



USDA SCRI
FUNDING# 2011-
01397

USDA SCRI
2016-51181-25404



Grafting Vegetables: The Science and Practice of Growing New Roots

Frank J. Louws
Department of Horticultural Science
North Carolina State University
Raleigh NC USA 27695
frank_louws@ncsu.edu

Tube Grafting (RS * YFT)



- Hole Insertion
- One Cotyledon
- Splice graft



OPTIMIZE ROOT GENETICS

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

Courtesy C. Kubota

BUILD THE TEAM



USDA SCRI
FUNDING#
2011-01397

2016-51181-25404

University and State:

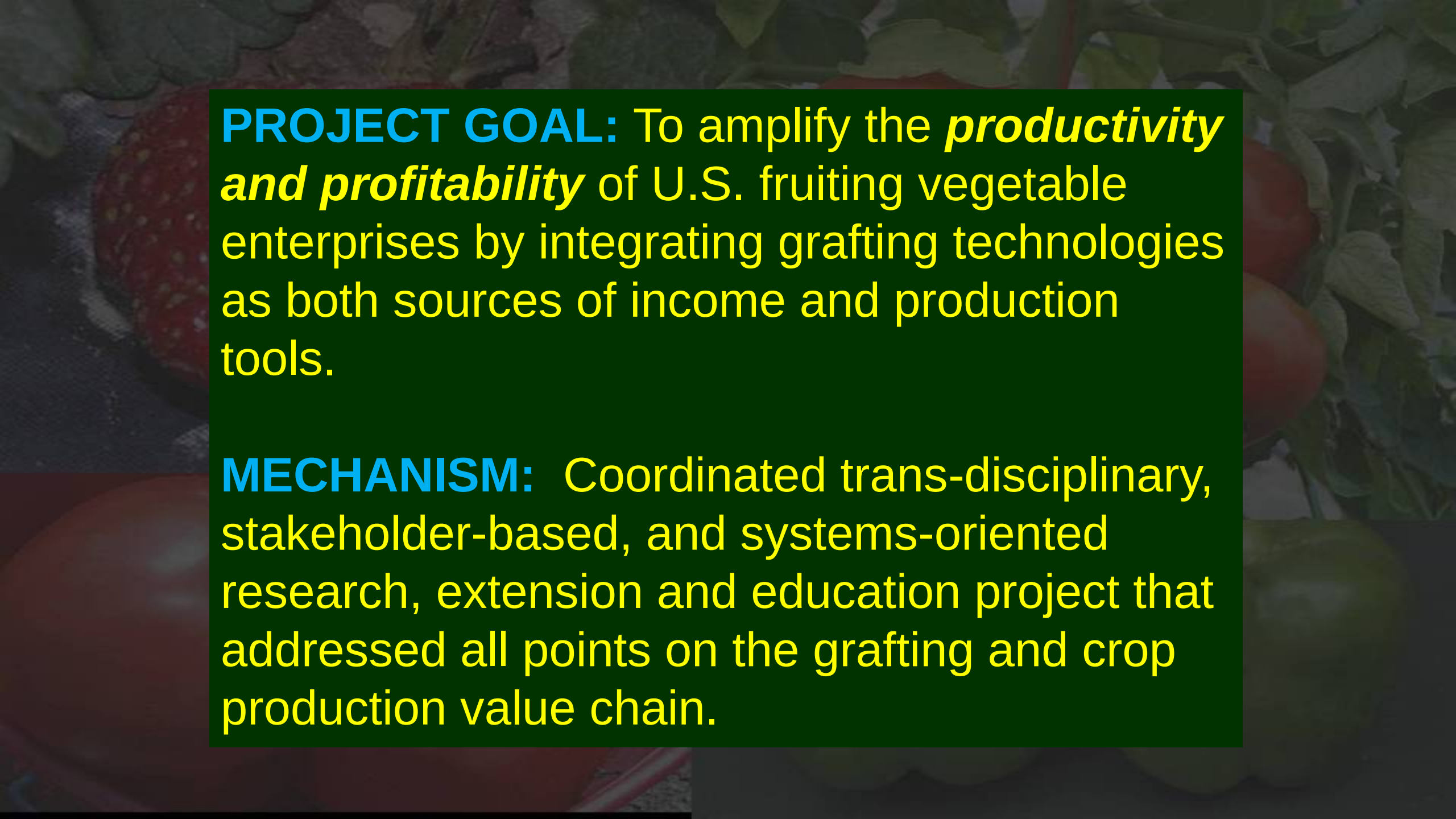
- 10 Universities
- 32 faculty
- Technicians
- Students
- Extension agents
- Multi-disciplinary

Private Industry:

- Robotic companies
- Seed companies
- Plant nurseries
- Gower associations
- Growers
- 75+ partners

ISHS 2nd International Conference
on Vegetable Grafting
Charlotte NC, 2019

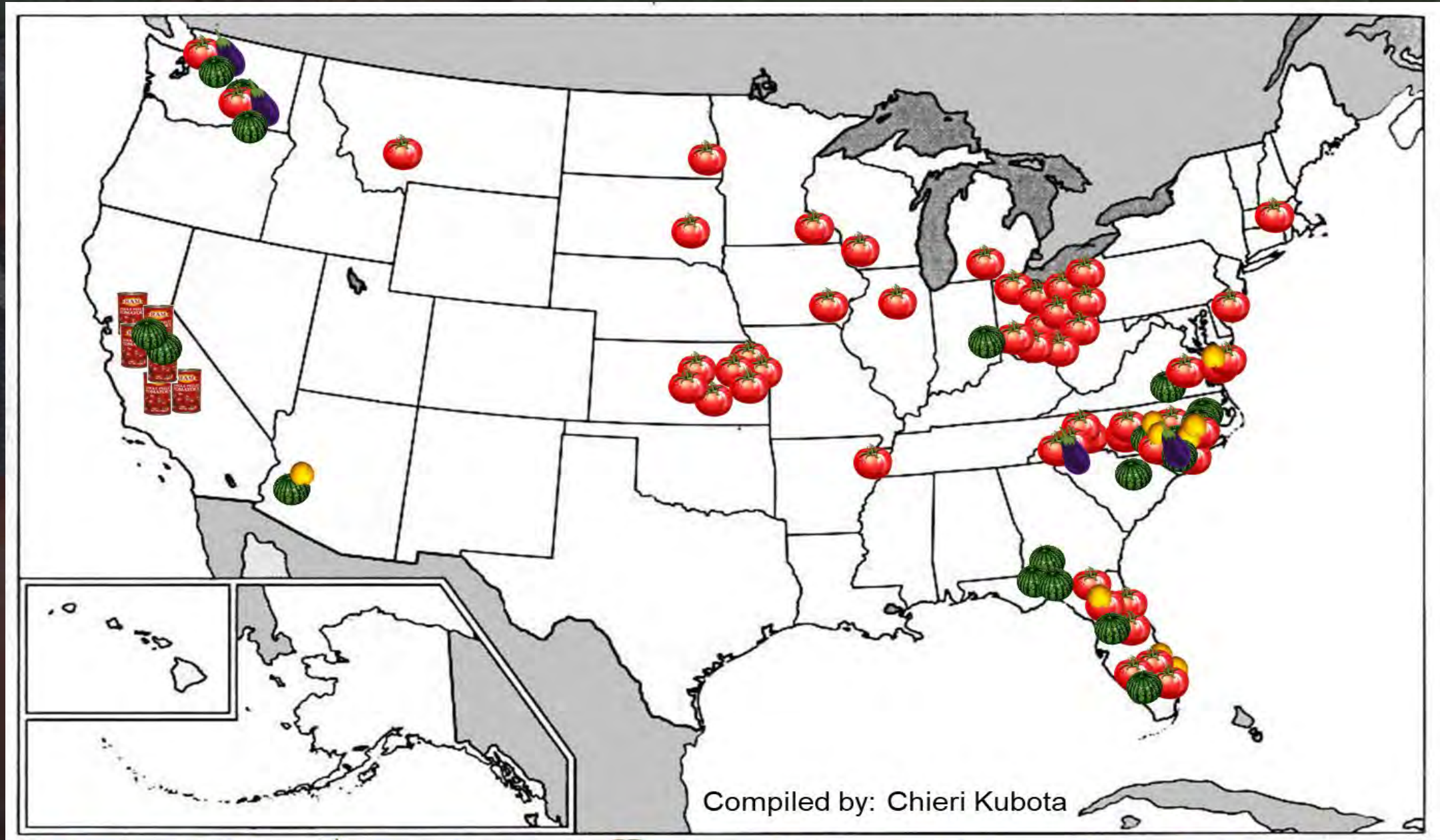




PROJECT GOAL: To amplify the *productivity and profitability* of U.S. fruiting vegetable enterprises by integrating grafting technologies as both sources of income and production tools.

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.

National Field Trials with Grafted Vegetables



Tomato (F)



Eggplant



Tomato (P)

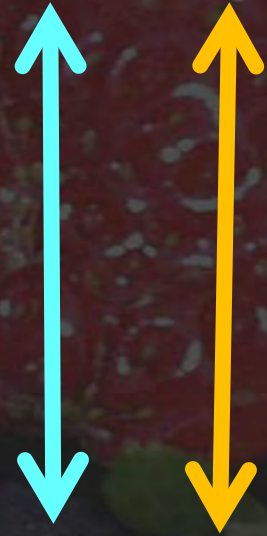


Watermelon



Melon

**System
Simplicity**



**Market
Niche**

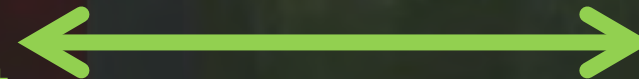
Scale neutral but system specific

LTD rotation + organic
Soilborne diseases
Indeterminate
Heirloom



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

**Length
of Harvest**



**Production
Issues**

Develop a comprehensive website: vegetablegrafting.org

The Vegetable Grafting Decision Support Tool

<http://graftingtool.ifas.ufl.edu>

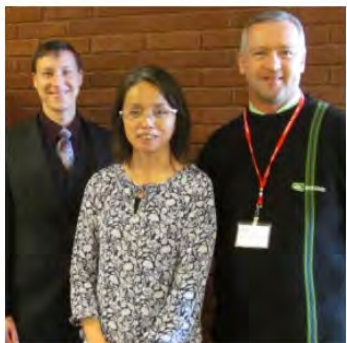


Home

Welcome to our Vegetable Grafting website!

Grafting is a long-standing technology. Grafting has been practiced for centuries and studied for decades, but its application to the U.S. and other vegetable industries continues to develop. Clearly, grafted plants are versatile, scaleable, genetic solutions to production issues for growers of Solanaceae and Cucurbitaceae plants such as tomato, pepper, watermelon, cantaloupe. Vegetable grafting can also provide income to propagators (grafted plant suppliers). Although grafted vegetable plant production and use in the U.S. are rising sharply, work is needed to improve its effectiveness and efficiency and increase learning opportunities for growers, researchers, and other members of this growing industry sector.

This website is part of a national research-extension effort to advance the science and practice of vegetable grafting. We strive to provide timely, direct access to relevant, research-based information for preparing, distributing, growing, evaluating, and studying grafted vegetable plants.



Vegetable Grafting Decision Support Tool

Decision support tool allows the user to evaluate the economic returns of adopting grafting in production. It integrates partial budget comparison analysis, sensitivity analysis, and breakeven analysis to help the user understand the economic benefits of adopting vegetable grafting technology and thereby make informed management decisions for improving vegetable production. If you use the tool, we strongly recommend you read our user manual: pdf, web p

To Get Started, Please Select Your Role

vegetable producer

Researcher

Extension Agent

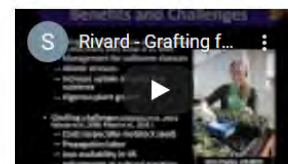


Home » Resources » Vegetable Grafting Webinar Series

Vegetable Grafting Webinar Series

"Growing New Roots" Vegetable Grafting Webinar Series

Grafting science and technology continue to advance. Members of the SCRI Grafting Project Team have offered webinars focused on various aspects of preparing, using, and evaluating the effects of using grafted plants. Links to these webinars are below. Check back for upcoming webinars.



Date: May 14, 2019

Title: Grafting to Increase Production for Small-acreage and High Tunnel Tomato Growers

Presenter: Dr. Cary Rivard, Kansas State University



Lecture- and hands on-based training in grower & stakeholder education; Many field days



Train Graduate Students and Professionals



LARGE SCALE FIELD TRIALS

TO GRAFT

OR

NOT TO GRAFT



Photo: Cary Rivard

Recommended Rootstocks for Bacterial Wilt of Tomato

Shin Cheong Gang	Seminis
RST-04-106-T	D Palmer Seeds
Armada	Takii Seed
Bowman (less effective in Eastern NC)	Sakata (more data)
Hawaii 7998 (open pollinated)	Grower (self)

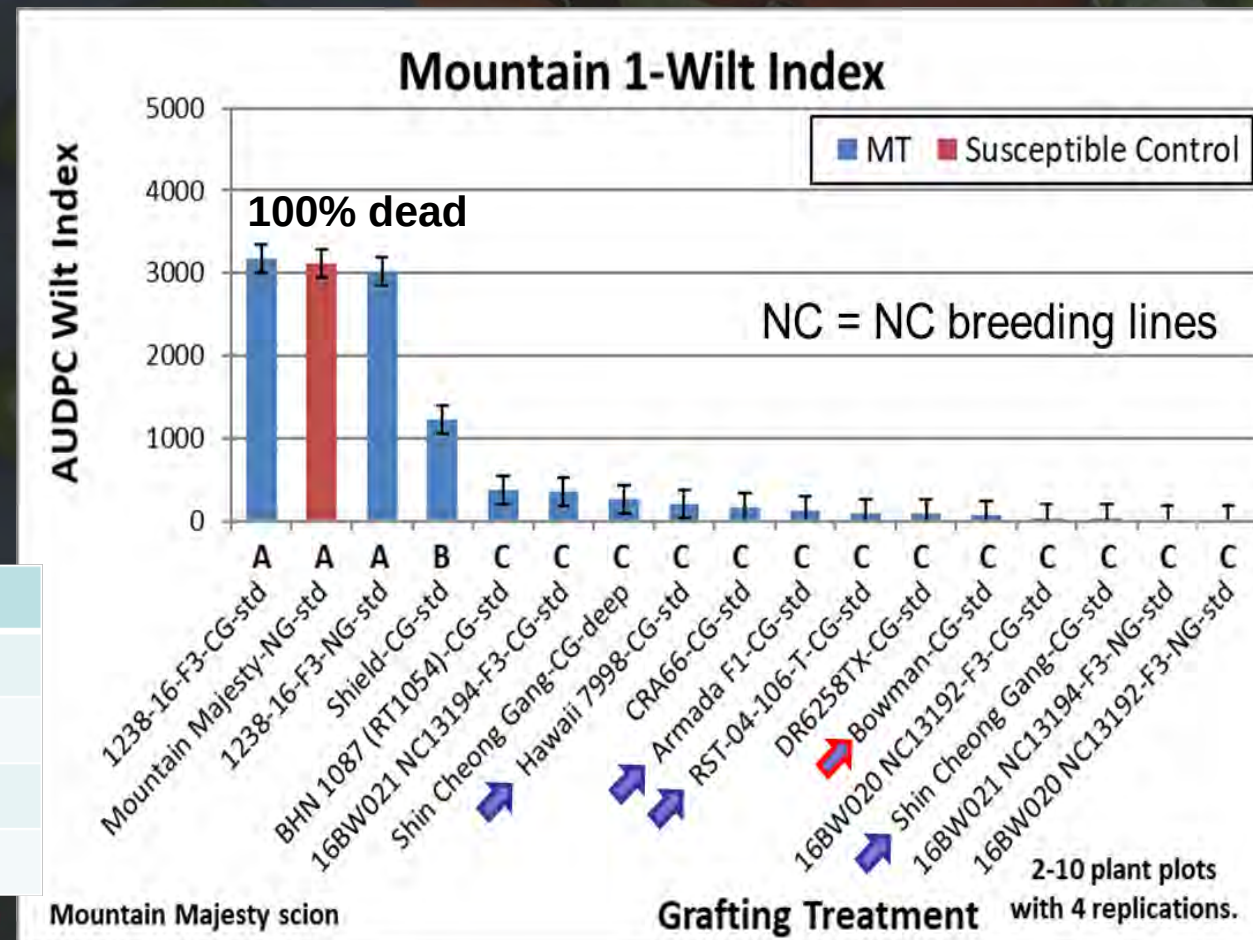
Bacterial Wilt

Ralstonia solanacearum

Race 1, biovar 1, phylotype II and sequevar 7

Not R3bv2

Available and emerging genetics

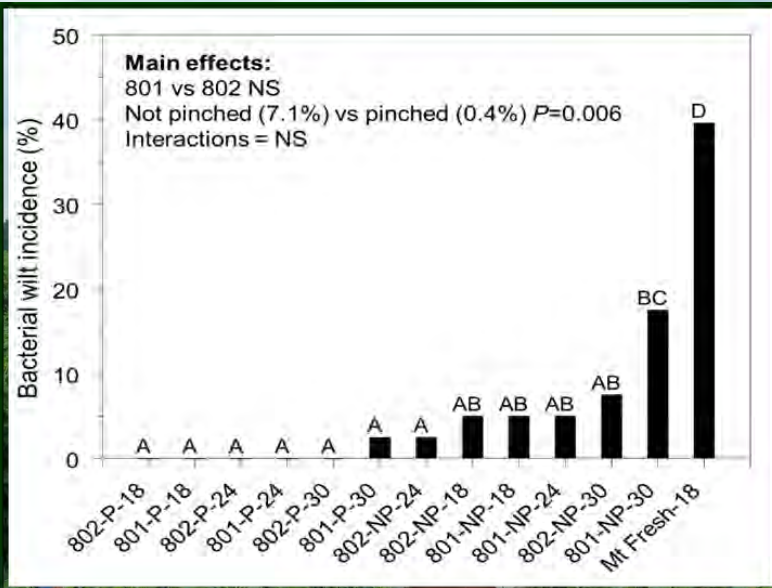


J. Kressin, D. Panthee, F. Louws

On Farm Research: Large scale grafting



Potential problems: Rooting of the susceptible scion (Mt. Fresh) into the soil. Scion roots may allow the bacteria to grow into the scion and cause it to wilt.



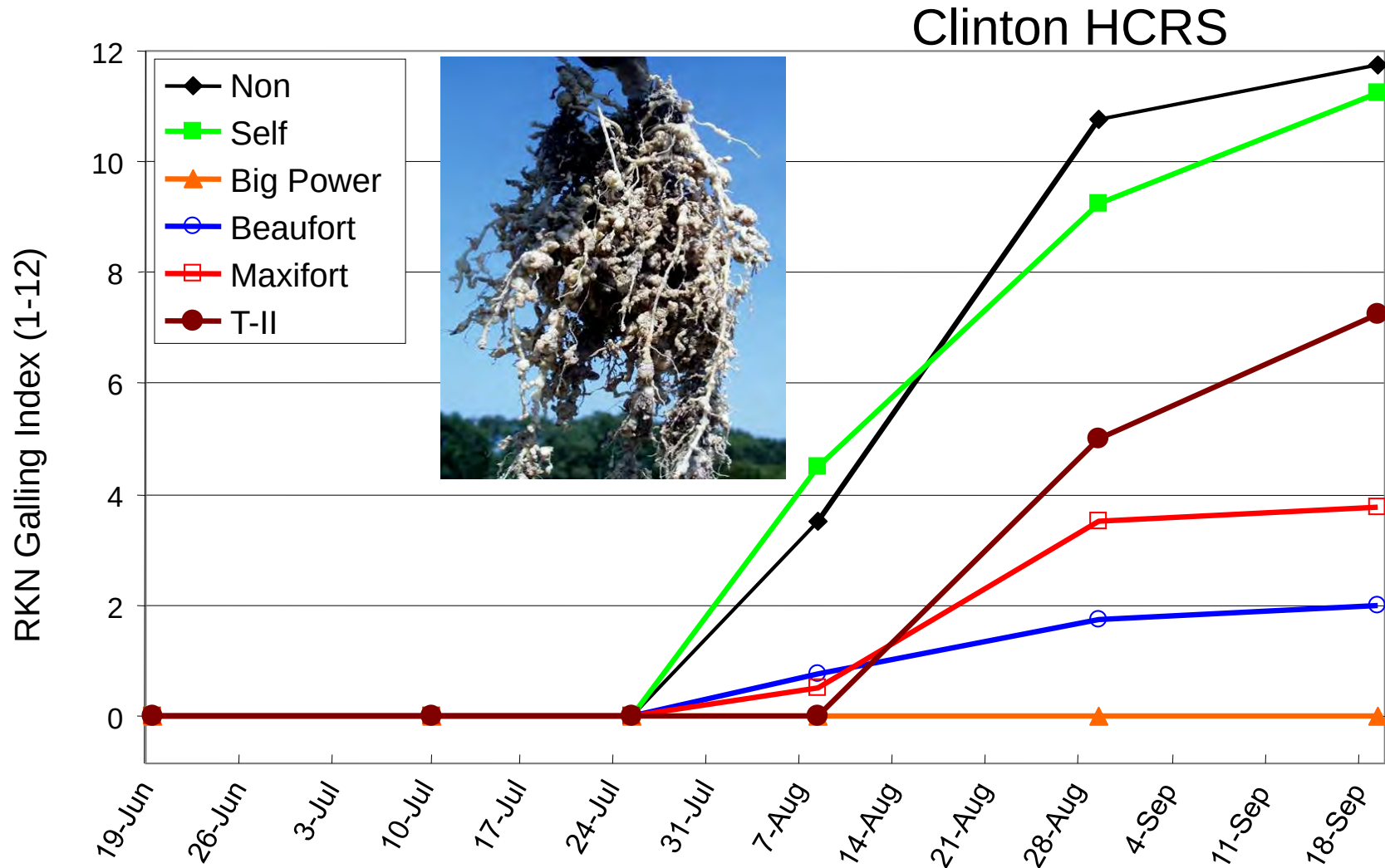
Grafting to Manage Bacterial Wilt



Patterson Farms, NC.
Thanks David Suchoff for sharing the photo.

Root Knot Nematode

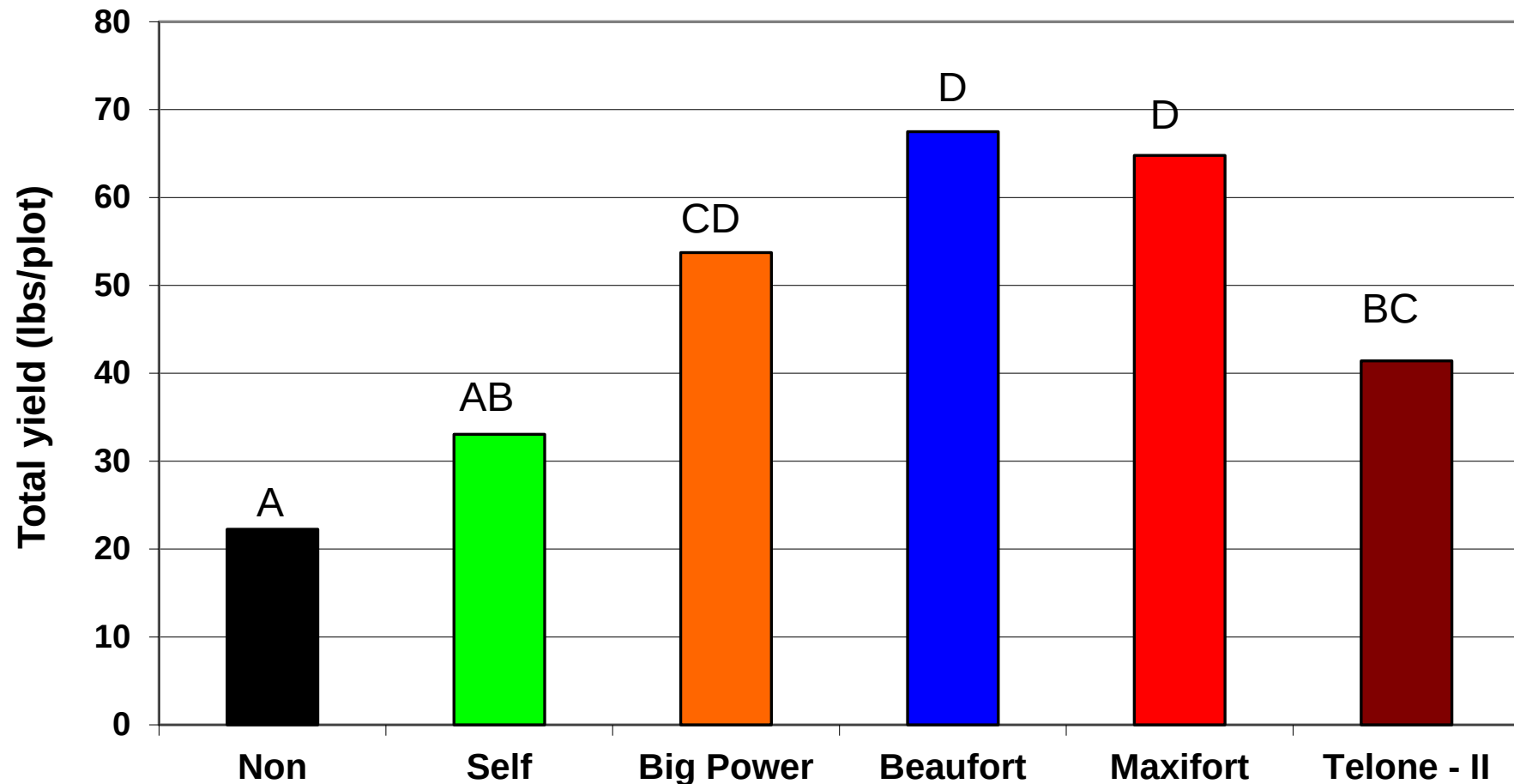
Meloidogyne incognita race 1 (Mi gene)



Root Knot Nematode

Meloidogyne incognita race 1

Clinton HCRS



Least Significant Difference at $P=0.05$

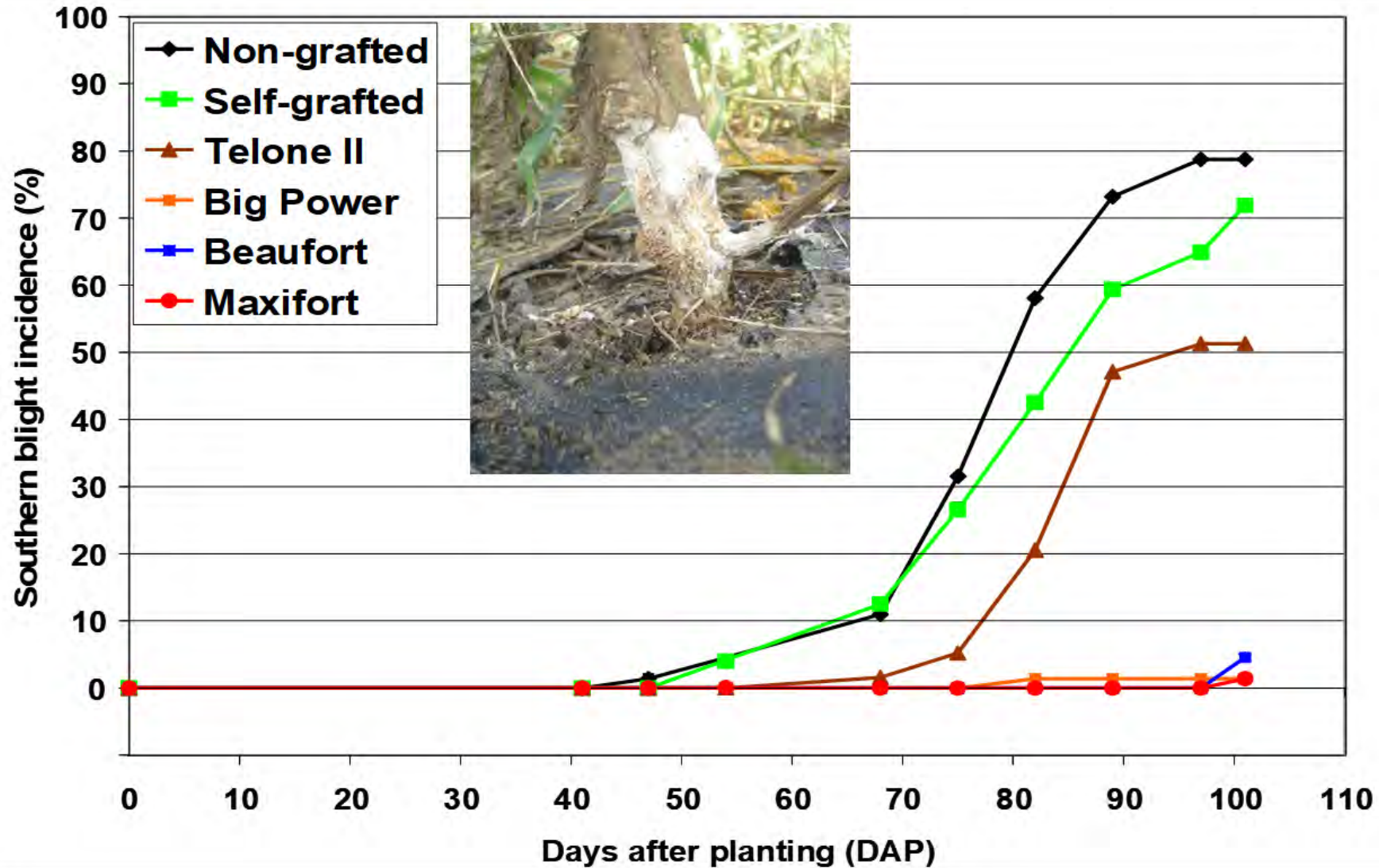
RKN Populations

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

Concerning: *Mi* genes do not confer resistance against *M. enterolobii*

Southern Blight Incidence



Fusarium oxysporum f. sp. *lycopersici*

- Fusarium Wilt
- Soil Inhabitant

f.sp. = *forma specialis*
(special form; host specific)



<https://peregrinefarm.net/tag/fusarium-wilt/>

Grafting confers complete resistance if the right rootstock is matched to the race(s) (1,2,3) of concern.

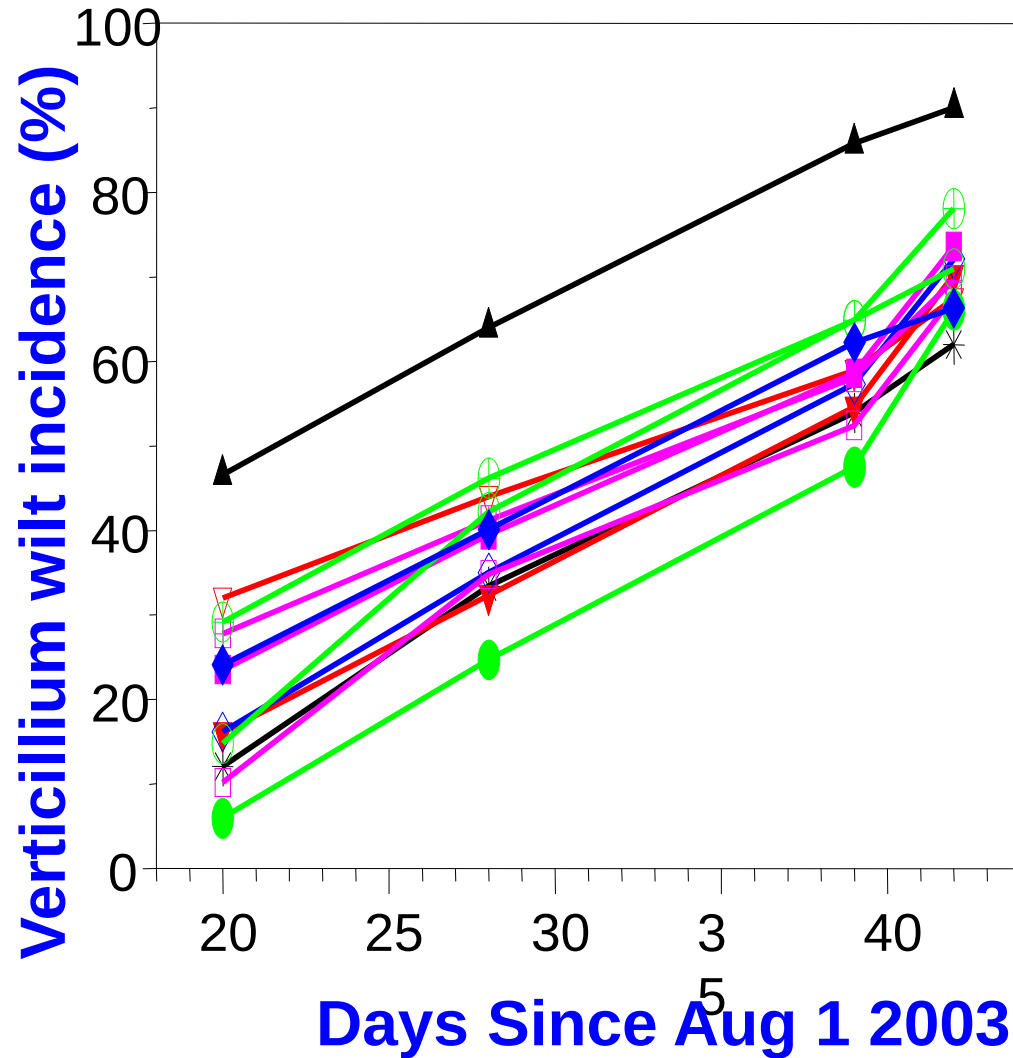
Same is true for Fusarium root and crown rot

Verticillium Wilt

- *Verticillium dahliae* (race 1 & 2)
 - Loss of vigor
 - Wilting and leaf necrosis
 - Favored in temperate climates
 - “Race 2” prevalent in WNC (*Bender & Shoemaker, 1984*)
 - Highly persistent in soils
 - Non-host specific

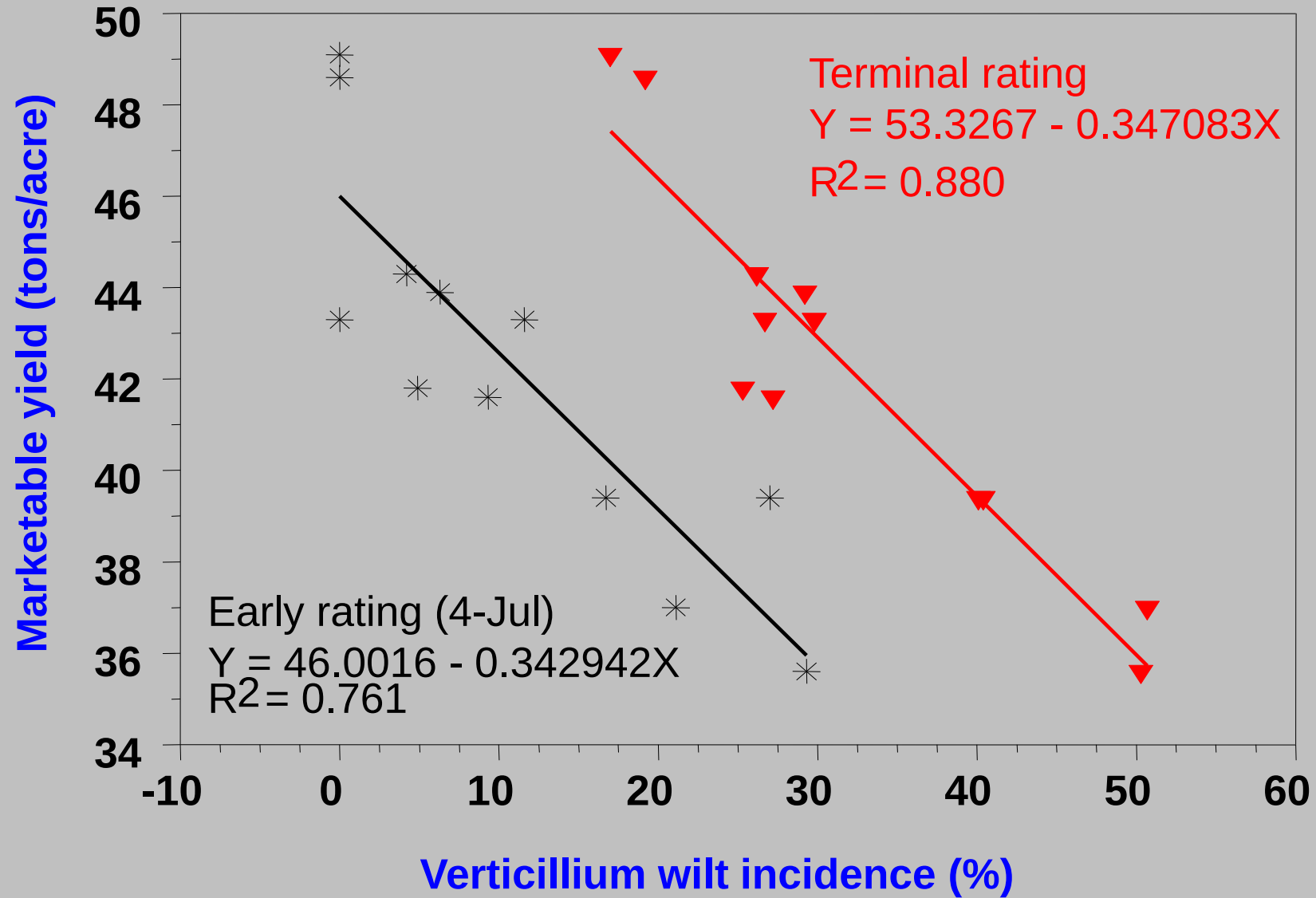


2003 Incidence of Verticillium Wilt



- *— Methvl Bromide 67:33
- △— Non-fumigated
- ▽— Telone-C35
- ▽— InLine
- ◇— Metam sodium drip
- ◇— Metam sodium spray
- Chloropicrin
- Chloropicrin EC
- Chloropicrin Plus
- Iodomethane 33:67
- Iodomethane 50:50
- ⊕— Iodomethane 33:67 EC

Verticillium Wilt Incidence and Yield



Life on the Farm: Systems Management



Planting Depth



Suckering



Twin leader for
European string trellis

Cedar Meadow Farm

- Can vigorous rootstock be used to manage verticillium wilt?
 - ‘Maxifort’
- How does grafting fit in with fumigation?
 - Additive or alternative
- Can we reduce economic constraints through cultural methods?
 - Plant spacing/Twin training

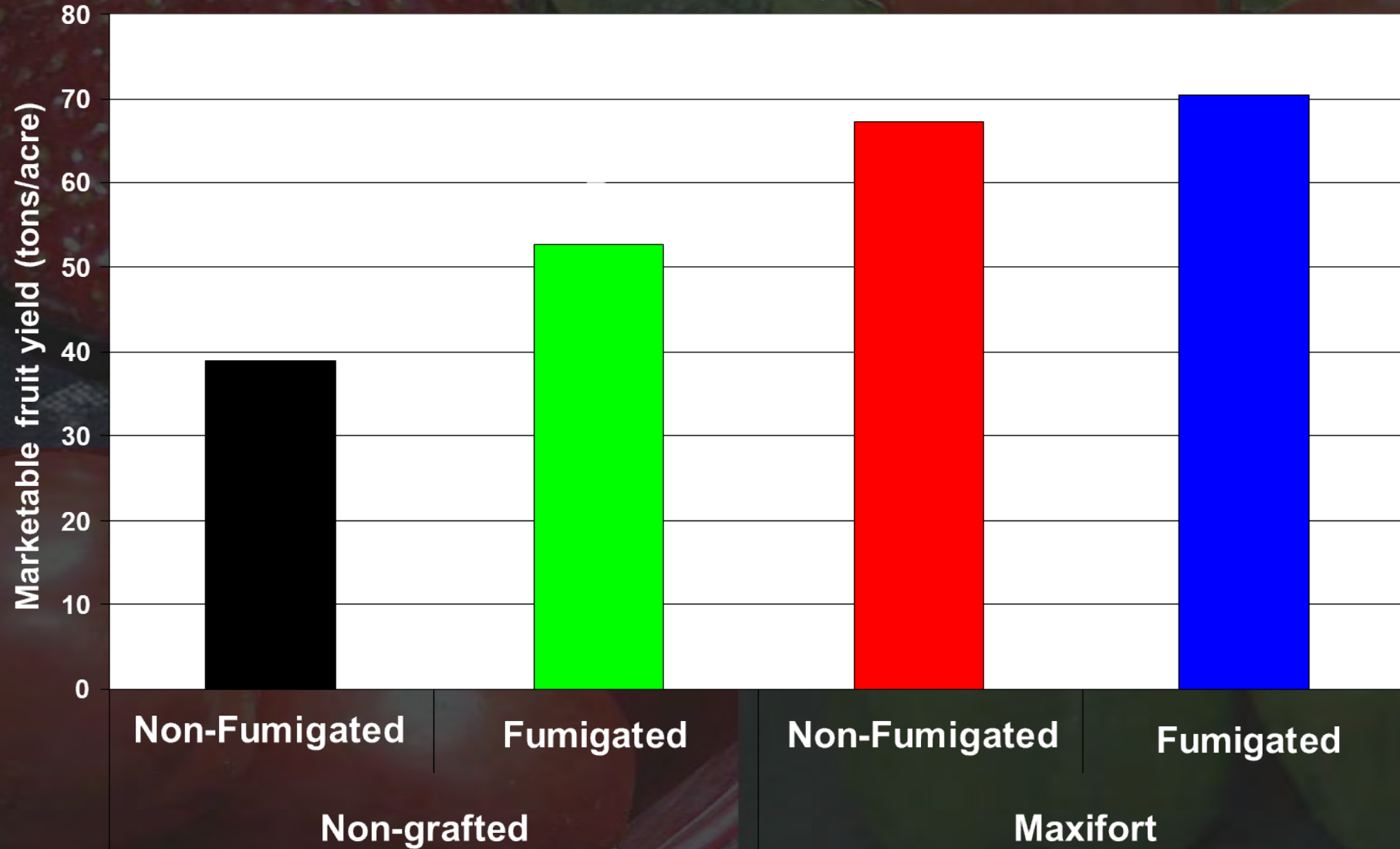


Steve Groff

Cedar Meadow Farm – Lancaster County, PA

Cedar Meadow Farm

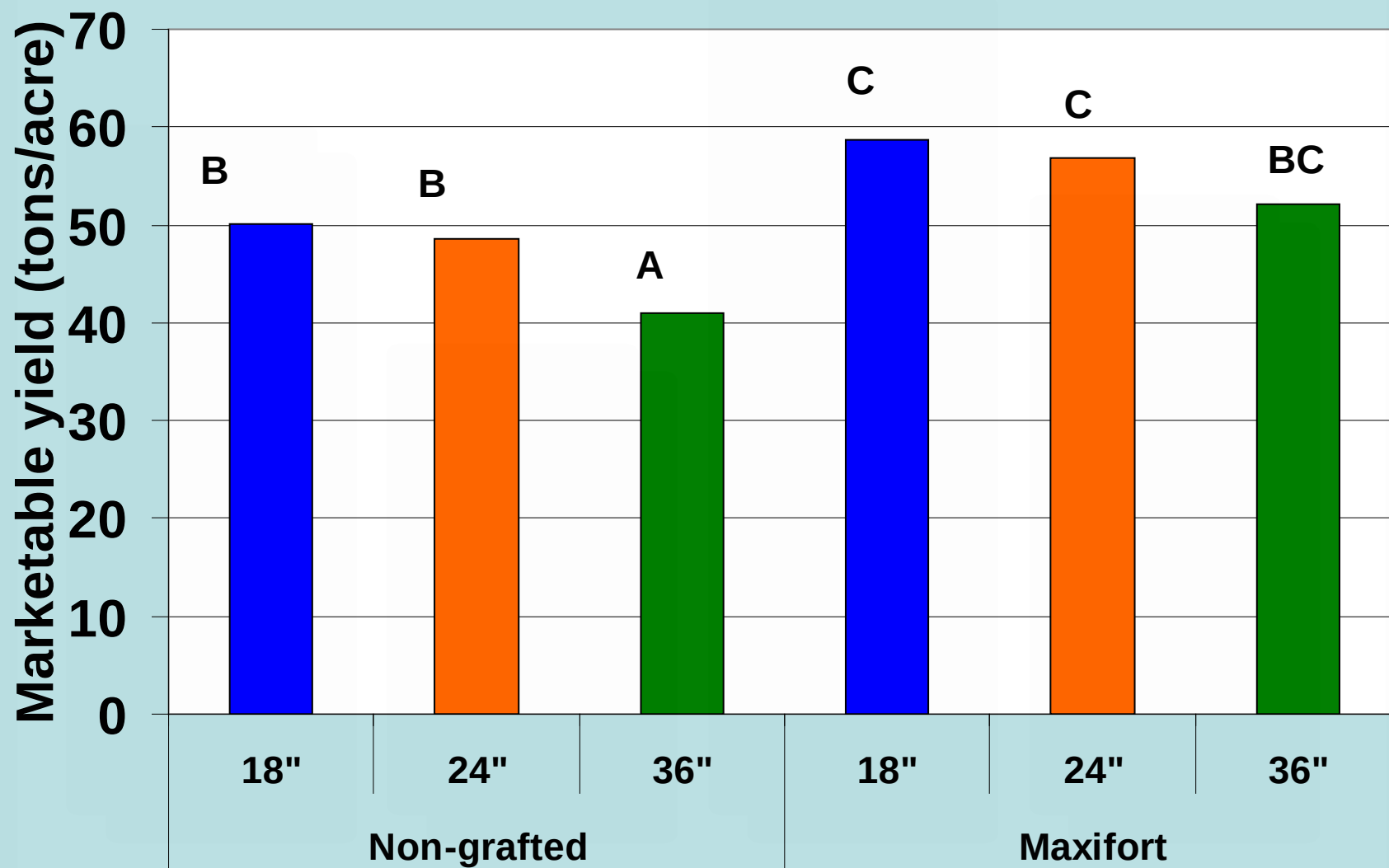
Lancaster County - 2009



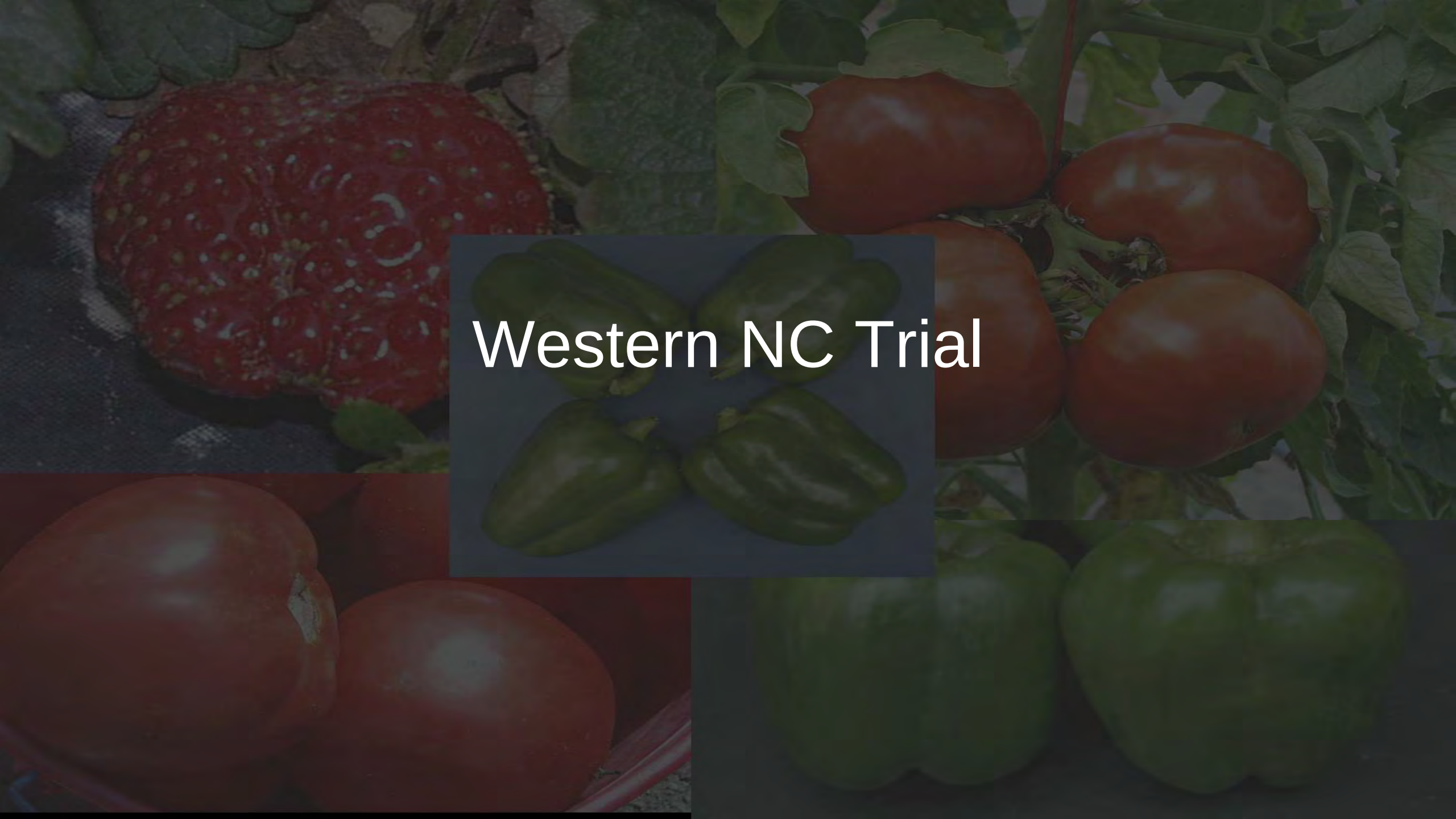
LSD $P = 0.05$

Cedar Meadow Farm (Verticillium is primary problem)

Lancaster County - 2008

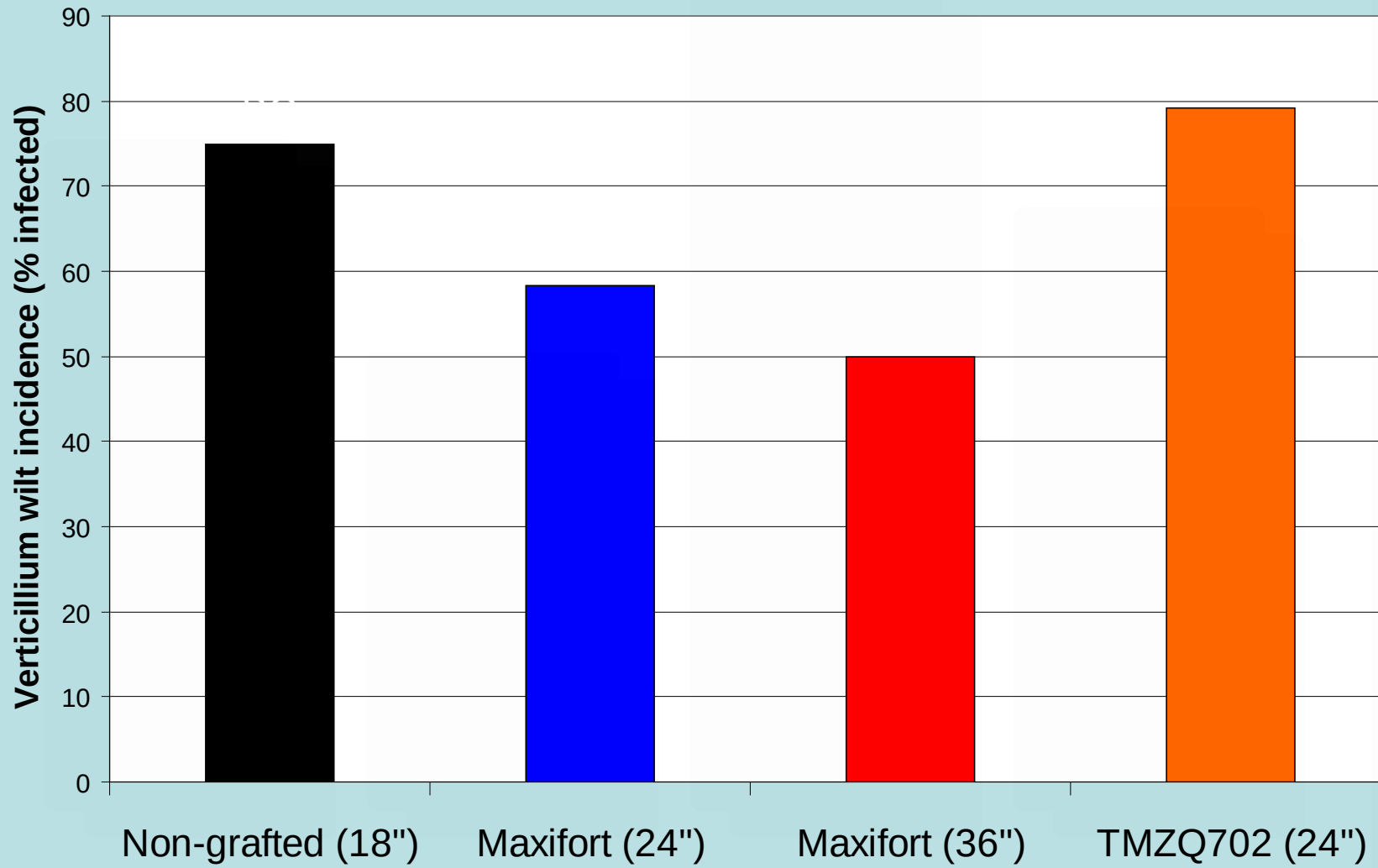


LSD based on $P=0.05$

The background is a collage of various vegetables. In the top left, there's a close-up of a strawberry. To its right and below are several tomatoes, some whole and some sliced. In the center, there's a dark rectangular area containing four green bell peppers. The bottom right shows more green bell peppers. The text "Western NC Trial" is overlaid in white on the central dark area.

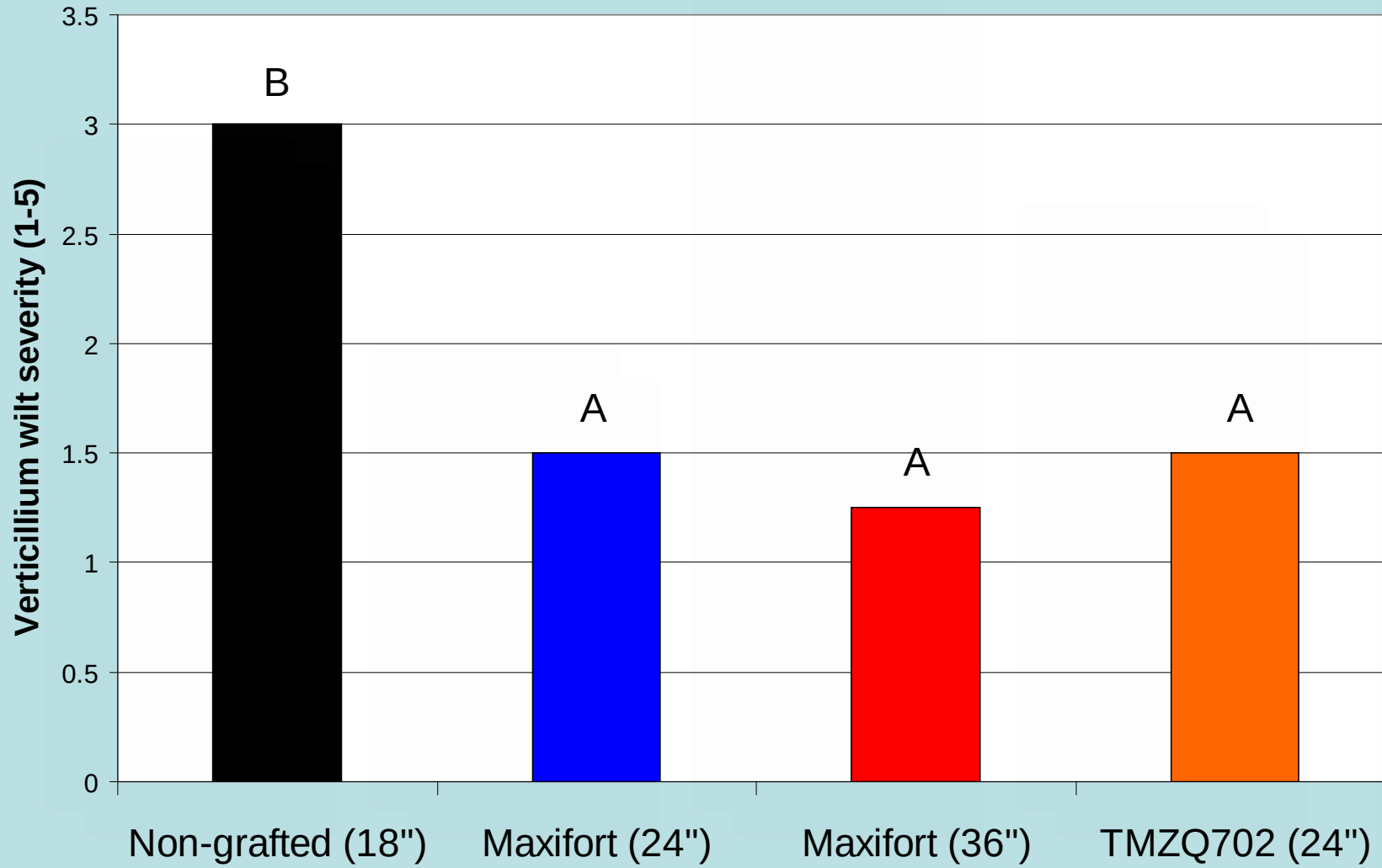
Western NC Trial

Verticillium Wilt - Madison Co.



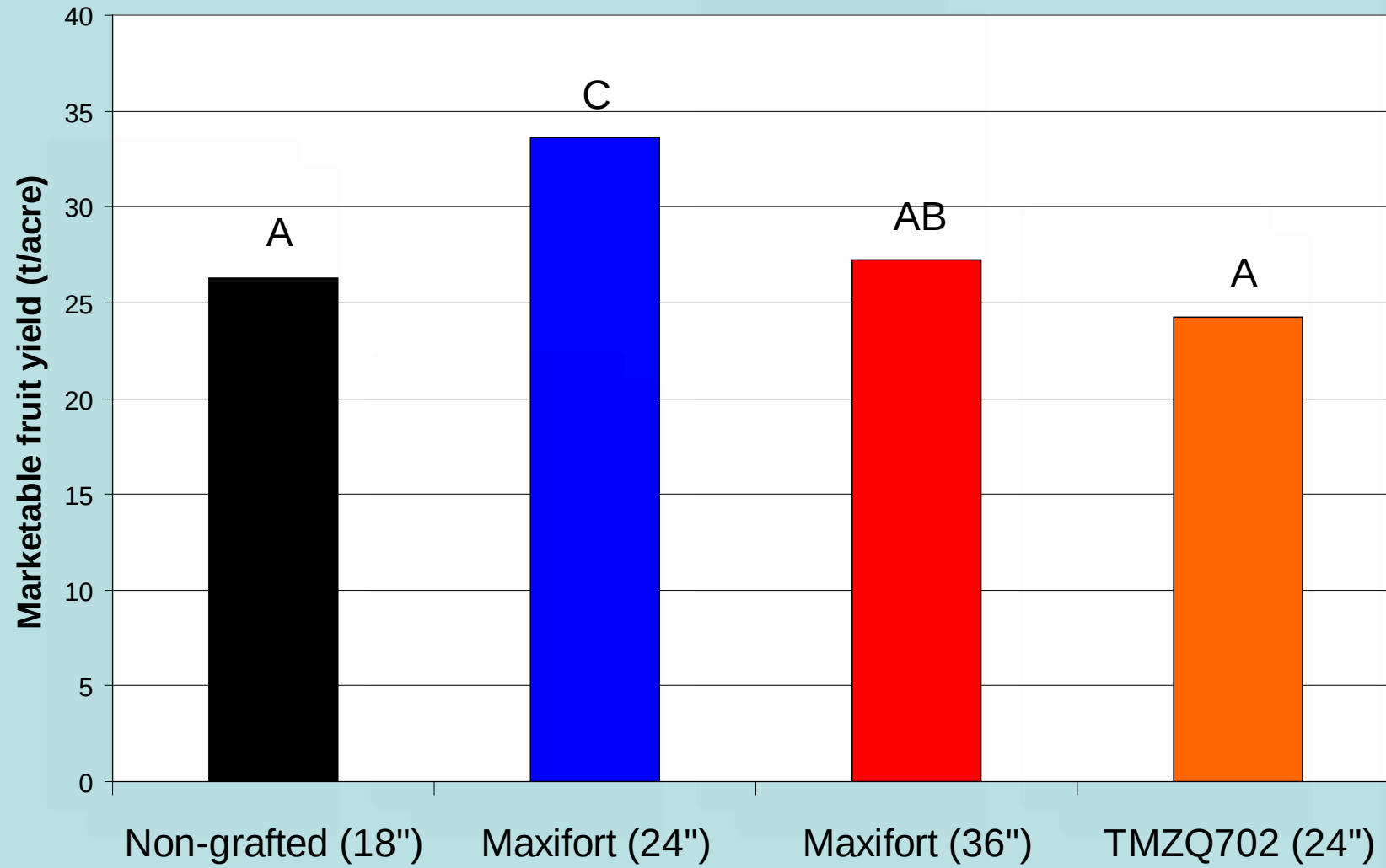
LSD at P = 0.05

Verticillium Wilt - Madison Co.



LSD at P = 0.05

Fruit Yield - Madison Co.



LSD at $P = 0.05$

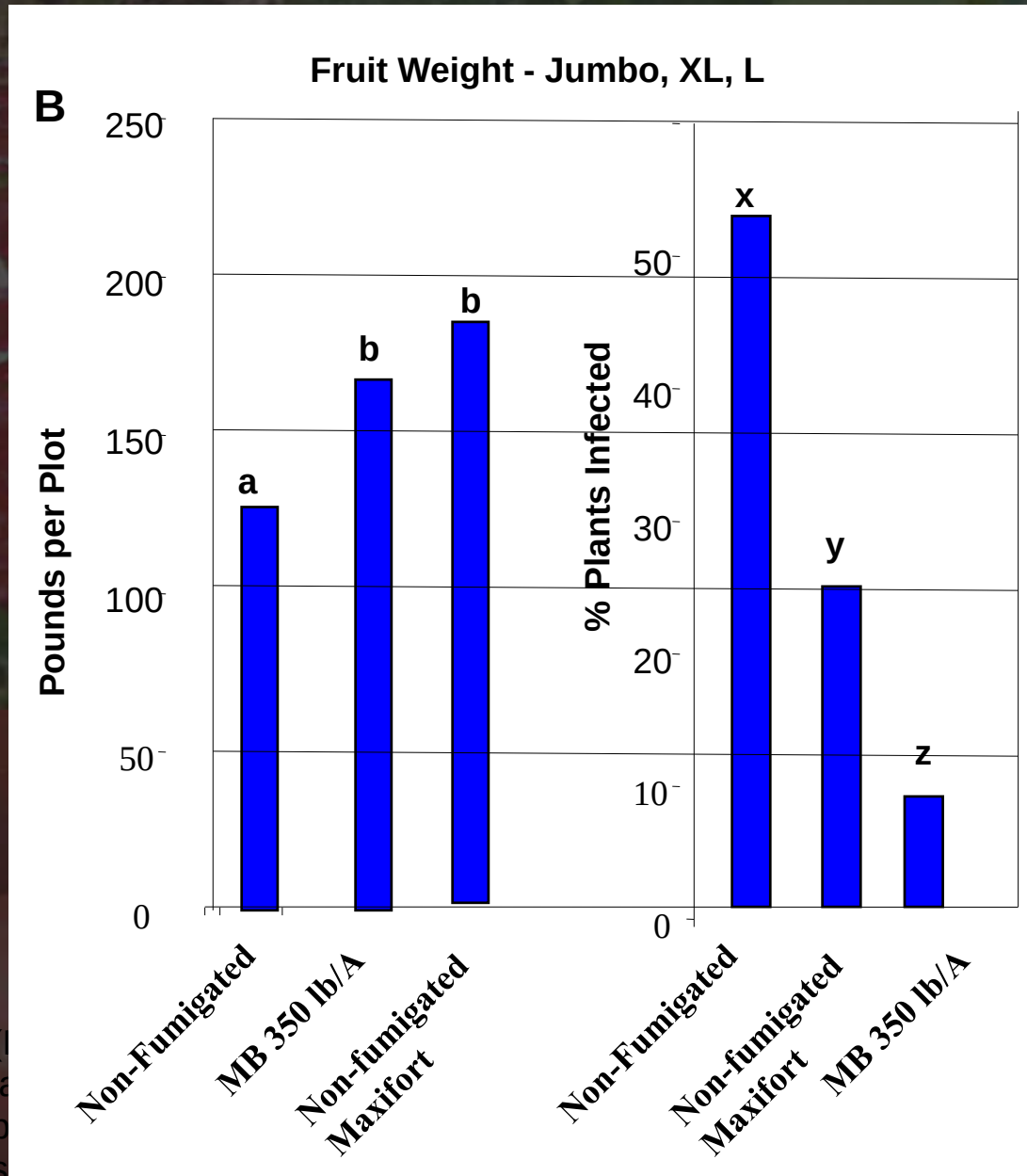
Verticillium Wilt



Non-grafted



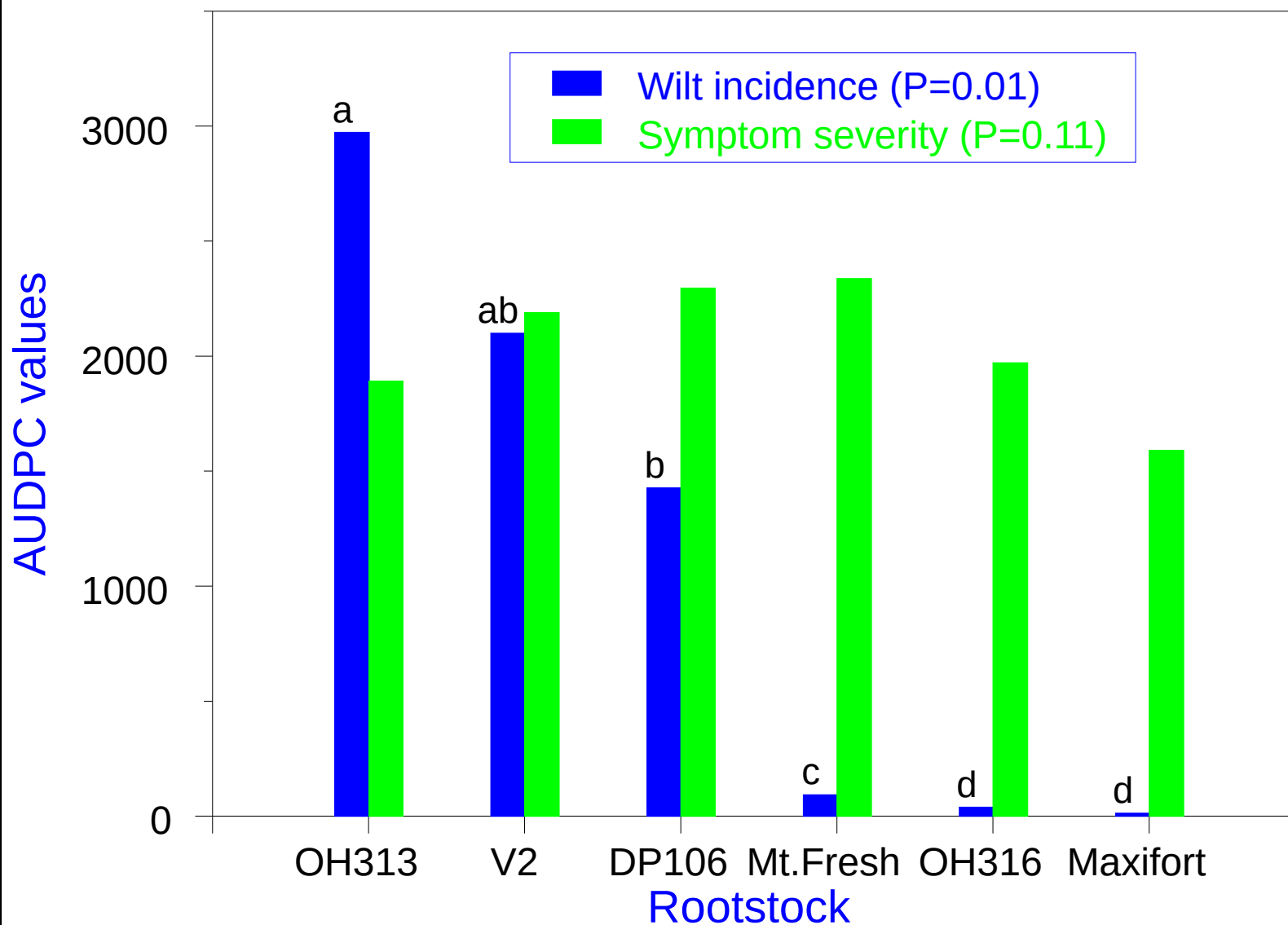
Maxifort



Maxifort rootstock substantially reduced VW incidence but not
was well as in MB treated plots.

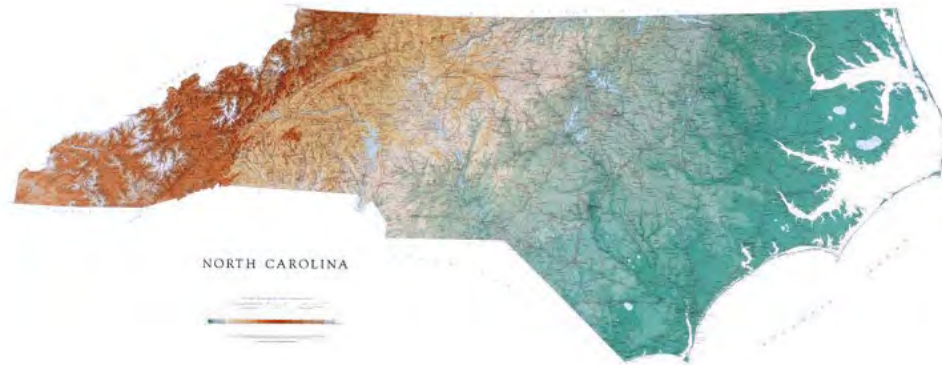
Our first indication NC strains were probably not “race 2”)

Incidence and severity of Verticillium wilt
On-Farm Research



Regional importance of various soilborne tomato pathogens in North Carolina

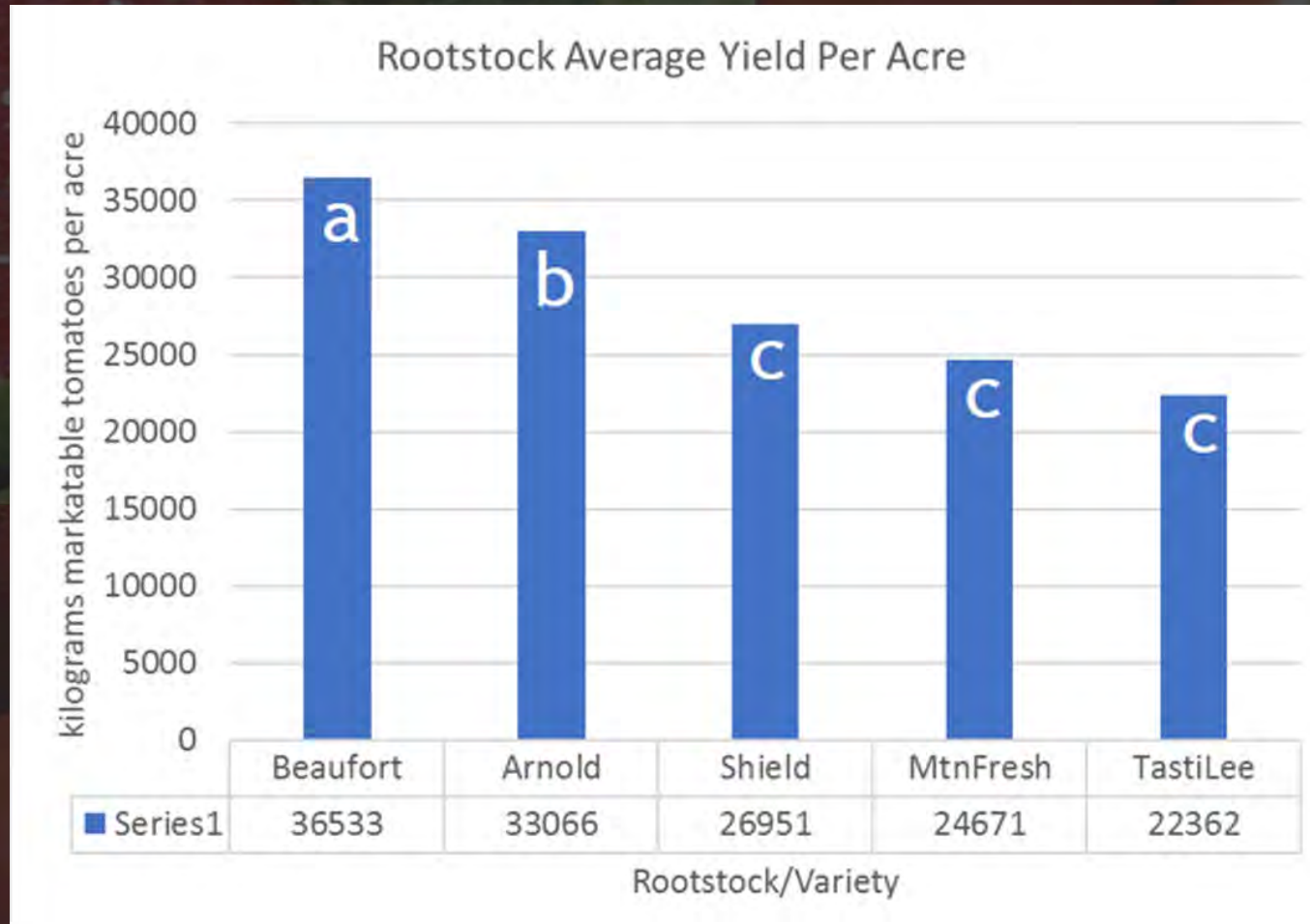
Pathogen	ECOLOGICAL ZONE			Graft Potential
	Coastal Plain	Piedmont	Mountains	
<i>Verticillium dahliae</i> race 1	----	*	***	*****
<i>Verticillium dahliae</i> race 2	----	*	*****	**
<i>Fus. oxy. f.sp. lycopersici</i> race 0 or 1	*****	*****	*****	*****
<i>Fus. oxy. f.sp. lycopersici</i> race 2	*	**	*****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



Louws et al. 2010

Does grafting help if there is no disease pressure?

It depends



Mills River Experiment: “New Land”; No fumigation



Grafting to Increase Production for High Tunnel Tomato Growers

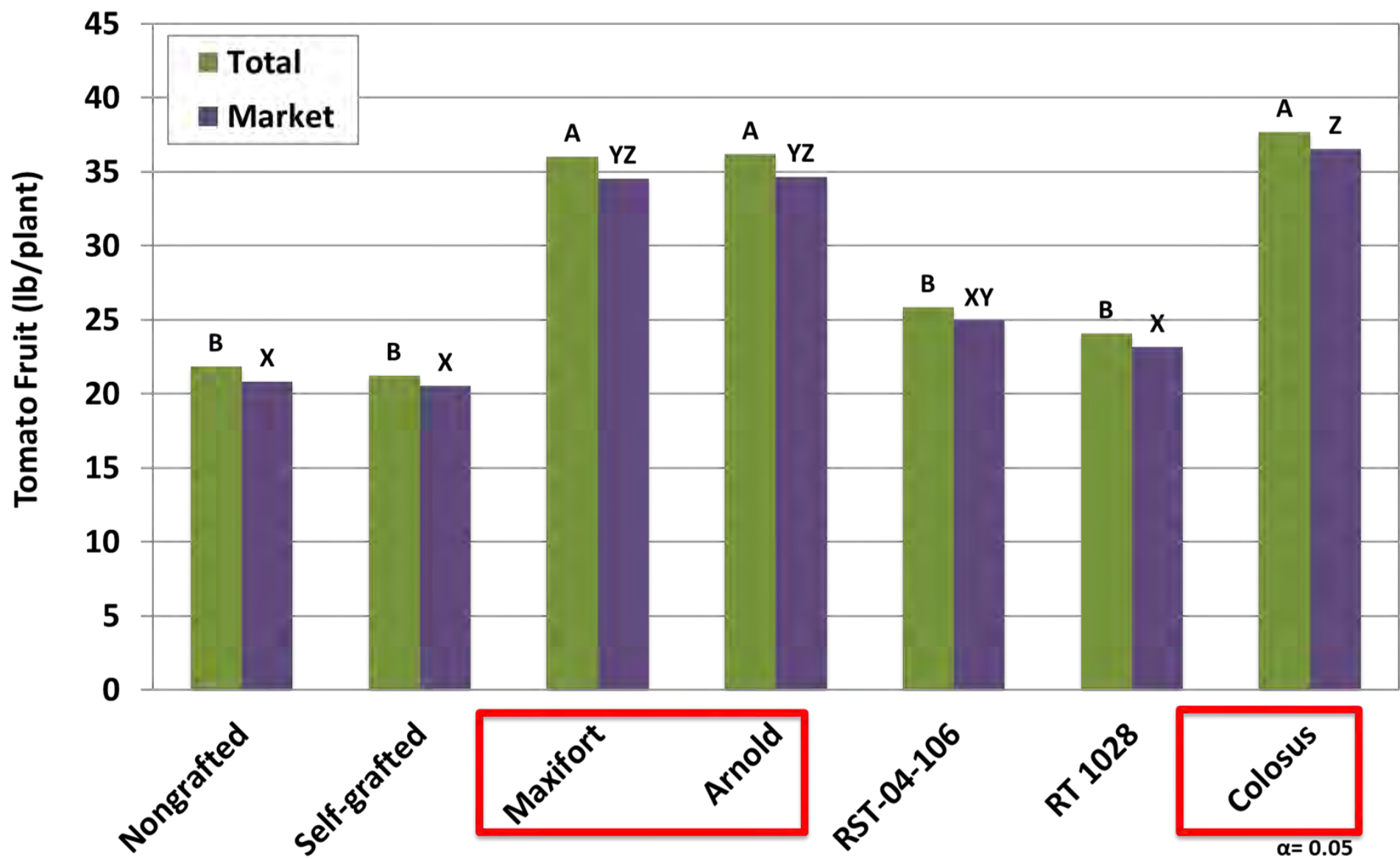
Cary L. Rivard, Ph.D.

**Dept. of Horticulture and
Natural Resources**



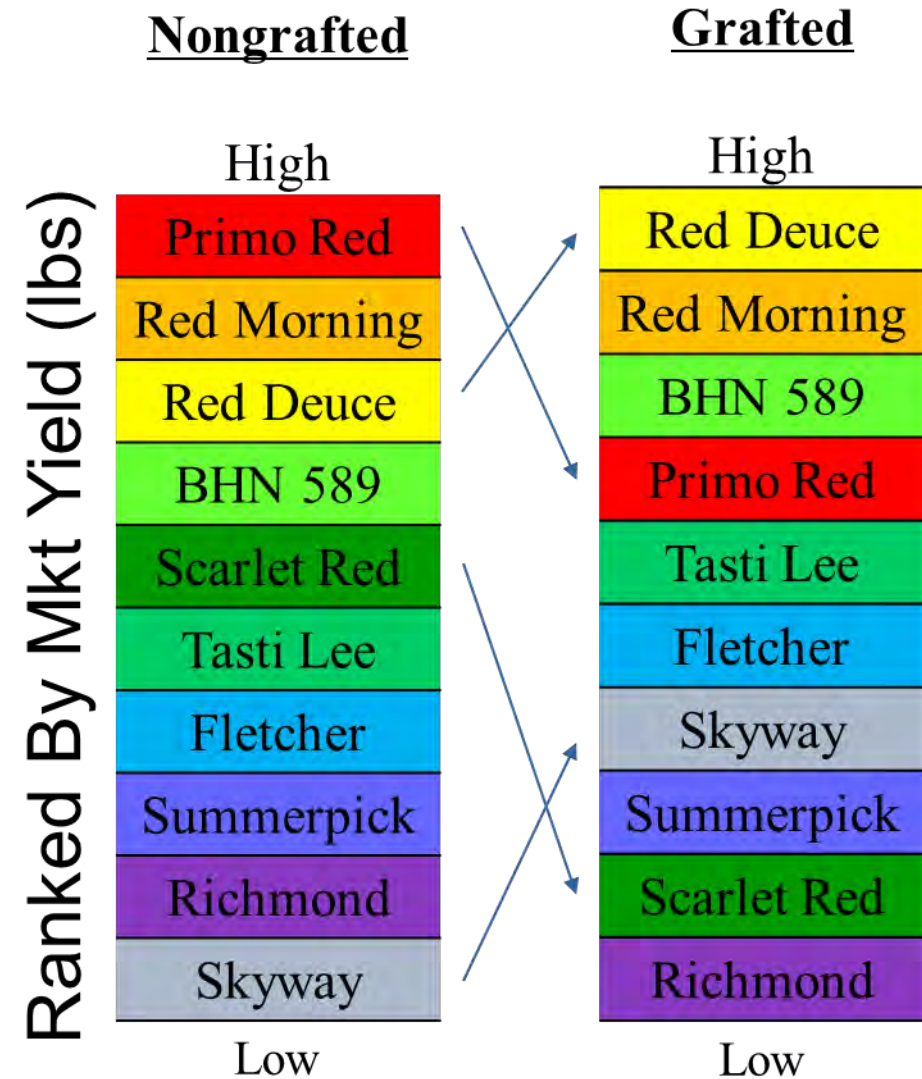
K-STATE
Research and Extension

Gieringers Marketable and Total Fruit Weight



Scion/Rootstock Compatibility

	Scion	change
Highly Compatible	Tasti Lee	60%
	Skyway	56%
	BHN 589	48%
	Fletcher ?	43%
	Red Deuce	41%
Moderately Compatible	Richmond	40%
	Summerpick	37%
Compatible	Red Morning	25%
	Scarlet Red	21%
	Primo Red	9%



(Loewen et al., 2018)

Growing New Roots

Grafting to Enhance Resiliency in U.S. Vegetable Industries

Developing New Rootstocks for U.S.A

Cucurbit

Working Group Report



**Pat Wechter,
Richard Hassell**

**USDA-ARS,
Clemson
University**

U.S.VegetableLaboratory

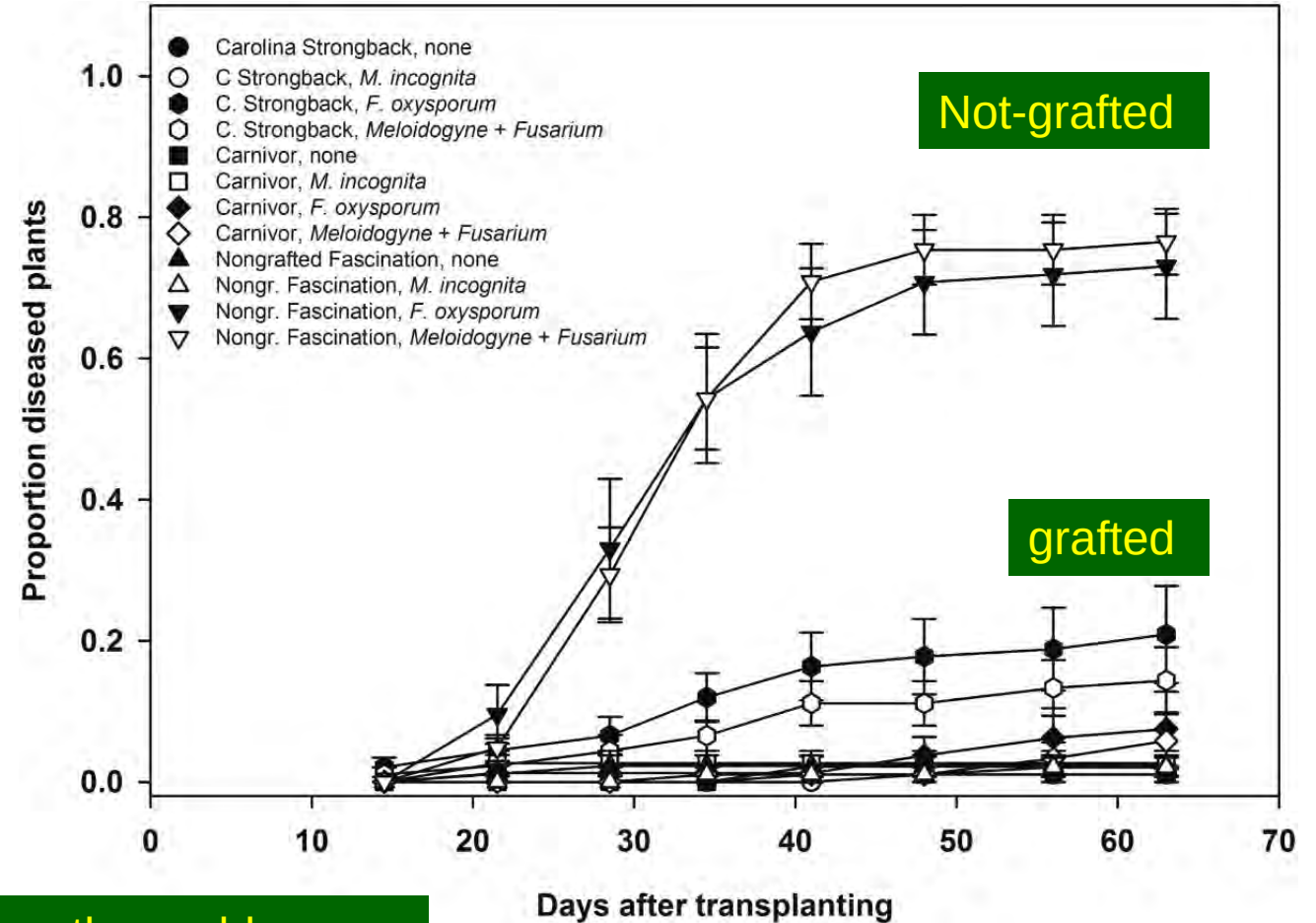
Charleston, SC

Incidence of Fusarium Wilt on Grafted and Non-Grafted 'Fascination' Inoculated with FON race 2, RKN, or Both Pathogens, Charleston, SC 2016 & 2018



Anthony Keinath,
Paula Agudelo and
Sean Toporek

Clemson University

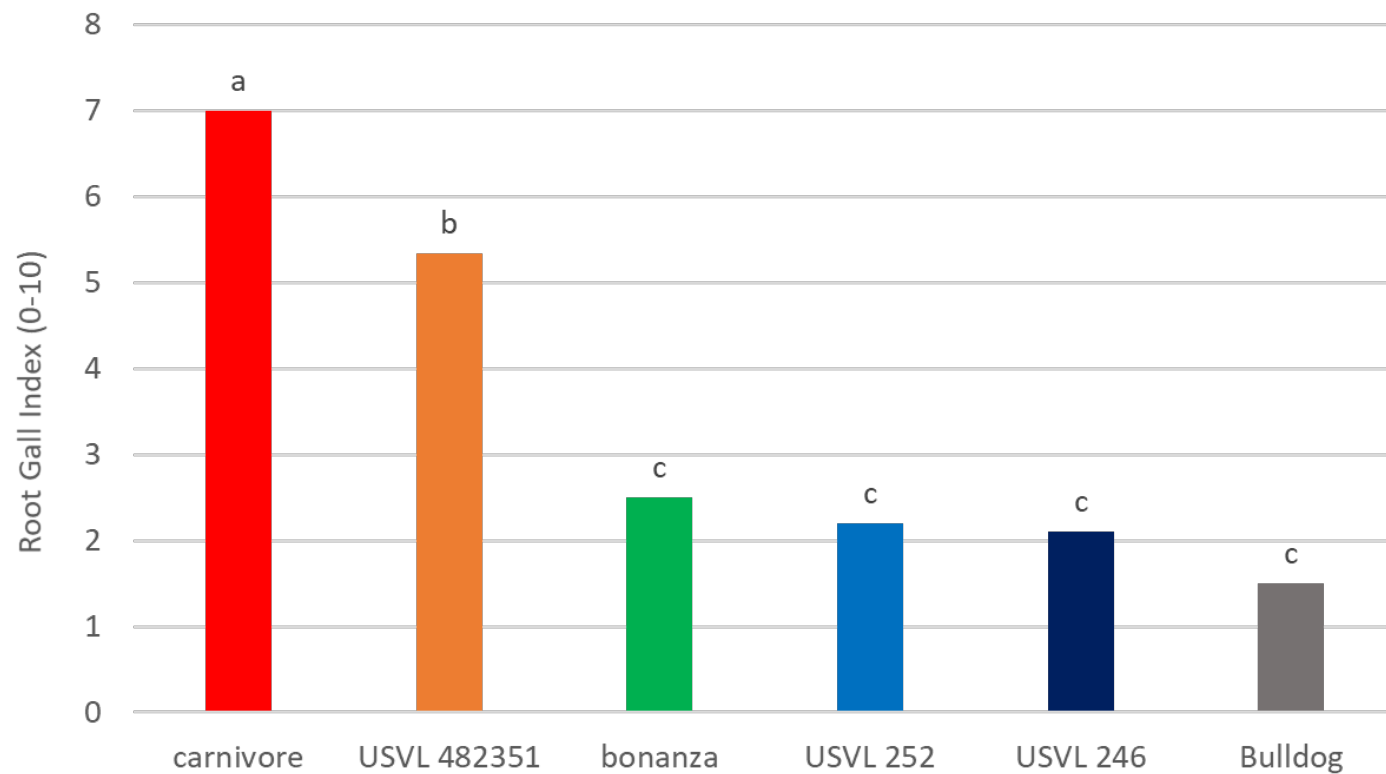


Know the problem:

Fusarium wilt?

Root knot nematode?

Root-Gall Index from Rootstocks Screened for Nematode Resistance in Quincy, FL (Josh Freeman)



Carolina Strongback-Rootstock

Cucurbit Working Group



Josh Freeman

University of Florida

North Florida Research
and Education Center



Carolina Strongback

- *Citrullus lanatus* var. *citroides* watermelon
- Developed and Released, USDA-ARS (Syngenta Vegetable Seeds)
- High Levels of Tolerance to *Fusarium oxysporum* f. sp. *Niveum* (Fon) races 1 & 2
- High Levels of Tolerance to Rootknot Nematode
- Produces an Abundance of Seed

Limited ROI in NC trials

- emerging data (specialty melons; FON)

Growing New Roots Grafting to Enhance Resiliency in U.S. Vegetable Industries

Grafting Technology Working Group Report

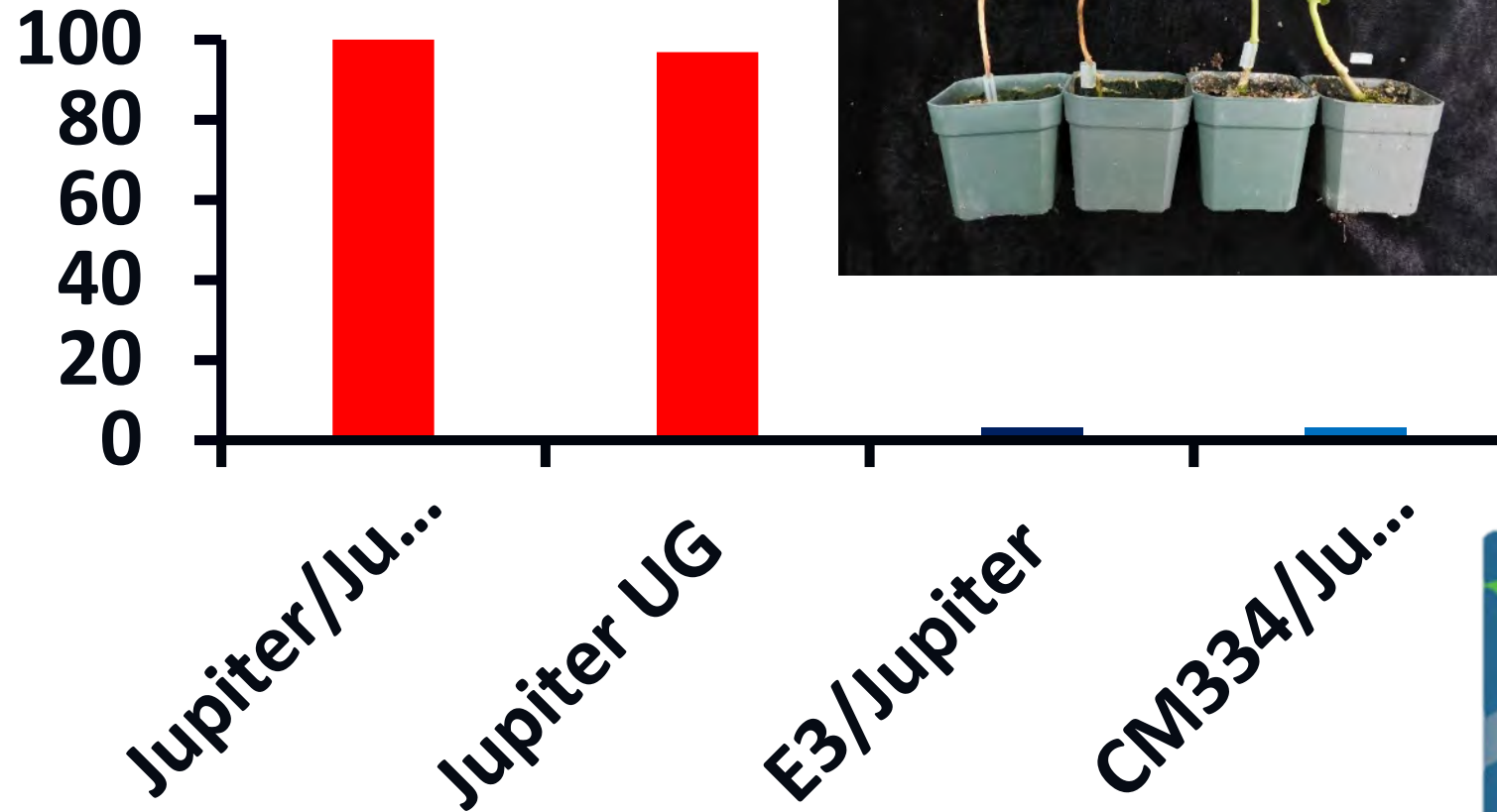


Jonathan Schultheis
North Carolina State
University
USDA



Phytophthora crown rot incidence on 'Jupiter' Bell Pepper grafted on New Resistant Rootstock in a Greenhouse Trial

Phytophthora crown rot (%)



Shaker Kousik
Research Plant
Pathologist at U.S.
Vegetable Laboratory,
USDA-ARS

Use of Unrooted Grafted Vegetable Cuttings



PI: Chieri Kubota

Postharvest Evaluations

(Penny Perkins-Veazie, Xin Zhao)





2012 PLANTING

Grafts

Rootstock

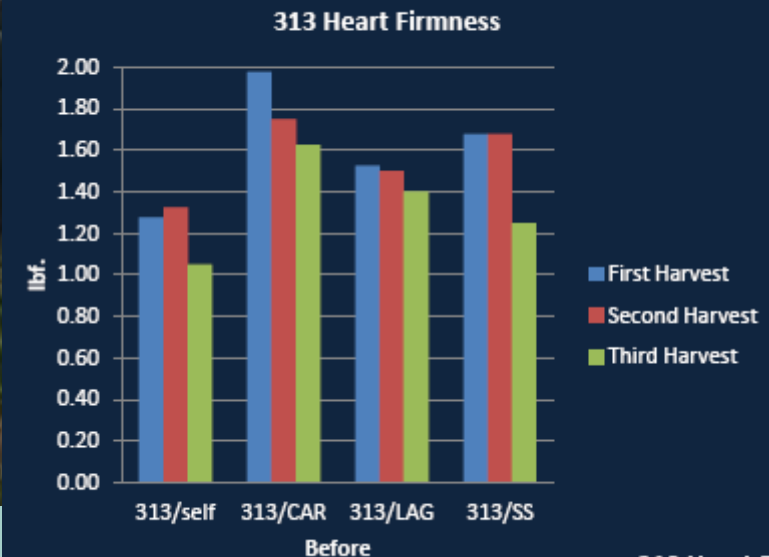
1. "Self"
2. Carnivor
3. Lagenaria
4. Super Shintosa

Scion

1. Tri-x-313
2. Fascination
3. Sugar Coat
4. Sugarheart
5. Sugar Red

Treatments

1. Zero weeks after ripeness
2. One week after ripeness
3. Two weeks after ripeness





Unique product lines for retail market



Photo by Alice Doyle

Tim Wada



Log House Plants



Photo by Hishtil





YOU CAN GROW ME!

veg-ease!

PREMIUM GRAFTED PLANTS

GRAFTED CELEBRITY



All America Selections winner! Heavy yields of tasty tomatoes.
An all-purpose variety with superb flavor, disease resistance and heavy yield on determinate plants. Crack-resistant fruits average 7 oz.

Why GRAFTED? Grafting is a natural art that joins the top of one plant to the root of another creating a stronger plant with high yields of great tasting fruit.



I like:
Full Sun



Fruit Size:
7 oz.



Plant Size:
3'-4'



Matures:
70 days



Fruit bearing:
Determinate



Plant me:
24"-36" apart



GRAFTED GROWERS

www.graftedgrowers.com

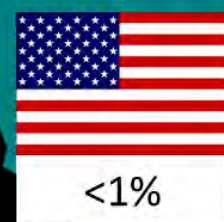
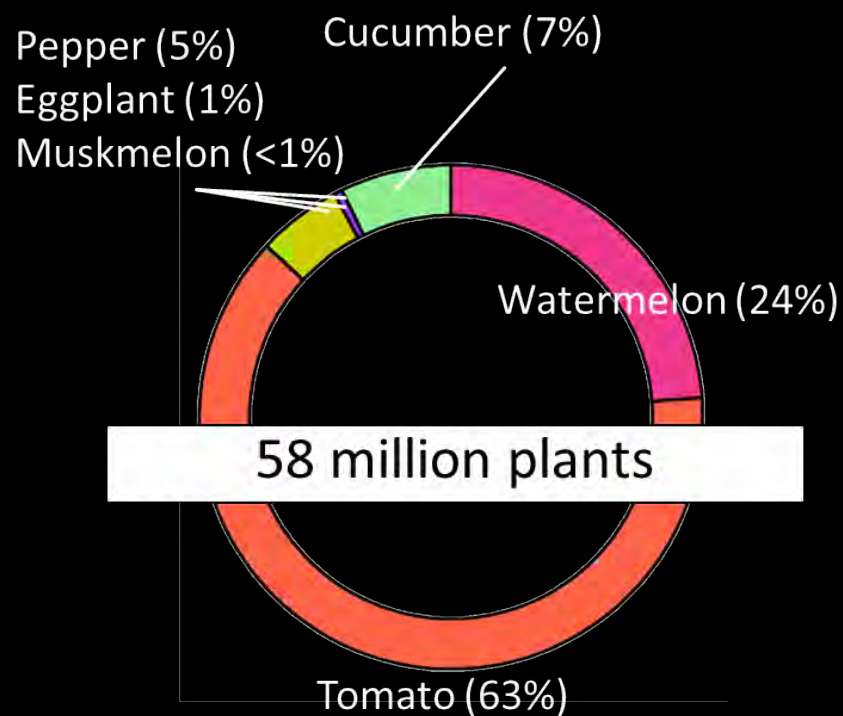


GMO

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

Transplant price premium				Sale prices			
	\$ 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
\$ 1.25	4.46	1.84	1.16	0.84	0.66	0.55	0.47
\$ 1.50	5.36	2.21	1.39	1.01	0.80	0.66	0.56
\$ 1.75	6.25	2.57	1.62	1.18	0.93	0.77	0.65
\$ 2.00	7.14	2.94	1.85	1.35	1.06	0.88	0.75
\$ 2.25	8.04	3.31	2.08	1.52	1.20	0.99	0.84
\$ 2.50	8.93	3.68	2.31	1.69	1.33	1.10	0.93

Grafting Production in North America



(2000): <100k*

(2012): 47 million*

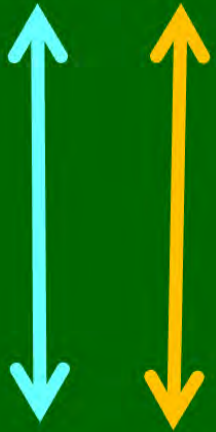
+23%

(2019): 58 million



Grafting: Where will it serve you best?

**System
Simplicity**



**Market
Niche**

Scale neutral but system specific

Limited rotation + organic
Soilborne pathogens
Indeterminate
Heirloom



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

**Length
of Harvest**



**Production
Issues**

