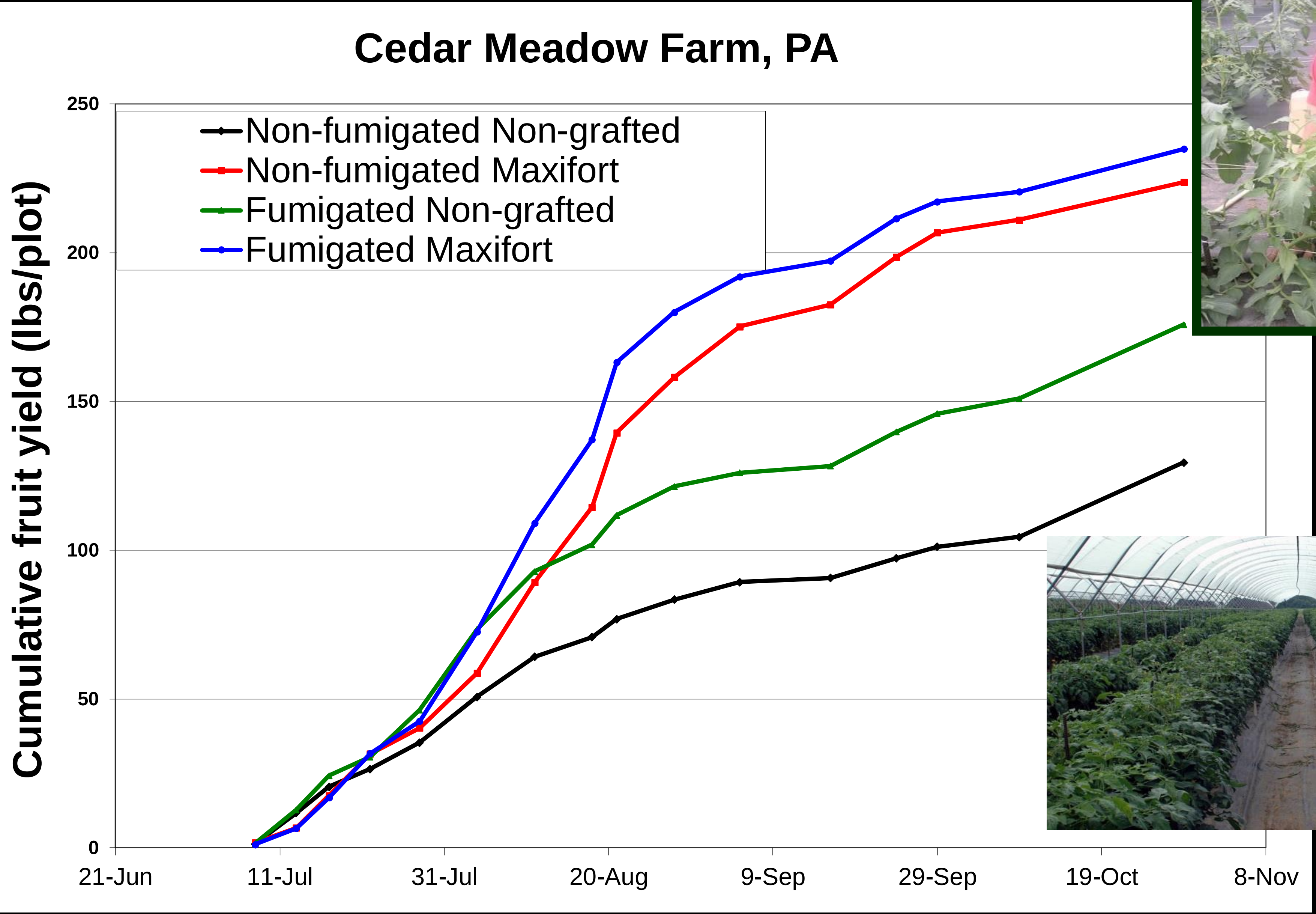
Verticillium Wilt

- ***Verticillium dahliae***
  - Loss of vigor
  - Wilting and leaf necrosis
  - Favored in temperate climates
  - Race 2 prevalent in WNC (*Bender & Shoemaker, 1984*)

Cedar Meadow Farm

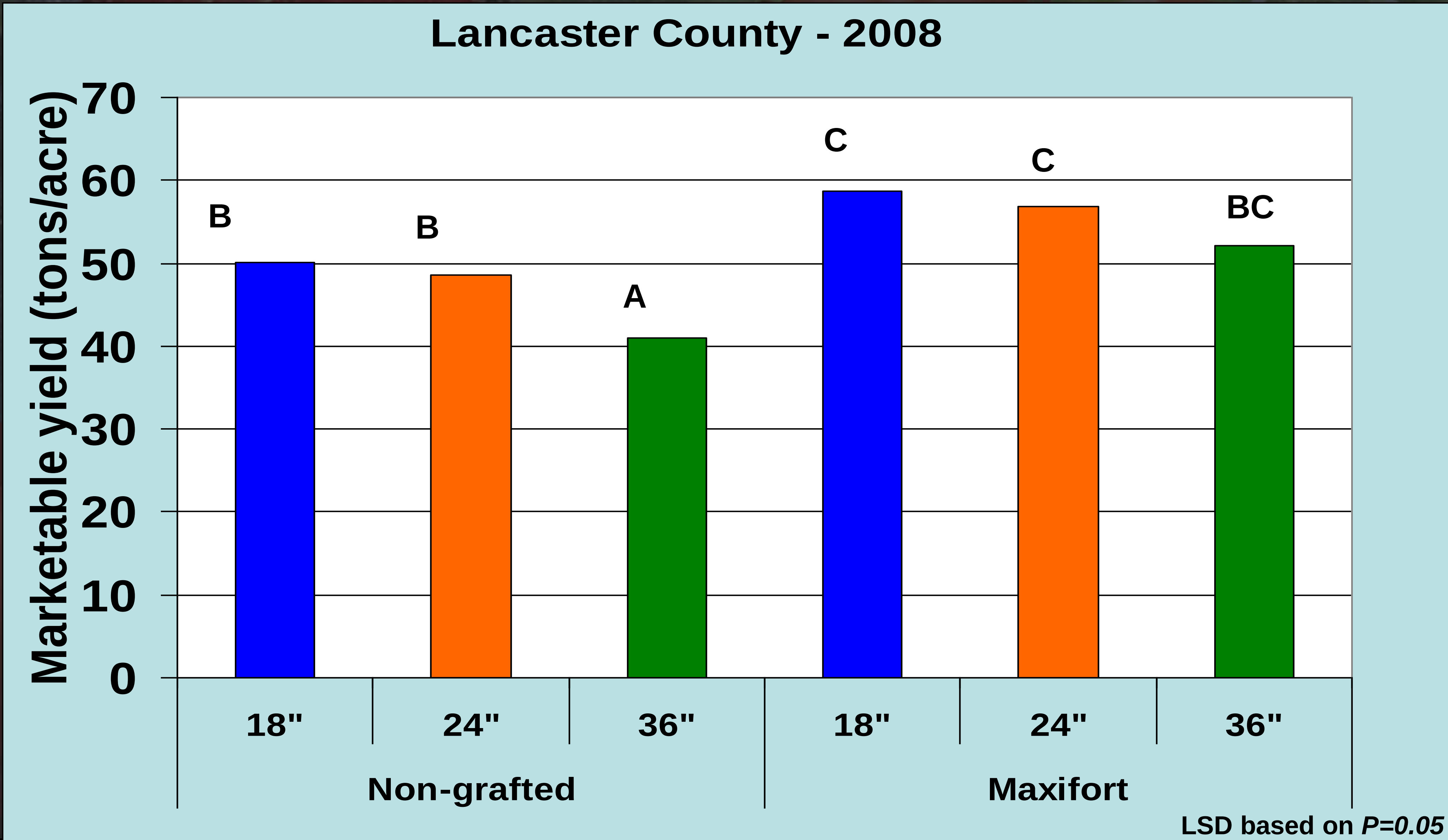
Steve Groff

Cedar Meadow Farm – Lancaster County, PA

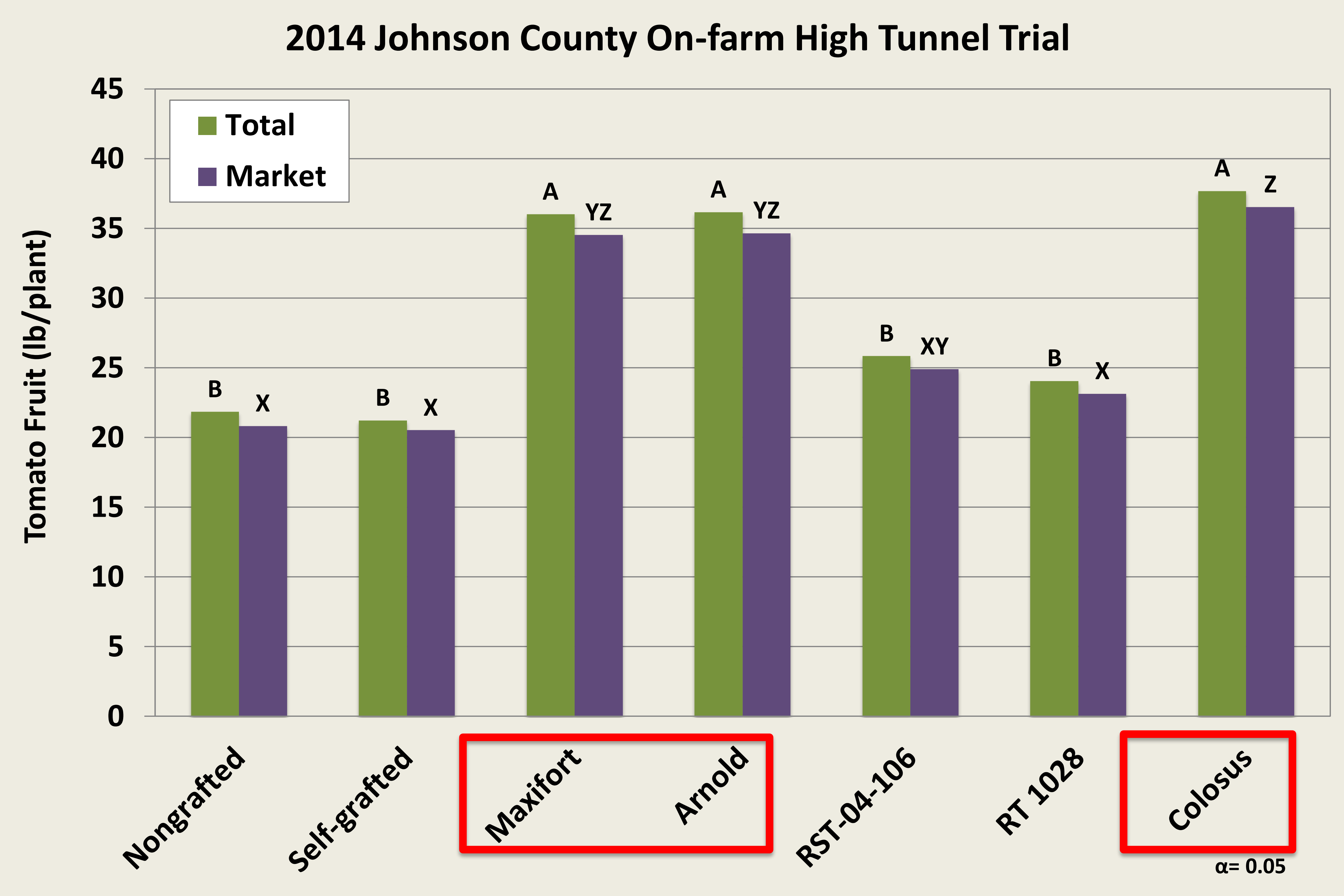


Cedar Meadow Farm – Lancaster County, PA

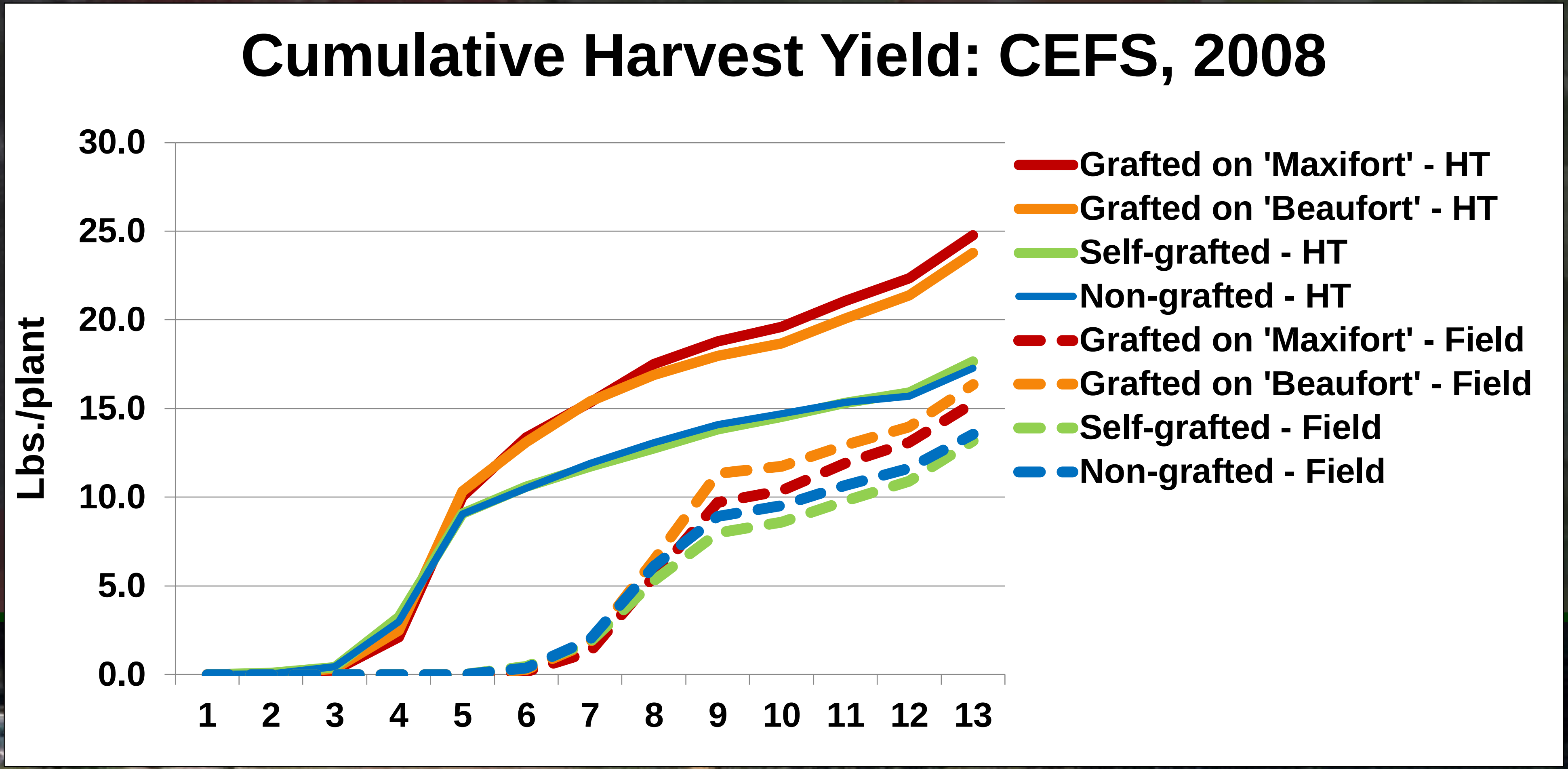
Cedar Meadow Farm




TOMATOES
TOMATOES
ATS
TOMATOES


2014 Johnson County On-farm High Tunnel Trial
Total
Market
Tomato Fruit (lb/plant)
45
40
35
30
25
20
15
10
5
0
B
X
B
X
A
YZ
A
YZ
B
XY
B
X
A
Z
Nongrafted
Self-grafted
Maxifort
Arnold
RST-04-106
RT 1028
Colosus
α= 0.05

Integrating Grafting and High Tunnels



O'Connell et al 2012 HortScience
Sydorovych et al. 2015, in prep

Table 2: Examples of rootstock names or codes and level of disease control observed through on-farm and research station experiments in North Carolina.

Rootstocks	ToMV[cd]	Fusarium (commonly called race 1, 2 & 3; new codes are 0, 1 & 2)			Verticillium (Vd[e])		Root Knot Nematode [b]	Rs[f]	SB
		FOL 0	FOL 1	FOL 2	race 1	race 2	Mi (race1)		
Solanum lycopersicum x *Solanum sp.* (interspecific hybrids)[g]									
Beaufort	5 [h]	5	5	0	5	---	4	1	4
Big Power	5	5	5	0	5	---	5	1	4
Maxifort	5	5	5	0	5	2	4	1	4
Robusta	5	3	---	0	5	---	---	1	---
TMZQ	5	5	5	0	5	0	---	1	---

Description of Commercial Tomato Rootstocks as of November 20, 2014

Common Tomato Diseases and Pests and usceptibility Characteristics

Rating rootstock characteristics is complex. For example, strains of pathogens differ and plant responses to them are rarely "yes" or "no." Therefore, many approaches are used to rate rootstock characteristics. This table is a compilation of publicly available information provided by seed companies in catalogs and at websites. Additional information from peer-reviewed technical and scientific reports is available in the table Addendum. The table is to be updated often.

Rootstock	Bacterial Wilt	Corky Root Rot	Fusarium Wilt Race 1	Fusarium Wilt Race 2	Fusarium Crown and Root Rot	outhern Blight	Verticillium Wilt	Nematode	Tomato Mosaic Virus	Tomato potted Wilt Virus	Developer
Aegis			R	R	R		R	R	R		Takii Seed
Aibou			R	R	R			R	R		Asahi Industries
Akaoni									R		Asahi Industries
Aligator		R	R	R	R		R	R	R		Gautier Seeds
Anchor-T			R	R	R		R	R	R		Takii Seed
Aooni			R	R			R	R	R		Asahi Industries
Arnold	R		R	R	R			R	R		Syngenta Seeds
Armada			R	R	R		R	R			Takii Seed
Armstrong		R	R	R	R		R	R	R		Syngenta Seeds
B.B.			R	R	R		R	R			Takii Seed
Beaufort		R	R	R	R		R	R	R		DeRuiter Seeds
BHN 1053											BHN Seed
BHN 1054											BHN Seed
BHN 998											BHN Seed
Block	R		R	R	R		R	R	R		Sakata Seed
Body		R		R			R	R	R		Bruinsma Seeds
Bolante			R	R	R		R	R	R		Takii Seed
Brigeor		R	R	R	R		R	R	R		Gautier Seeds
Bruce RZ		R	R	R	R		R		R		Rijk Zwaan

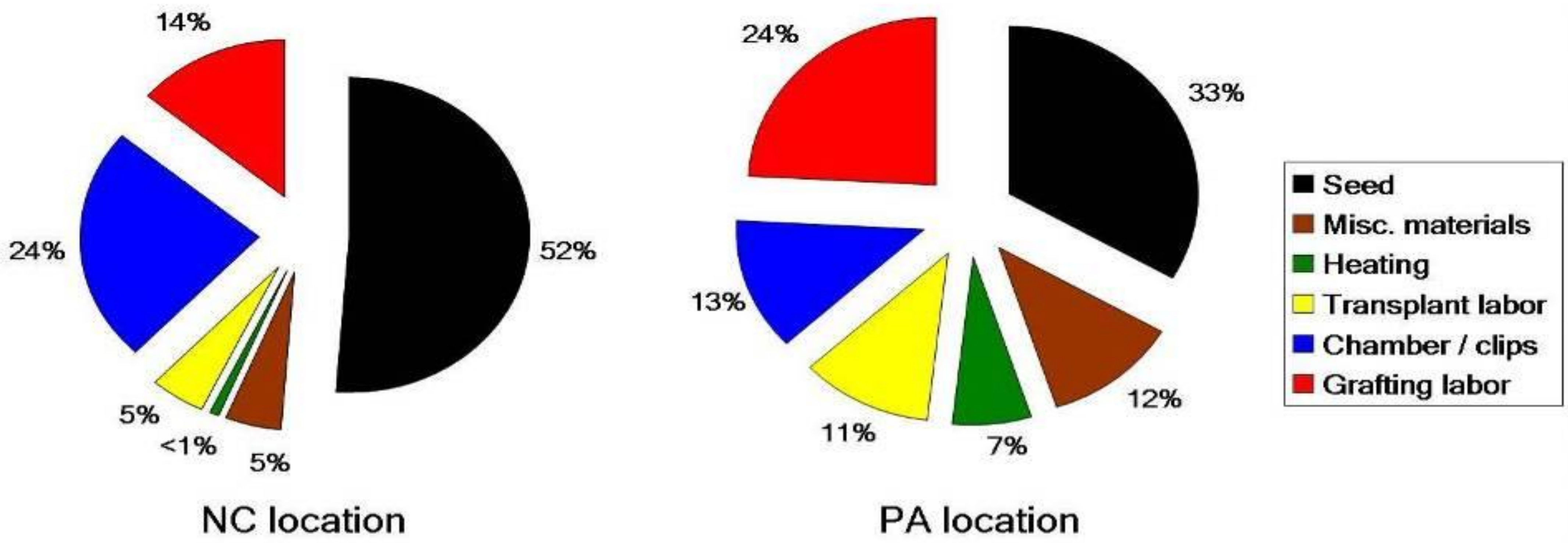
Notes: Blank –susceptible or information is **not** available R – Resistant (full or partial) For additional information on rootstock descriptions please contact developer directly.

This table was developed with support provided by USDA-National Institute of Food and Agriculture (NIFA) (Specialty Crop Research Initiative Award # 2011-51181-30963; "Development of Grafting Technology to Improve Sustainability and Competitiveness of the U.S. Fruiting Vegetable Industry"), institutions participating in that project and their collaborators. Please direct questions and comments about the table to Dr. Matthew D. Kleinhenz, Dept. of Horticulture and Crop Science, The Ohio State University-OARDC

*currently under revision

Propagation Costs

- Proportion of added costs
  - e.g. seed costs (%) = $(SEED_{graft} - SEED_{non}) / (TOTAL_{graft} - TOTAL_{non})$



$0.46 / plant **$0.74 / plant = Added cost**

(Rivard et al., 2010)

Cost analysis for use of grafted plants

Added yield per plant (lb) needed to compensate for higher transplant prices - tomato

Transplant price premium	Sales price ($/lb)						
	$ 0.40	$ 0.80	$ 0.80	$ 1.60	$ 2.00	$ 2.40	$ 2.80
$ 0.50	**1.79**	**0.74**	0.46	0.34	0.27	0.22	0.19
$ 0.75	**2.68**	**1.10**	0.69	0.51	0.40	0.33	0.28
$ 1.00	**3.57**	**1.47**	0.93	0.68	0.53	0.44	0.37

Transplant price premium= Price grafted – Price non-grafted
A baseline yield = 9.3 lb/plant

Data by Olya Rysin & Frank Louws HortTechnology (NCSU)

LOG HOUSE PLANTS

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GRAFTED GROWERS™

www.citizen-times.com/story/news/local/2014/08/07/plant-company-employ-mills-river/13716437/

CITIZEN-TIMES
A GANNETT COMPANY

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Plant company to employ 125 in Mills River

John Boyle, jboyle@citizen-times.com 10:09 a.m. EDT August 7, 2014

The international partnership, Tri-Hishtil, will be headquartered in Henderson County.

(Photo: John Salter , Special to the Citizen-Times)

MILLS RIVER – A collaboration between companies in the United States, Israel and Italy will result in 125 new jobs in Mills River at a facility that will graft vegetable plants for growers all along the Eastern Seaboard.

The new company, Tri-Hishtil will build the grafting operation on 42 acres in Mills River, land it is buying from the Van Wingerden plant nursery operation. The project has been in the works for two years and brings together major players in the plant grafting and breeding, soil management and plant distribution.

TOP VIDEOS

Re-Di-Vined

Unique product lines for retail market


Photo by Alice Doyle

Tim Wada

Log House Plants


Photo by Hishtil

RISK: " shifty enemies" Invasive species
"Know your enemy"

Over reliance on grafting in the absence of other IPM tactics:

Re-emergence of minor pathogens. *Colletotrichum coccodes*, *Rhizoctonia* (AG-4) and other pathogens (Garibaldi et al. 2008; Minuto et al. 2008; Minuto et al. 2007).

Grafting can double or triple your chances of spreading seedborne and mechanically transmitted pathogens (e.g.) Clavibacter, Acidovorax, viruses.

Market Niche

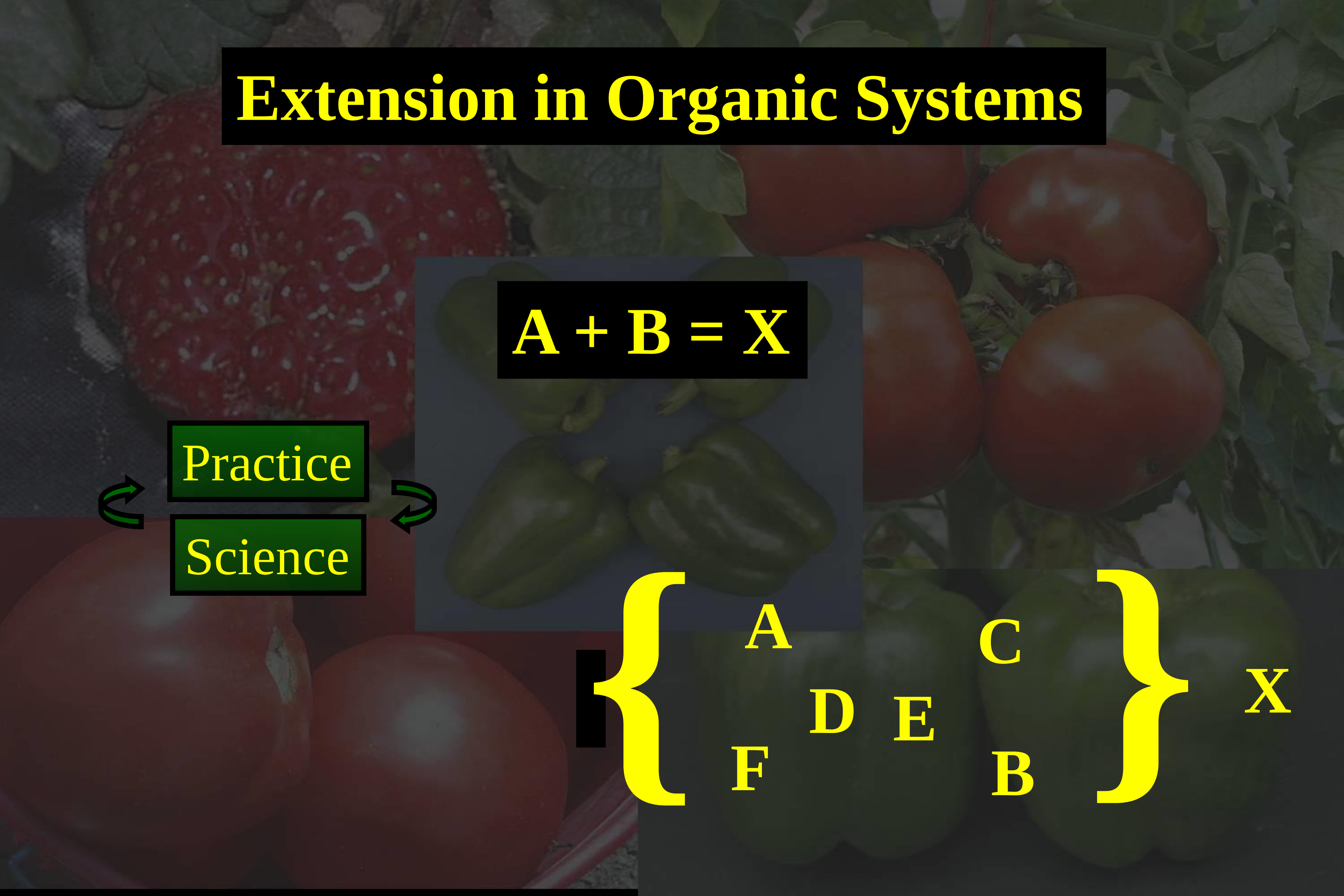
System Simplicity

LTD rotation + organic
Soilborne diseases
Indeterminate
Heirloom

3-yr rotation + fumigation
No soilborne diseases
Determinate
Green market

Length of Harvest

Production Issues


Extension in Organic Systems
A + B = X
Practice
Science
A
C
D
E
F
B
X

SCRI GRANTS PROGRAM

USDA Proposal
2011-01397

THANKS!

USDA United States Department of Agriculture

National Institute of Food and Agriculture

North Carolina Tomato Growers Association

SOUTHERN SARE Sustainable Agriculture Research & Education

NORTH CAROLINA VEGETABLE GROWERS ASSOCIATION