USDA SCRI
FUNDING# 2011-01397

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2016-51181-25404

Grafting Vegetables:
The Science and Practice of Growing New Roots

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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

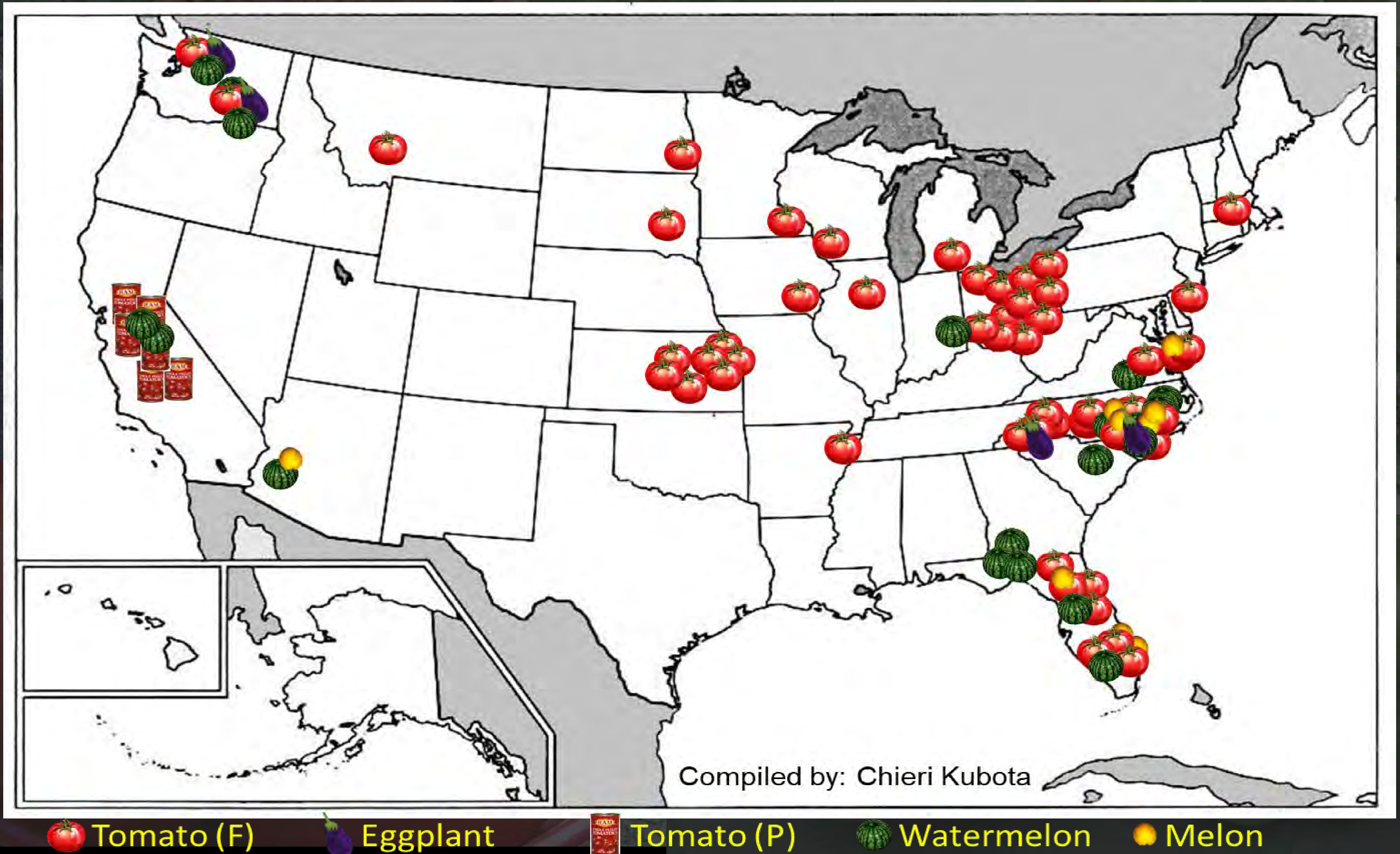
Private Industry:
- Robotic companies
- Seed companies
- Plant nurseries
- Gower associations
- Growers
- 75+ partners

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



Scale neutral but system specific

System Simplicity

Market Niche

LTD rotation + organic
Soilborne diseases
Indeterminate
Heirloom

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

Length of Harvest

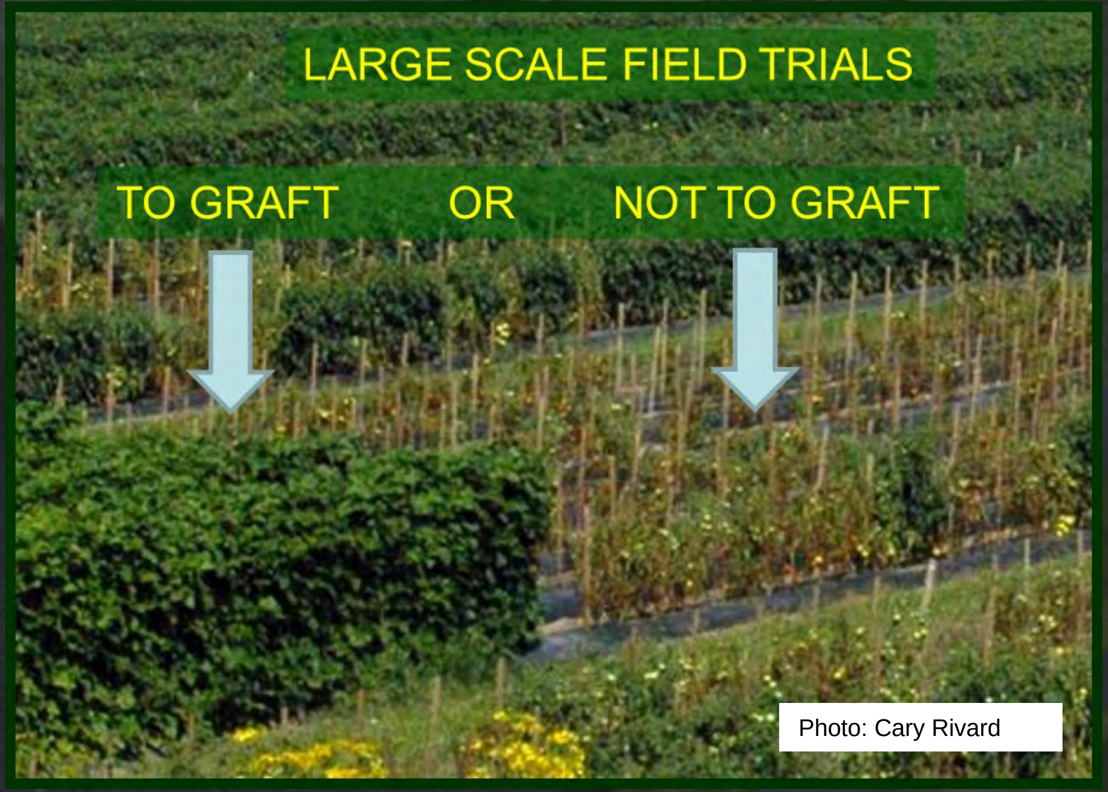
Production Issues

Develop a comprehensive website: vegetablegrafting.org

The **Vegetable Grafting Decision Support Tool**
http://graftingtool.ifas.ufl.edu

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

Train Graduate Students and Professionals

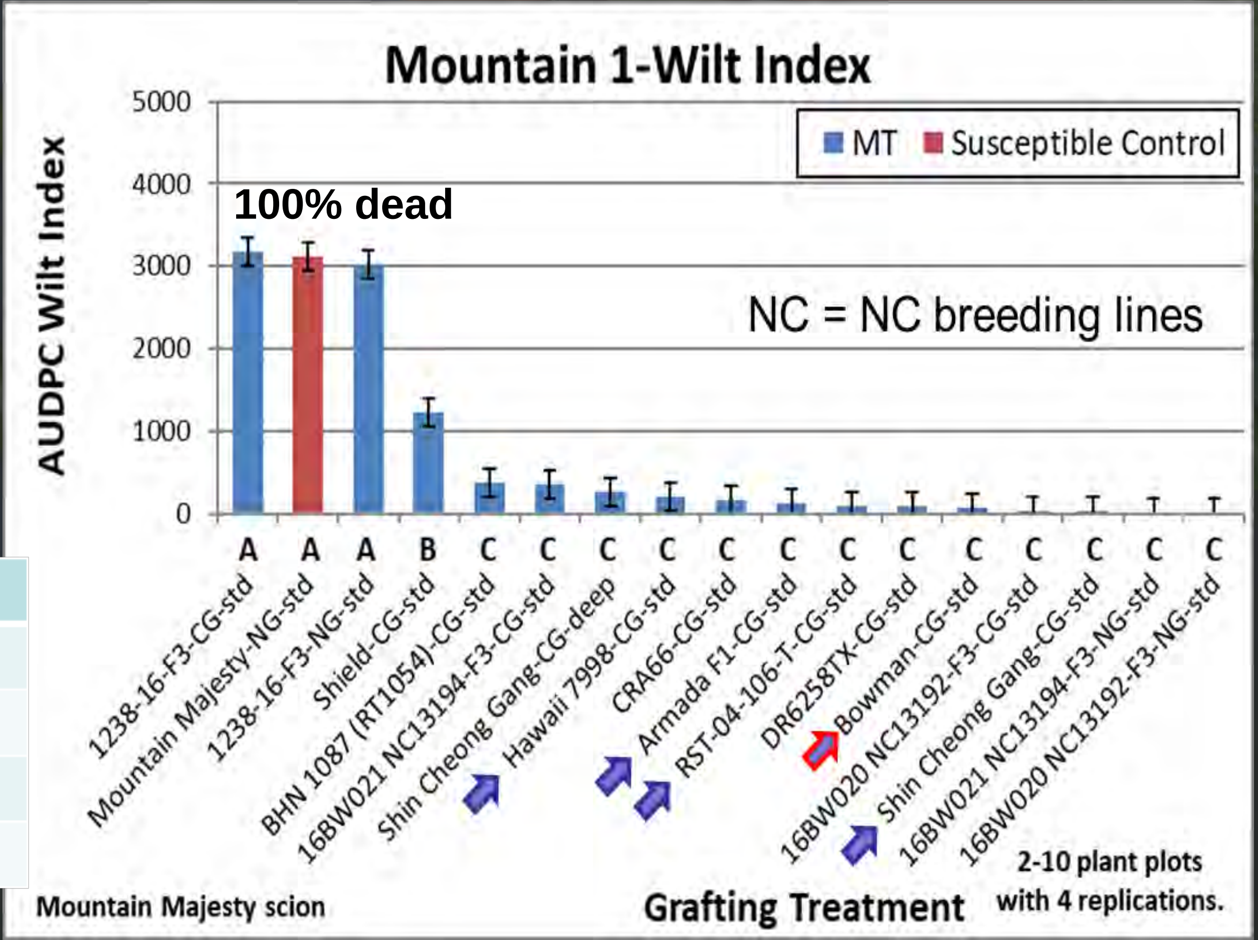


Bacterial Wilt
Ralstonia solanacearum

Race 1, biovar 1, phylotype II and sequevar 7

Not R3bv2

Available and emerging genetics



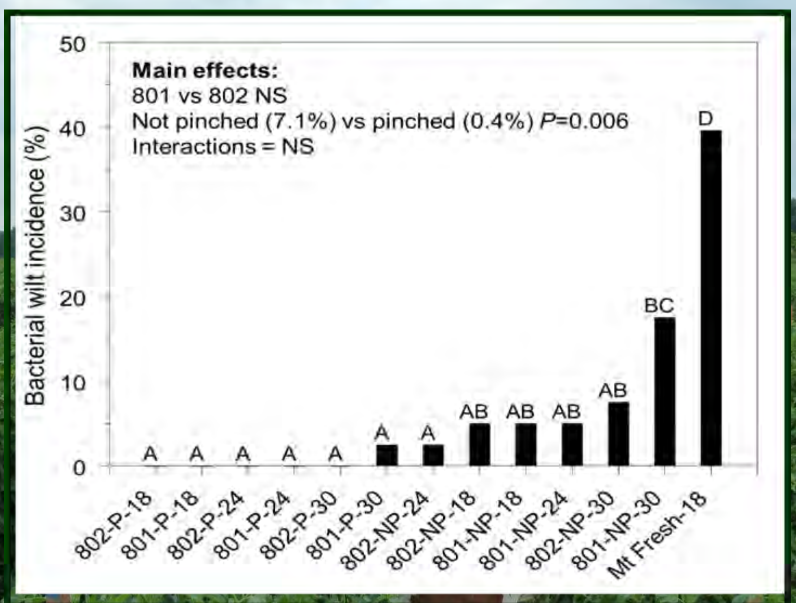
Recommended Rootstocks for Bacterial Wilt of Tomato

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)**

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.

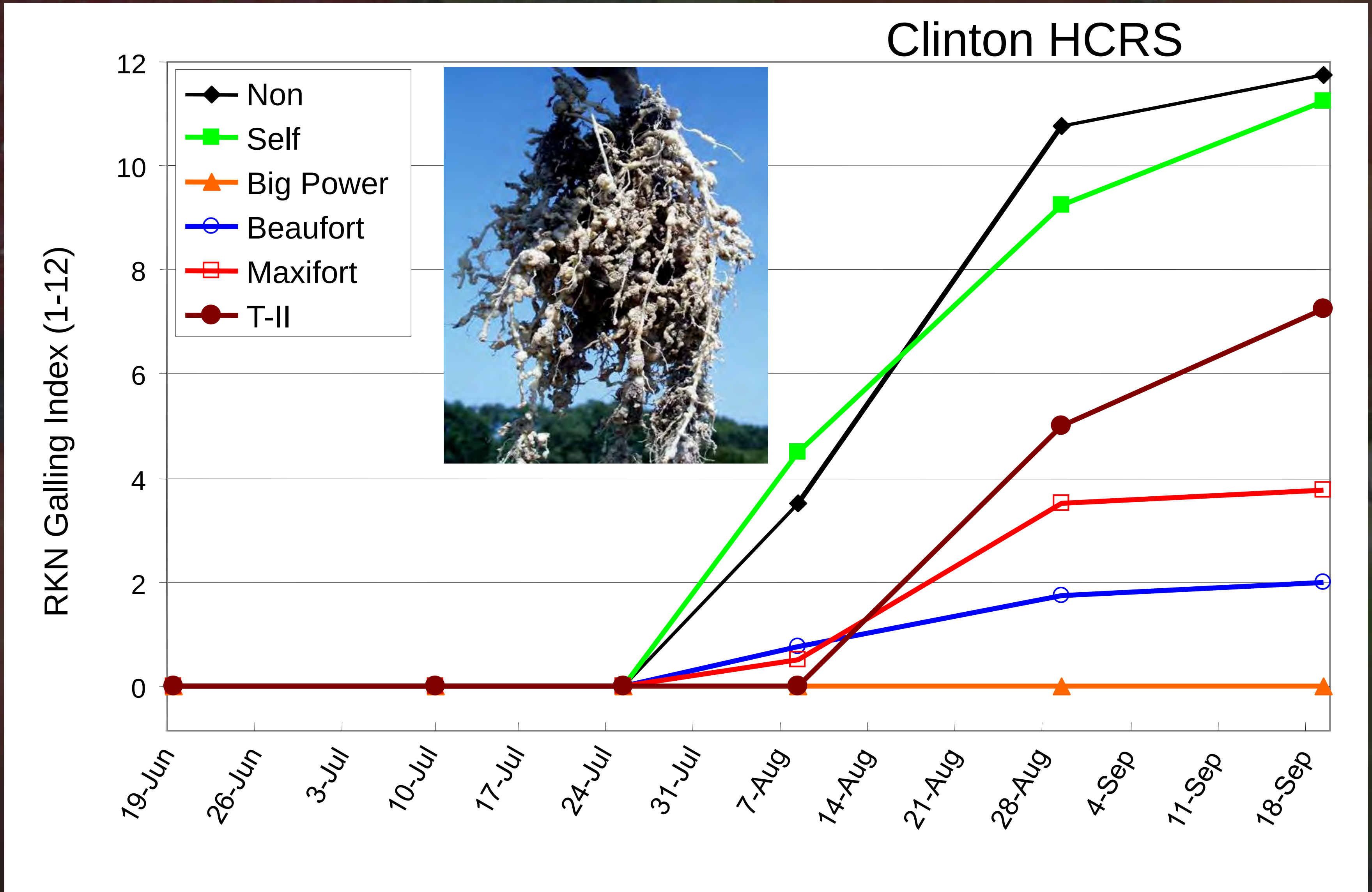


Grafting to Manage Bacterial Wilt

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

Root Knot Nematode

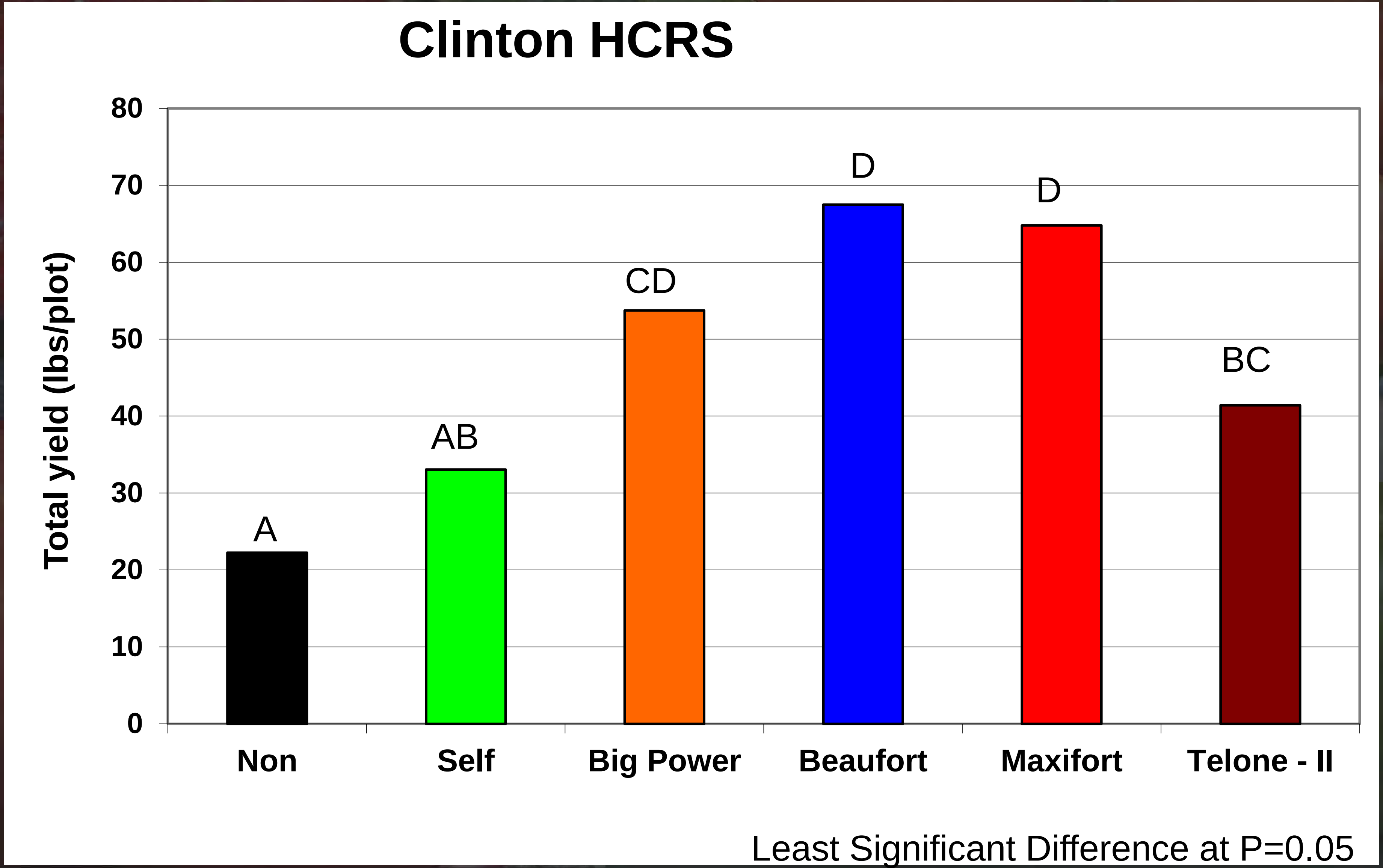
Meloidogyne incognita race 1 (Mi gene)



Rivard and Louws, 2008

Root Knot Nematode

Meloidogyne incognita race 1



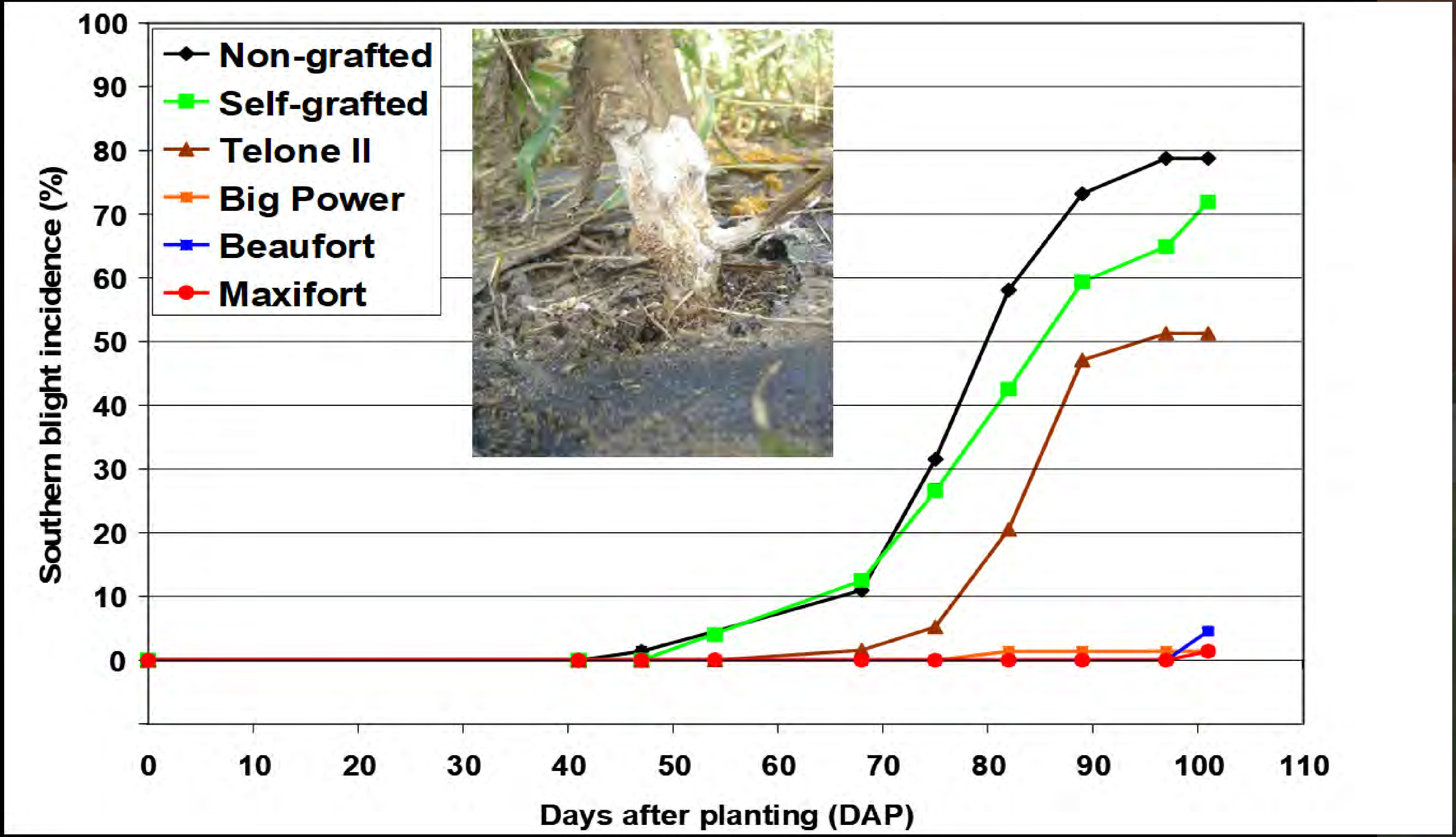
RKN Populations

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

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)

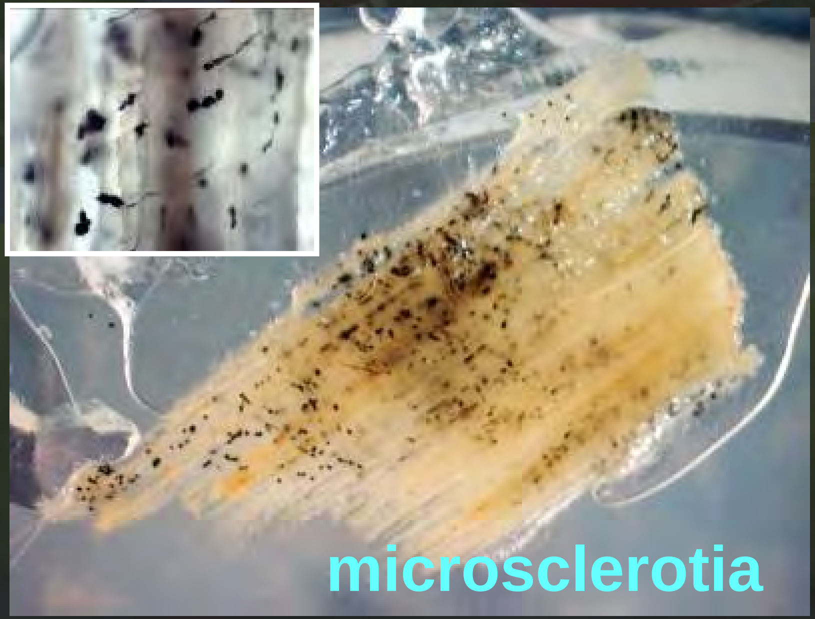
https://peregrinefarm.net/tag/fusarium-wilt/

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

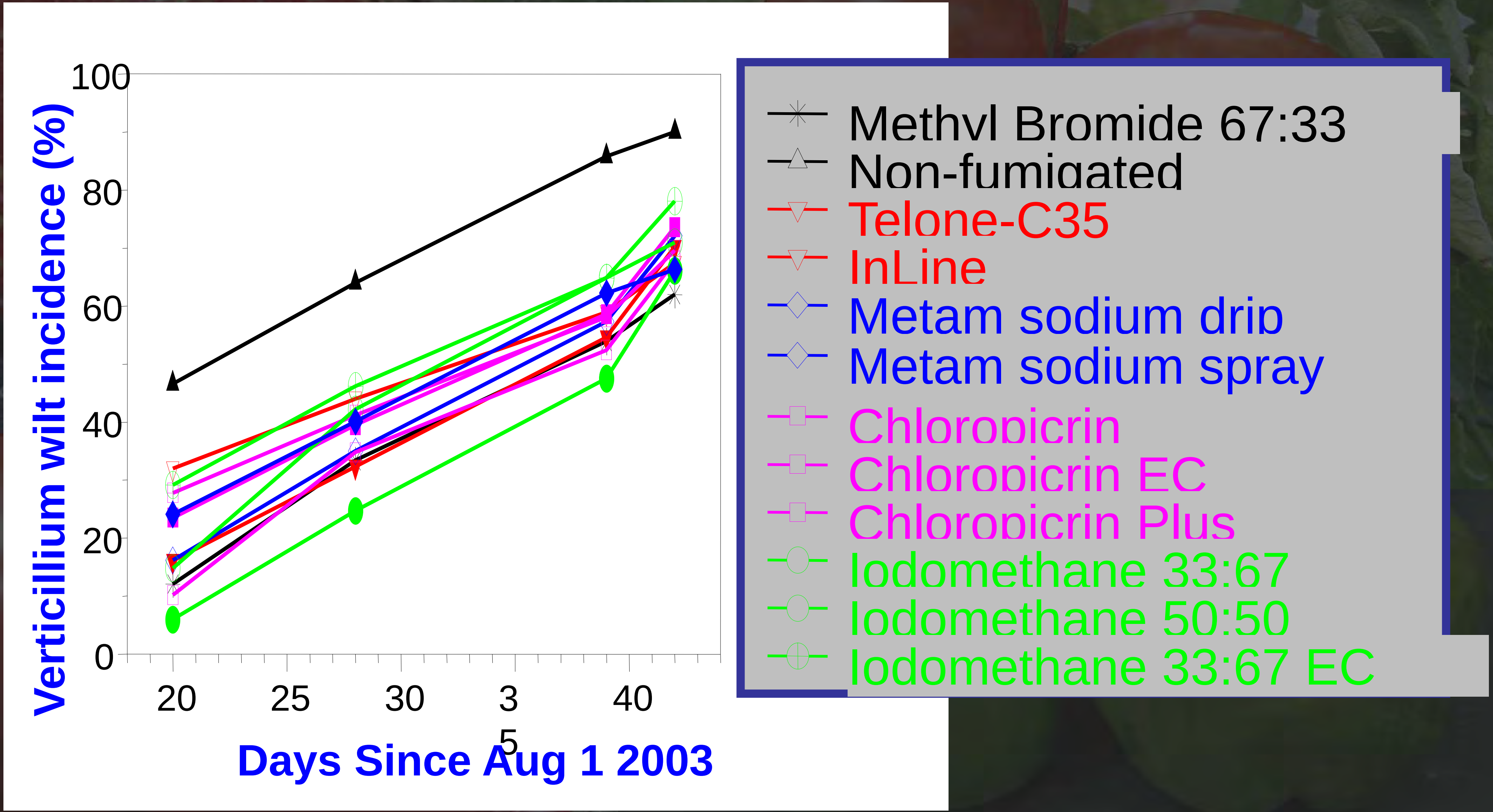
Same is true for Fusarium root and crown rot

Verticillium Wilt

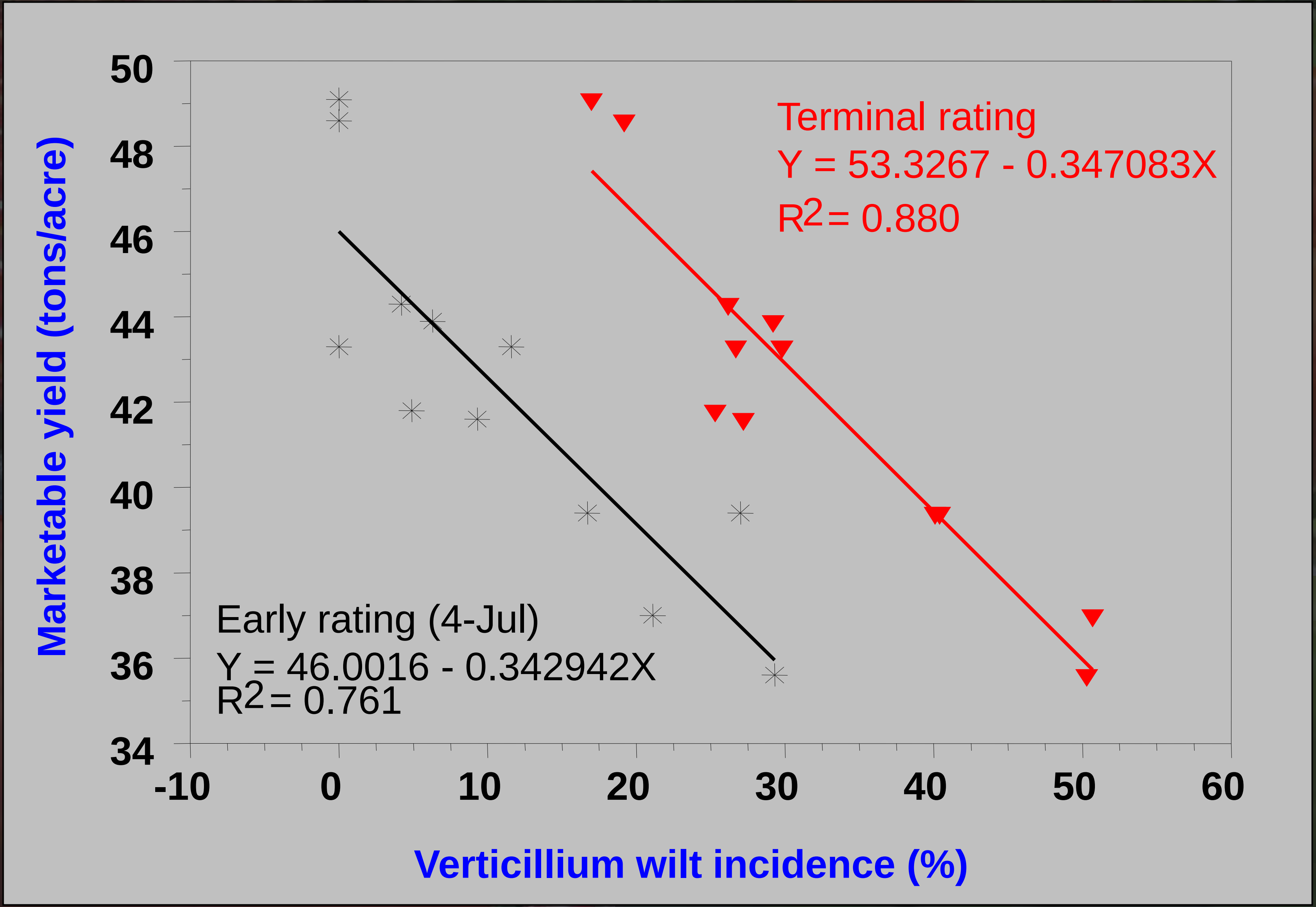
- ***Verticillium dahliae* (race 1 & 2)**
  - Loss of vigor
  - Wilting and leaf necrosis
  - Favored in temperate climates
  - "Race 2" prevalent in WNC (*Bender & Shoemaker, 1984*)
  - Highly persistent in soils
  - Non-host specific



2003 Incidence of Verticillium Wilt



Verticillium Wilt Incidence and Yield



Life on the Farm:
Systems Management

Planting Depth

Suckering

Twin leader for
European string trellis

Cedar Meadow Farm

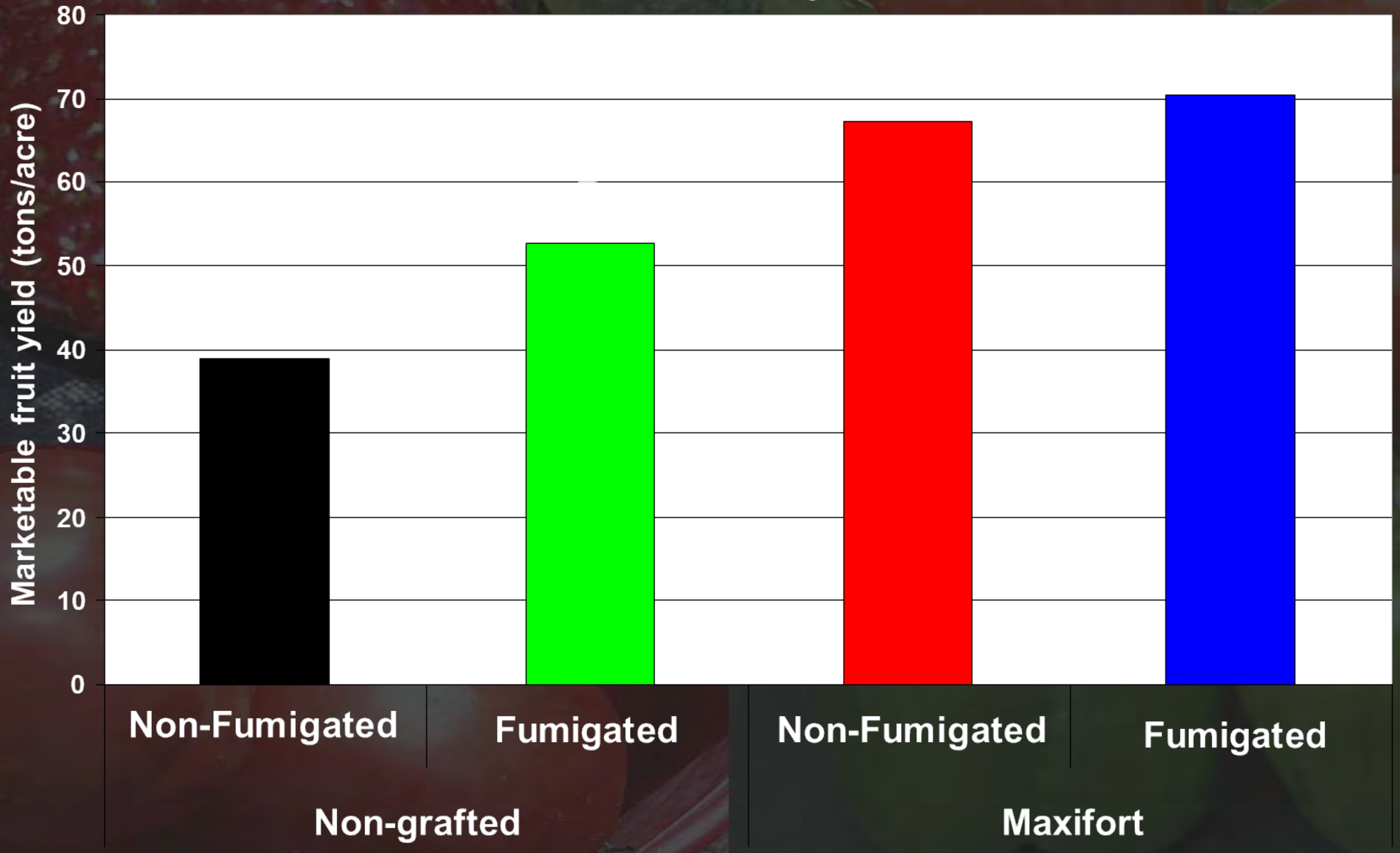
- Can vigorous rootstock be used to manage verticillium wilt?
  - ‘Maxifort’
- How does grafting fit in with fumigation?
  - Additive or alternative
- Can we reduce economic constraints through cultural methods?
  - Plant spacing/Twin training

Steve Groff

Cedar Meadow Farm – Lancaster County, PA

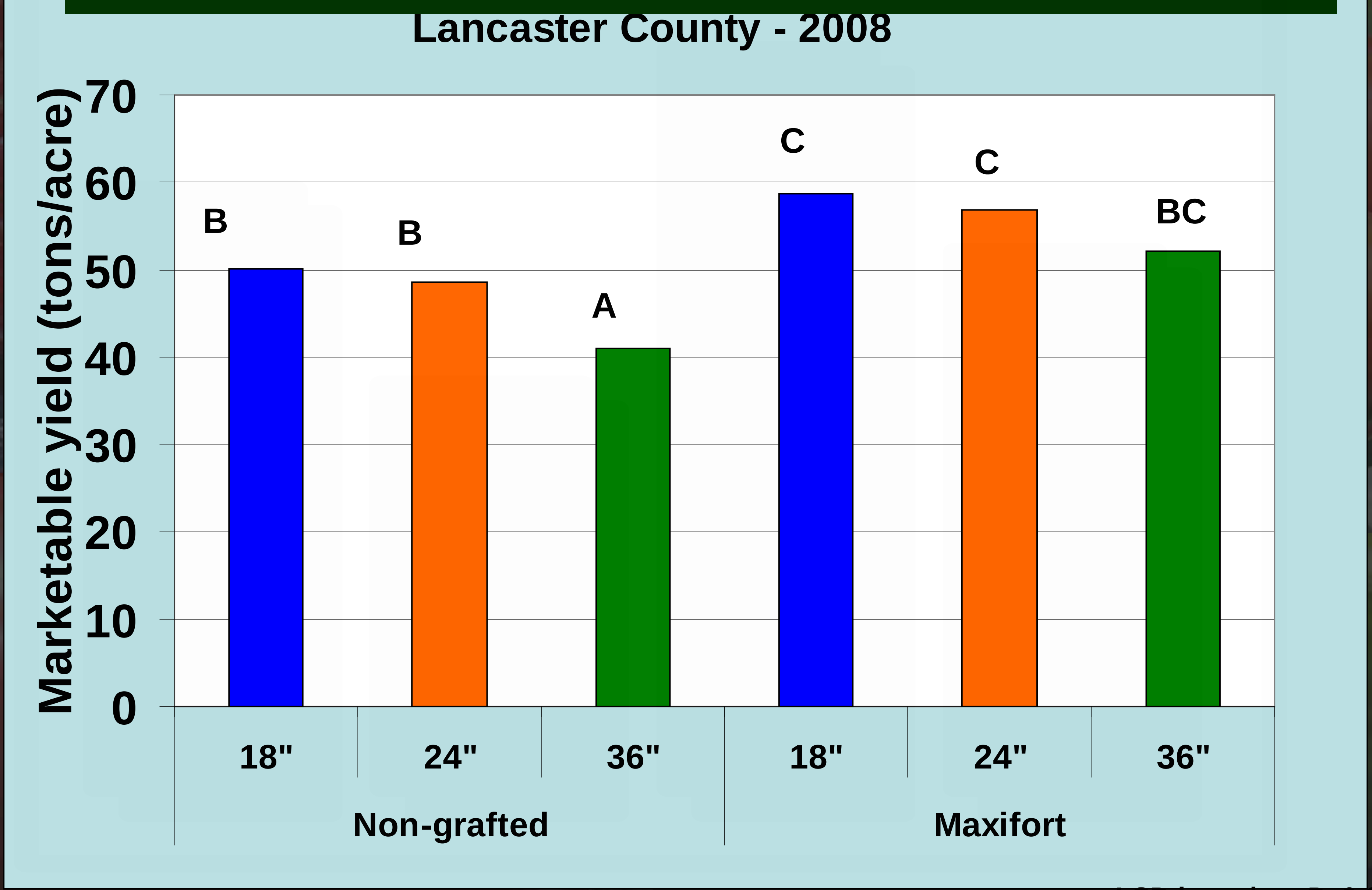
Cedar Meadow Farm

Lancaster County - 2009



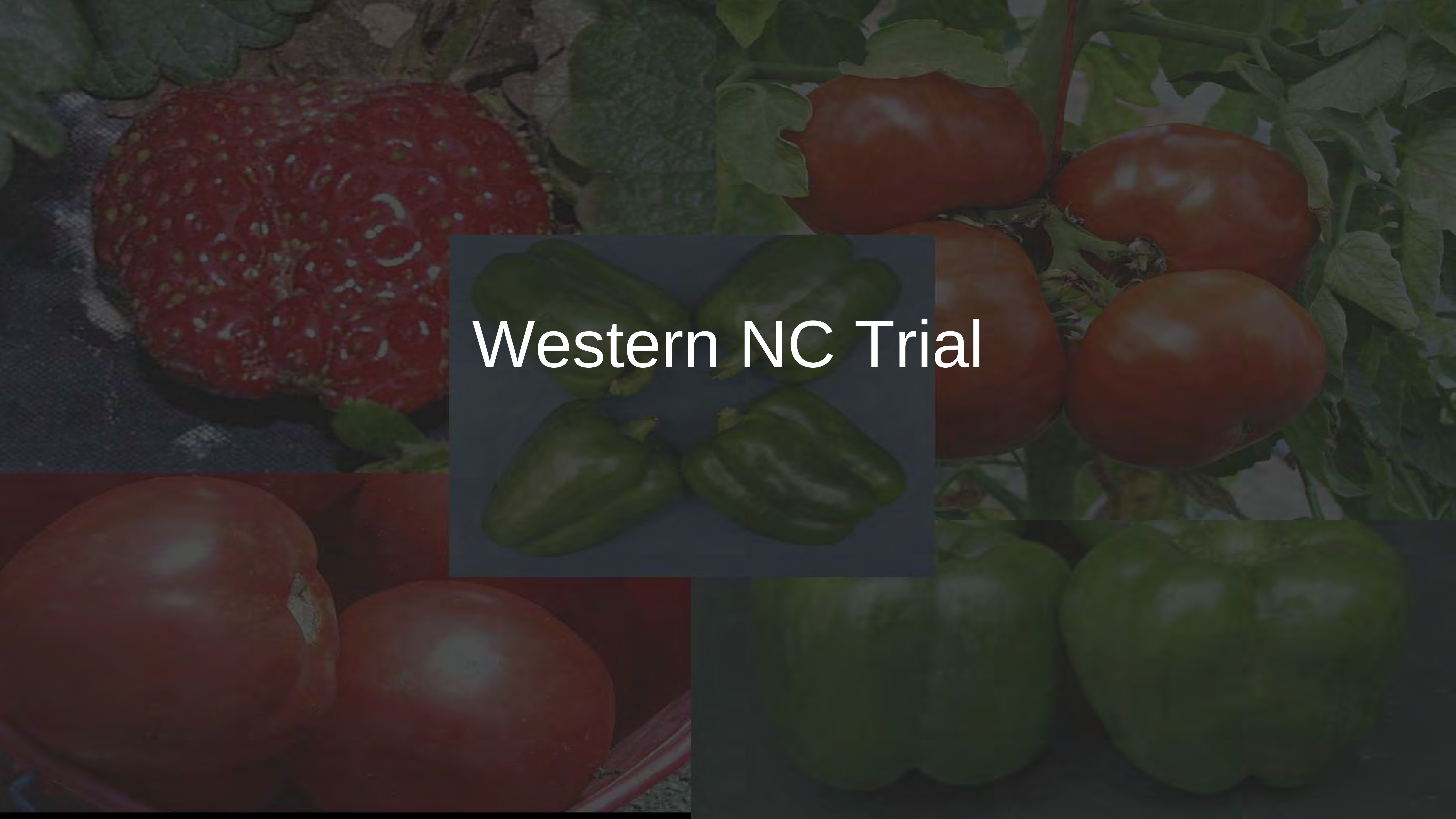
LSD *P = 0.05*

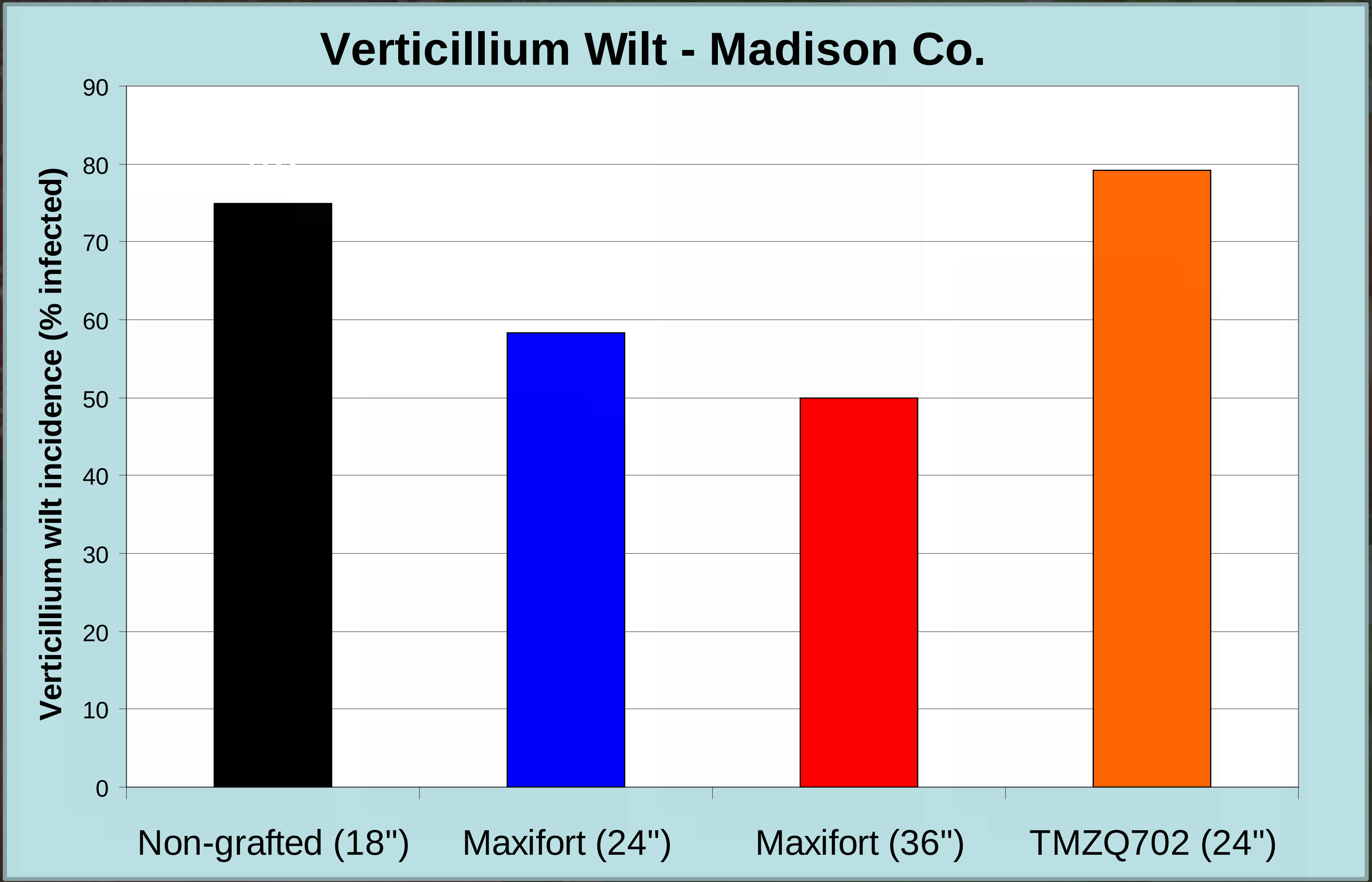
Cedar Meadow Farm (Verticllium is primary problem)



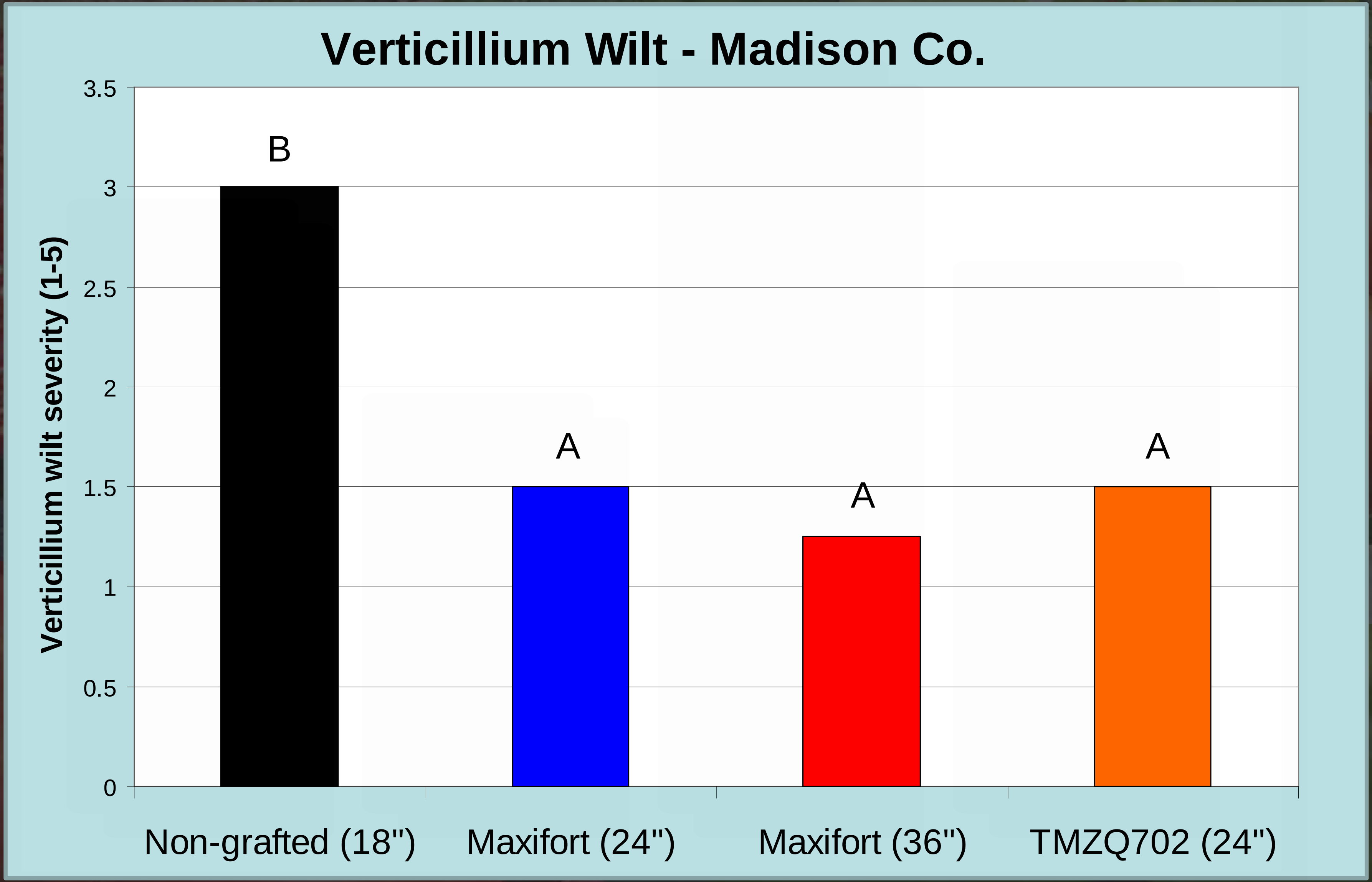
LSD based on *P=0.05*

Western NC Trial



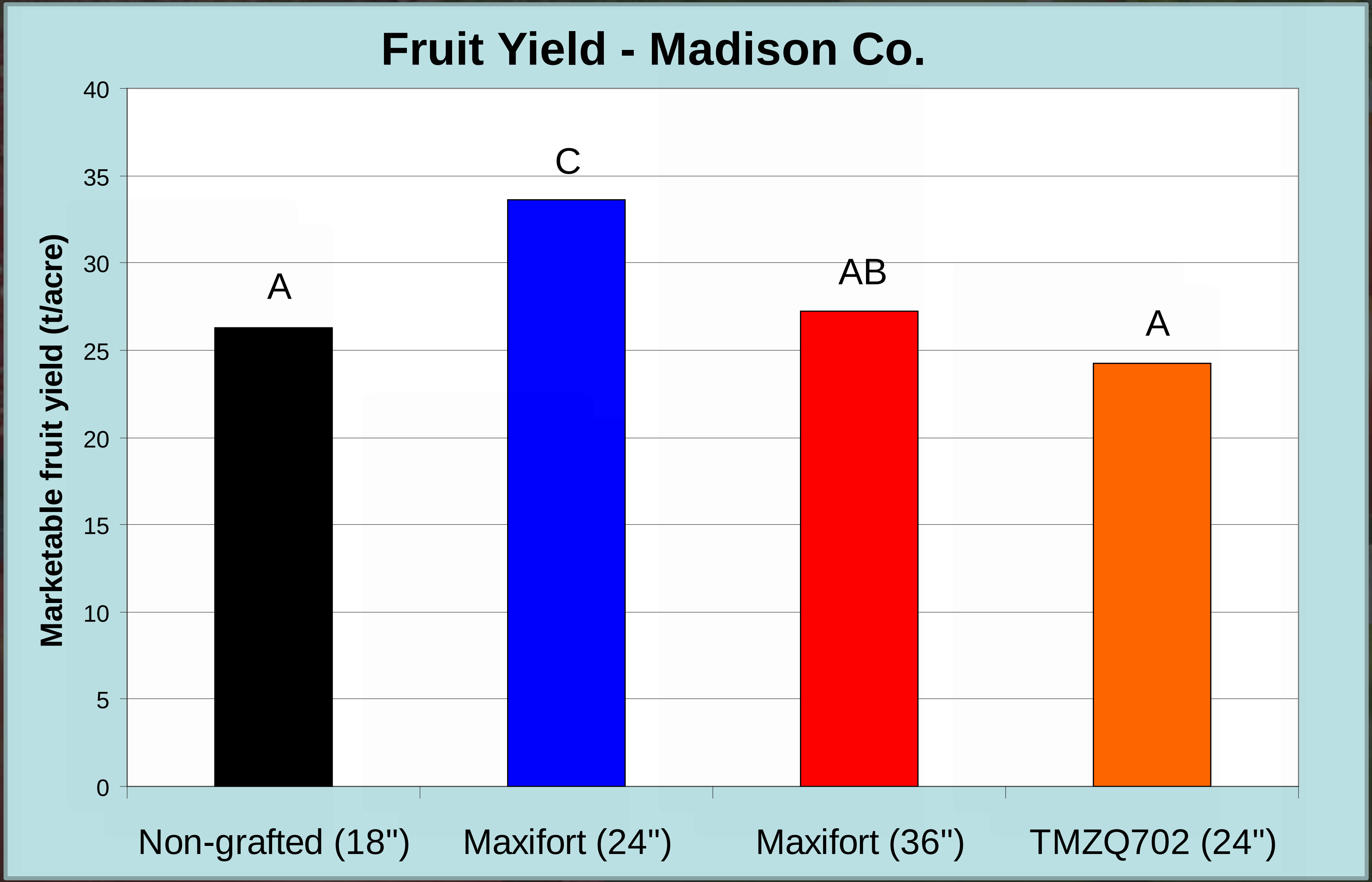

Verticillium Wilt - Madison Co.
Verticillium wilt incidence (% infected)
0
10
20
30
40
50
60
70
80
90
Non-grafted (18")
Maxifort (24")
Maxifort (36")
TMZQ702 (24")

LSD at P = 0.05



Verticillium Wilt - Madison Co.
Verticillium wilt severity (1-5)
3.5
3
2.5
2
1.5
1
0.5
0
B
A
A
A
Non-grafted (18")
Maxifort (24")
Maxifort (36")
TMZQ702 (24")

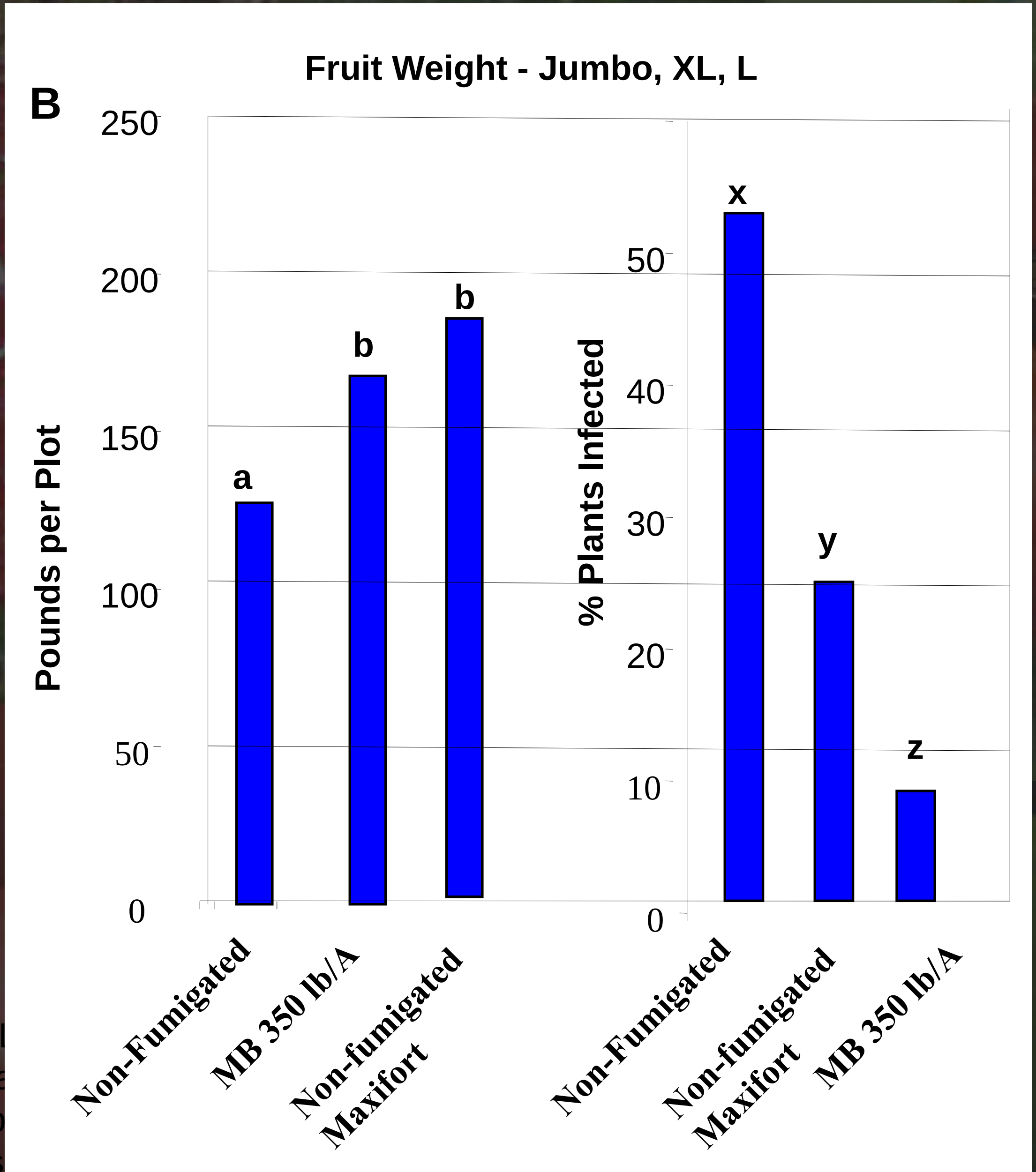
LSD at P = 0.05



Fruit Yield - Madison Co.
Marketable fruit yield (t/acre)
0
5
10
15
20
25
30
35
40
A
C
AB
A
Non-grafted (18")
Maxifort (24")
Maxifort (36")
TMZQ702 (24")

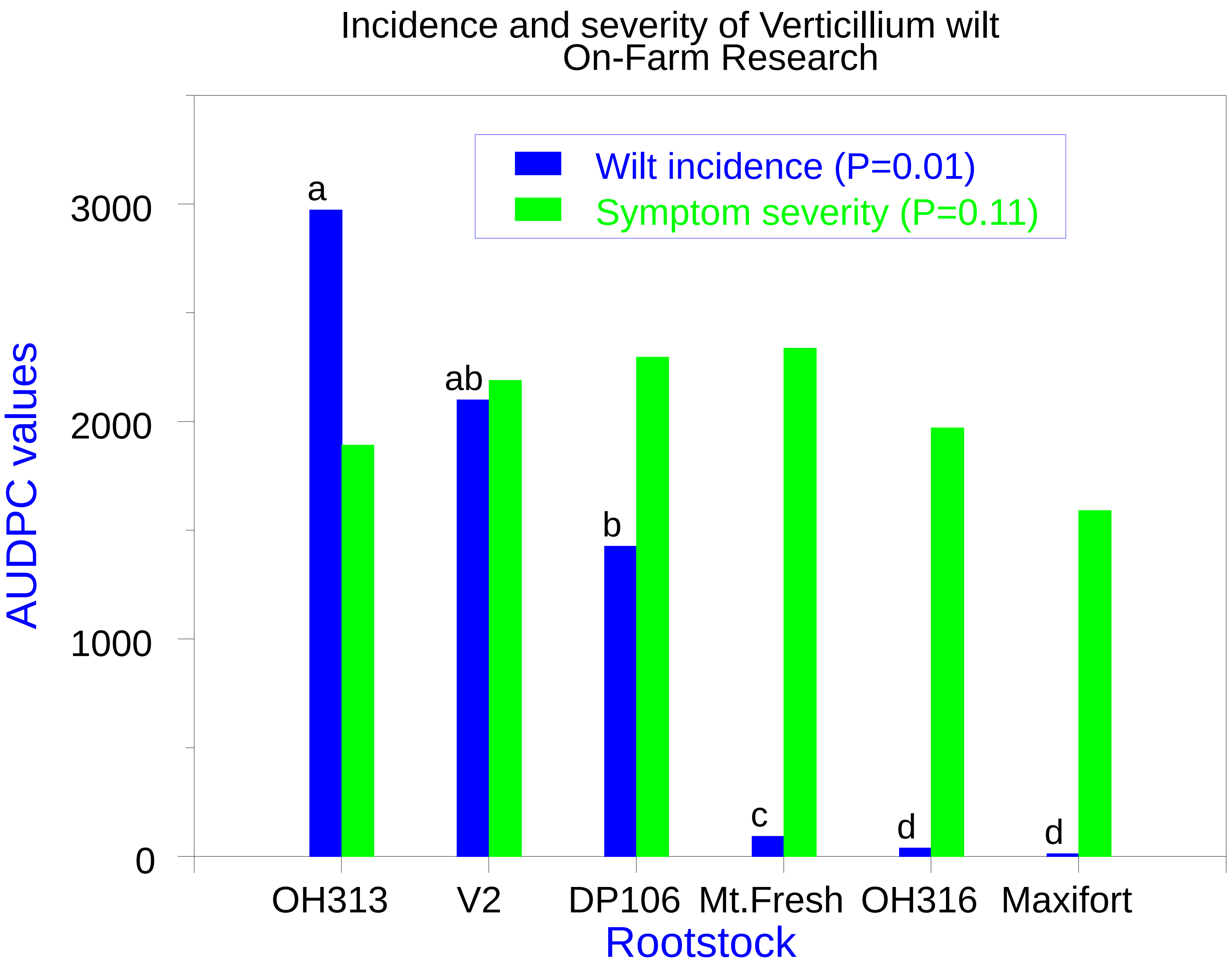
LSD at P = 0.05

Verticillium Wilt



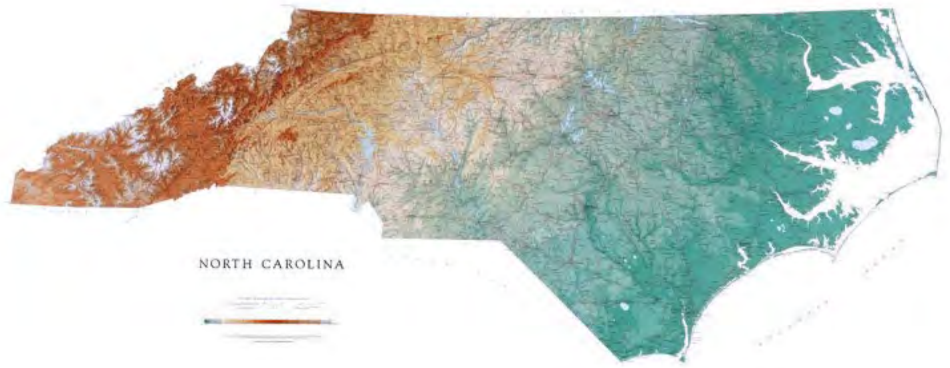
(I
la
p
s
Maxifort rootstock substantially reduced VW incidence but not
was well as in MB treated plots.

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



Regional importance of various soilborne tomato pathogens in North Carolina

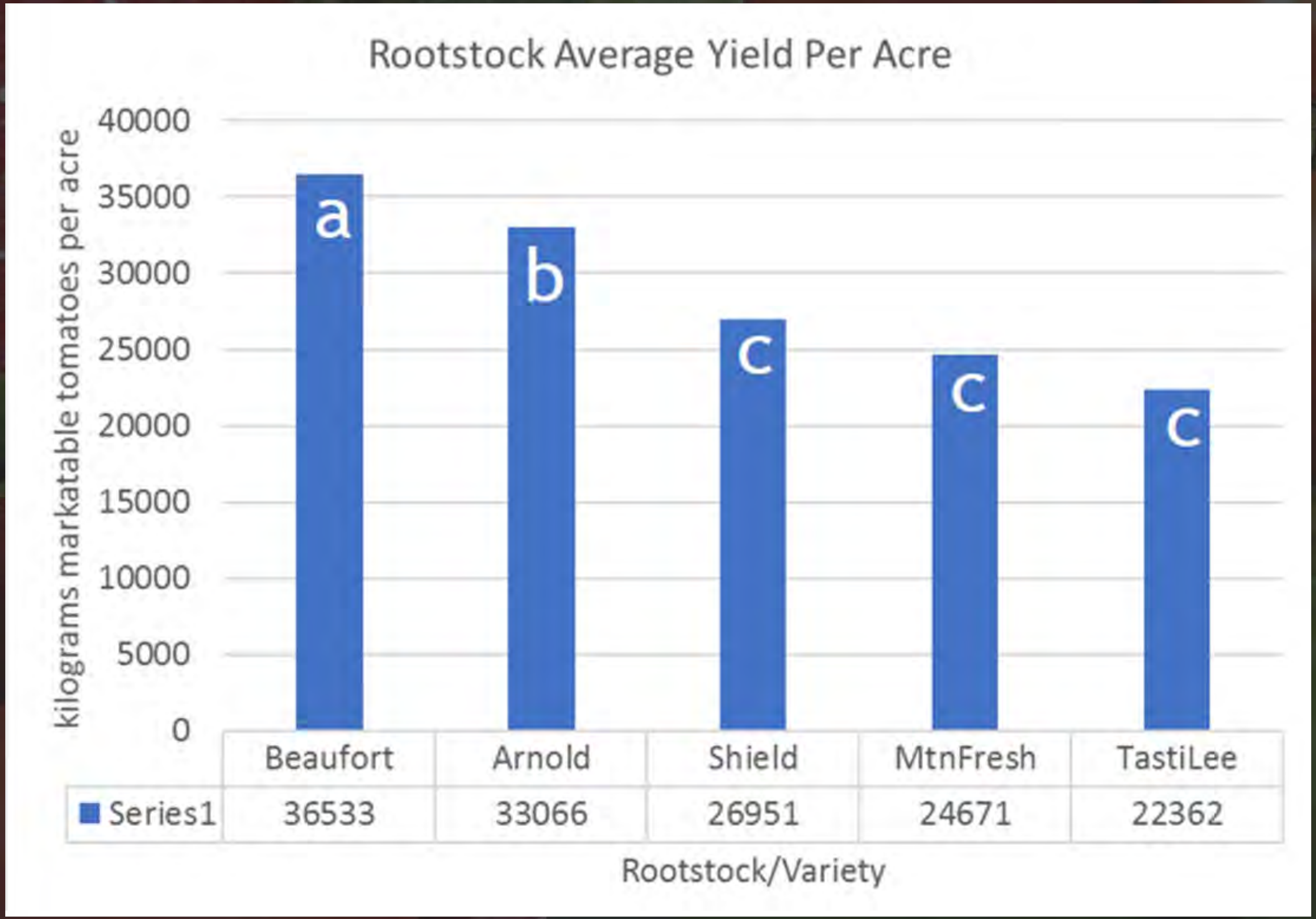
	ECOLOGICAL ZONE			
Pathogen	**Coastal Plain**	**Piedmont**	**Mountains**	**Graft Potential**
Verticillium dahliae race 1	----	*	***	****
Verticillium dahliae race 2	----	*	****	**
Fus. oxy. f.sp. *lycopersici race 0 or 1*	****	****	****	****
Fus. oxy. f.sp. *lycopersici race 2*	*	**	****	**
Ralstonia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



Louws et al. 2010

Does grafting help if there is no disease pressure?

It depends



	Beaufort	Arnold	Shield	MtnFresh	TastiLee
Series1	36533	33066	26951	24671	22362

Mills River Experiment: “New Land”; No fumigation

Grafting to Increase Production for High Tunnel Tomato Growers

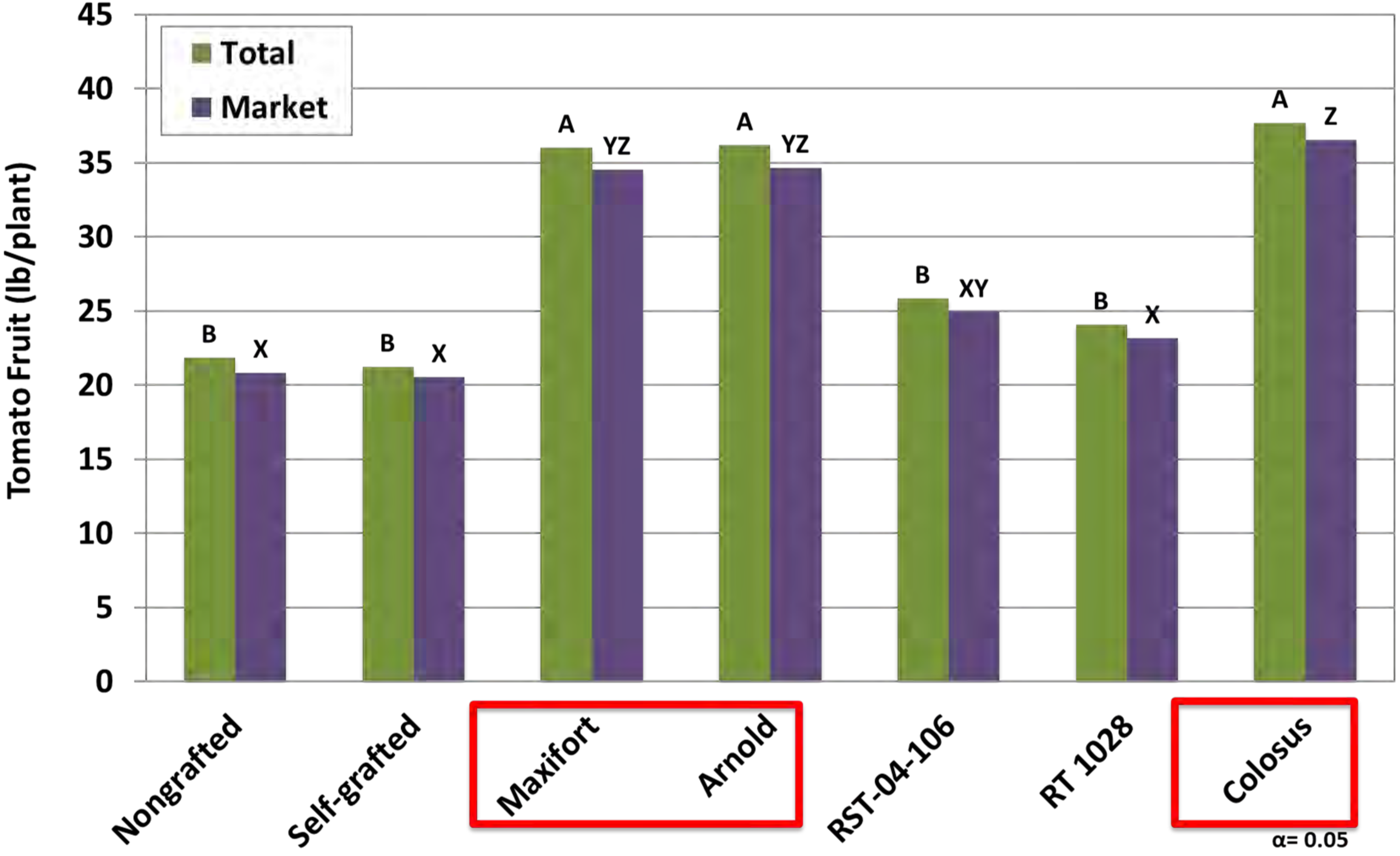
Cary L. Rivard, Ph.D.

Dept. of Horticulture and Natural Resources

NIFA

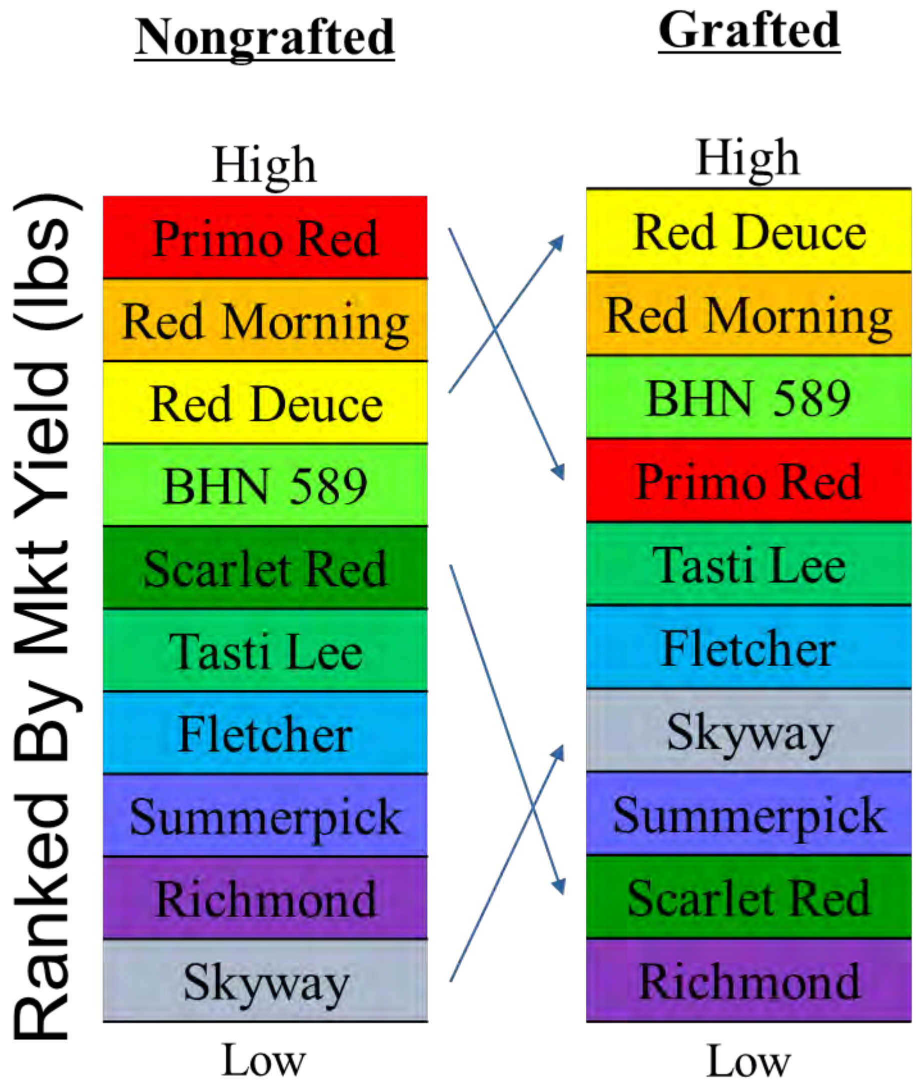
K·STATE
Research and Extension

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

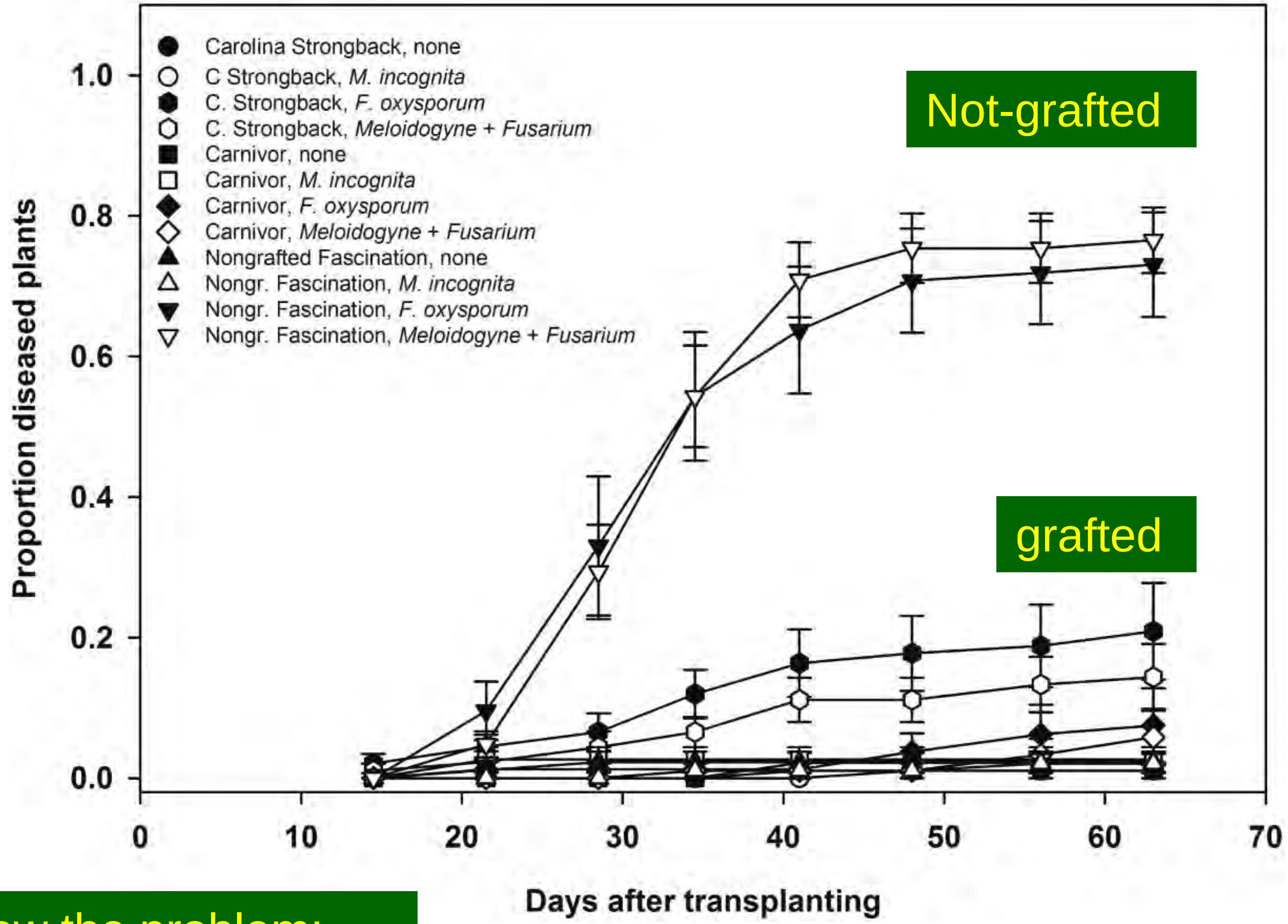
U.S.VegetableLaboratory

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

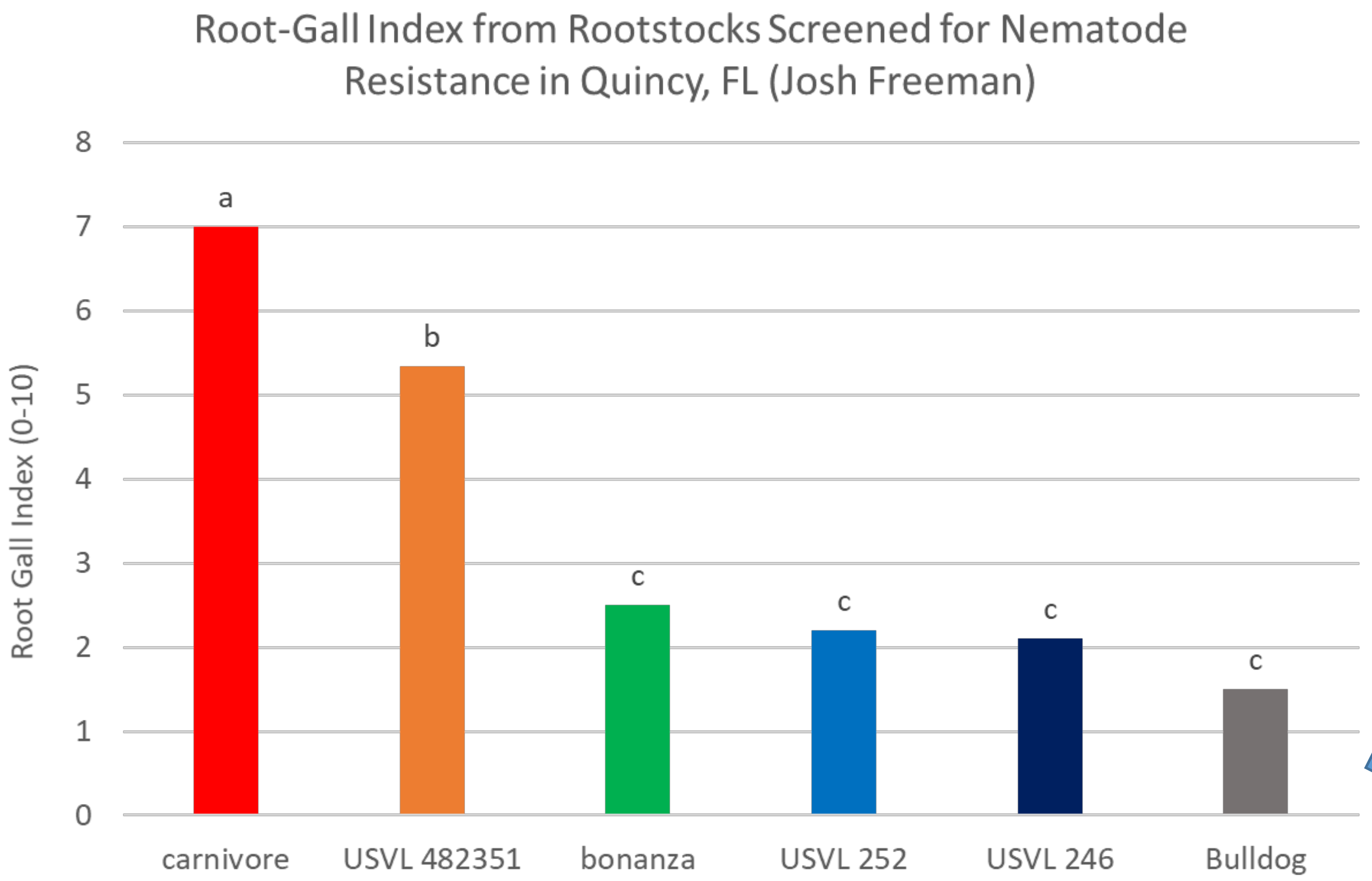
Anthony Keinath,
Paula Agudelo and
Sean Toporek

Clemson University



Know the problem:

Fusarium wilt?
Root knot nematode?



Carolina Strongback- Rootstock

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

Cucurbit Working Group

Josh Freeman

University of Florida

North Florida Research and Education Center

Limited ROI in NC trials

- emerging data (specialty melons; FON)

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

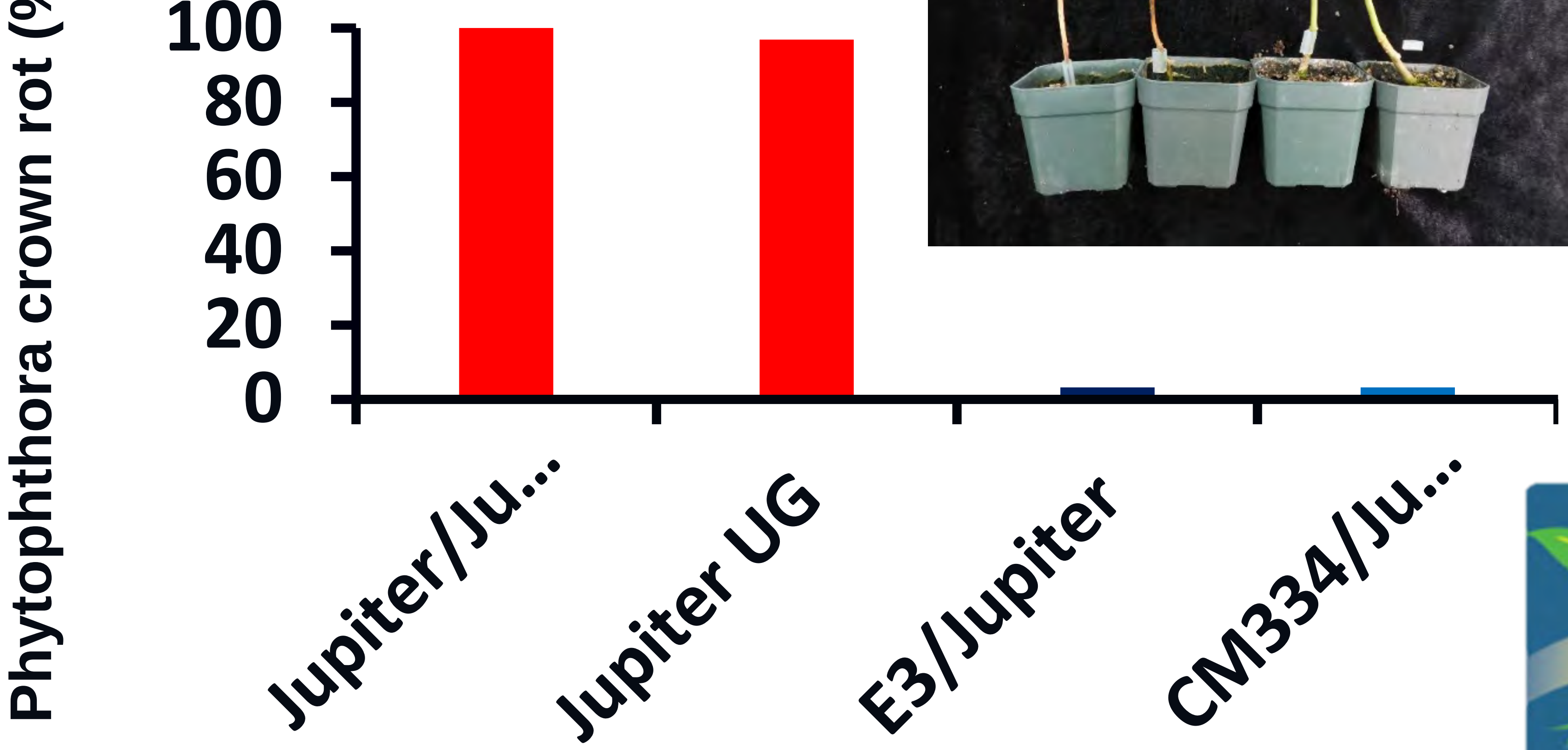
Grafting Technology Working Group Report

Jonathan Schultheis

North Carolina State University

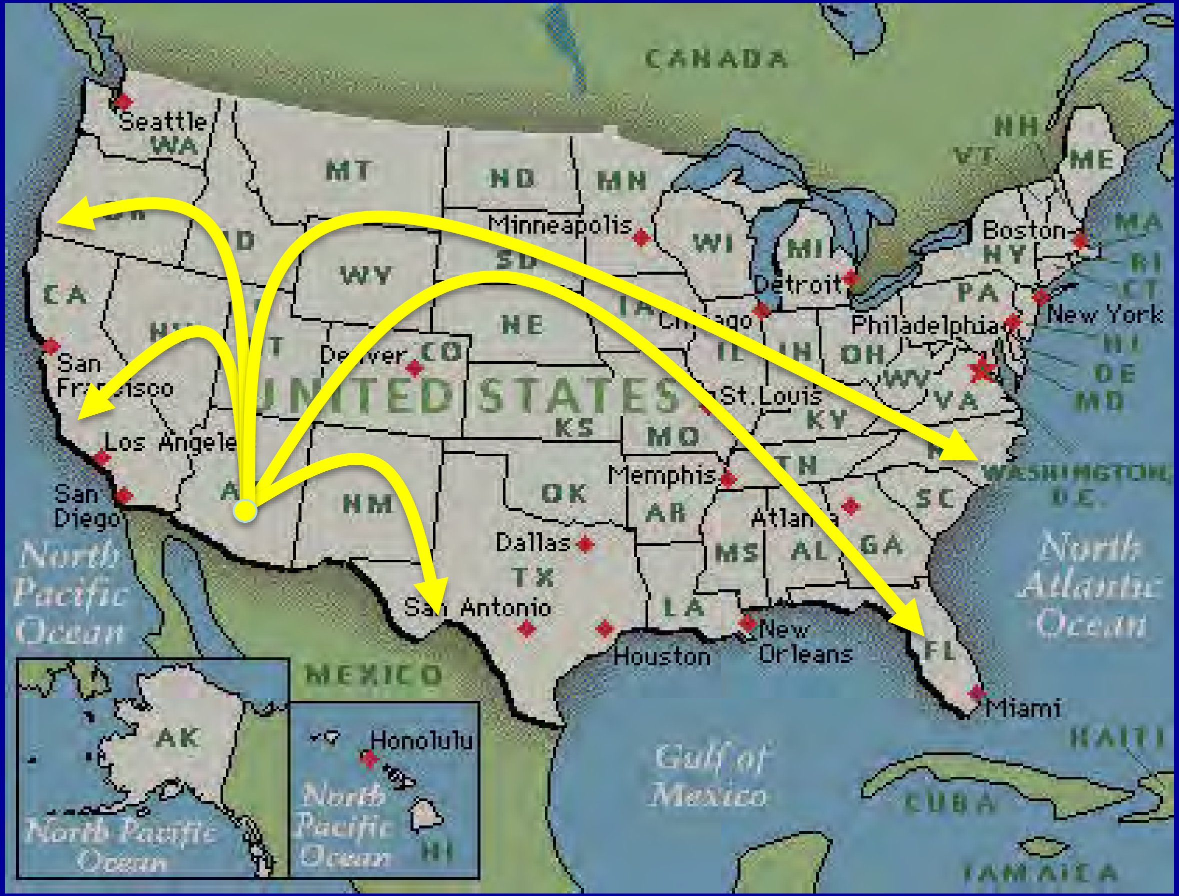
USDA

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



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

Use of Unrooted Grafted Vegetable Cuttings

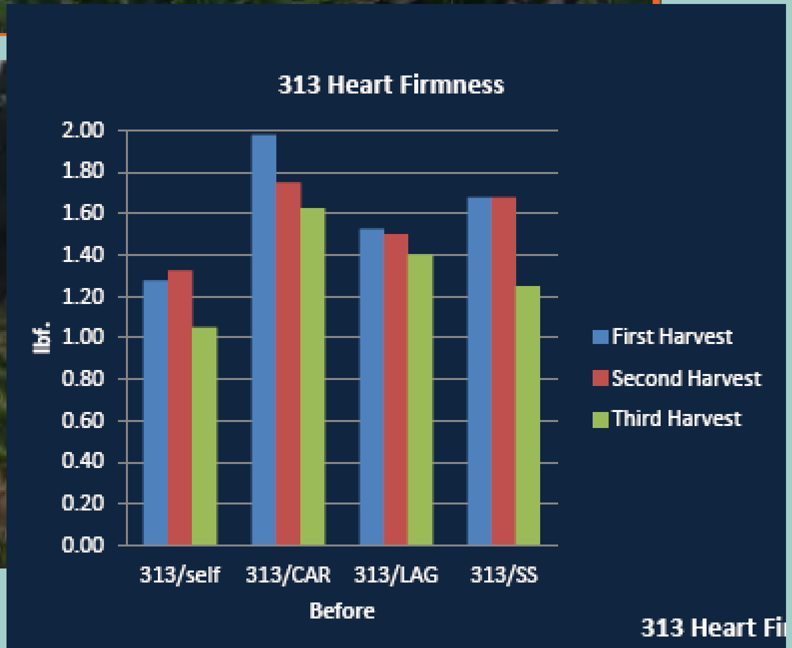


PI: Chieri Kubota

Postharvest Evaluations

(Penny Perkins-Veazie, Xin Zhao)

Dr. Richard Hassell



LOG HOUSE PLANTS

Plug Connection®

BANNER
GREENHOUSES

Re-Di-Vined

GRAFTED GROWERS™

TRI HISHTIL

Unique product lines for retail market

Photo by Alice Doyle

Tim Wada

Ketchup n'Fries BY TOMTATO

Log House Plants

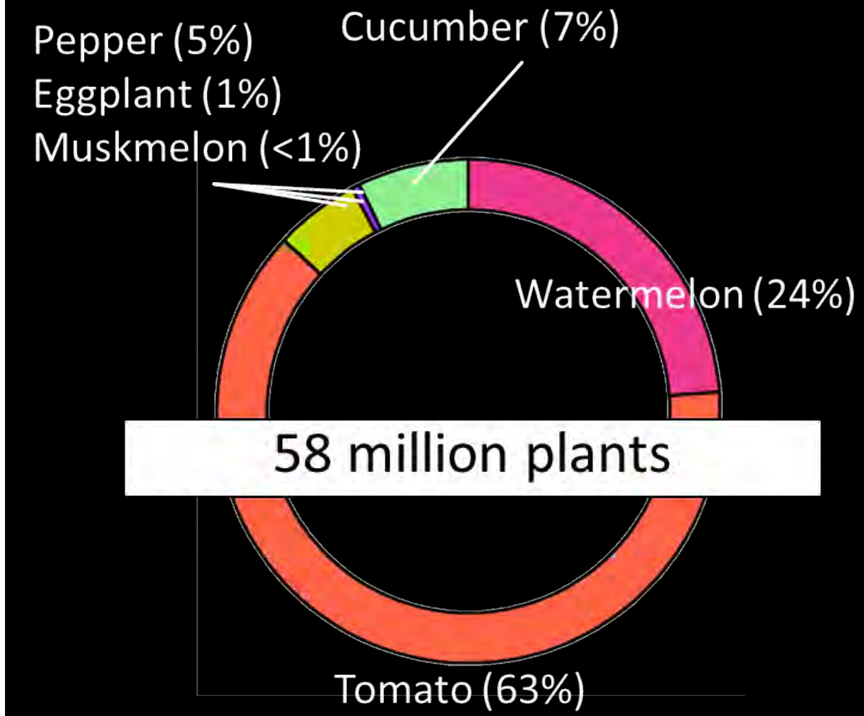
Photo by Hishtil

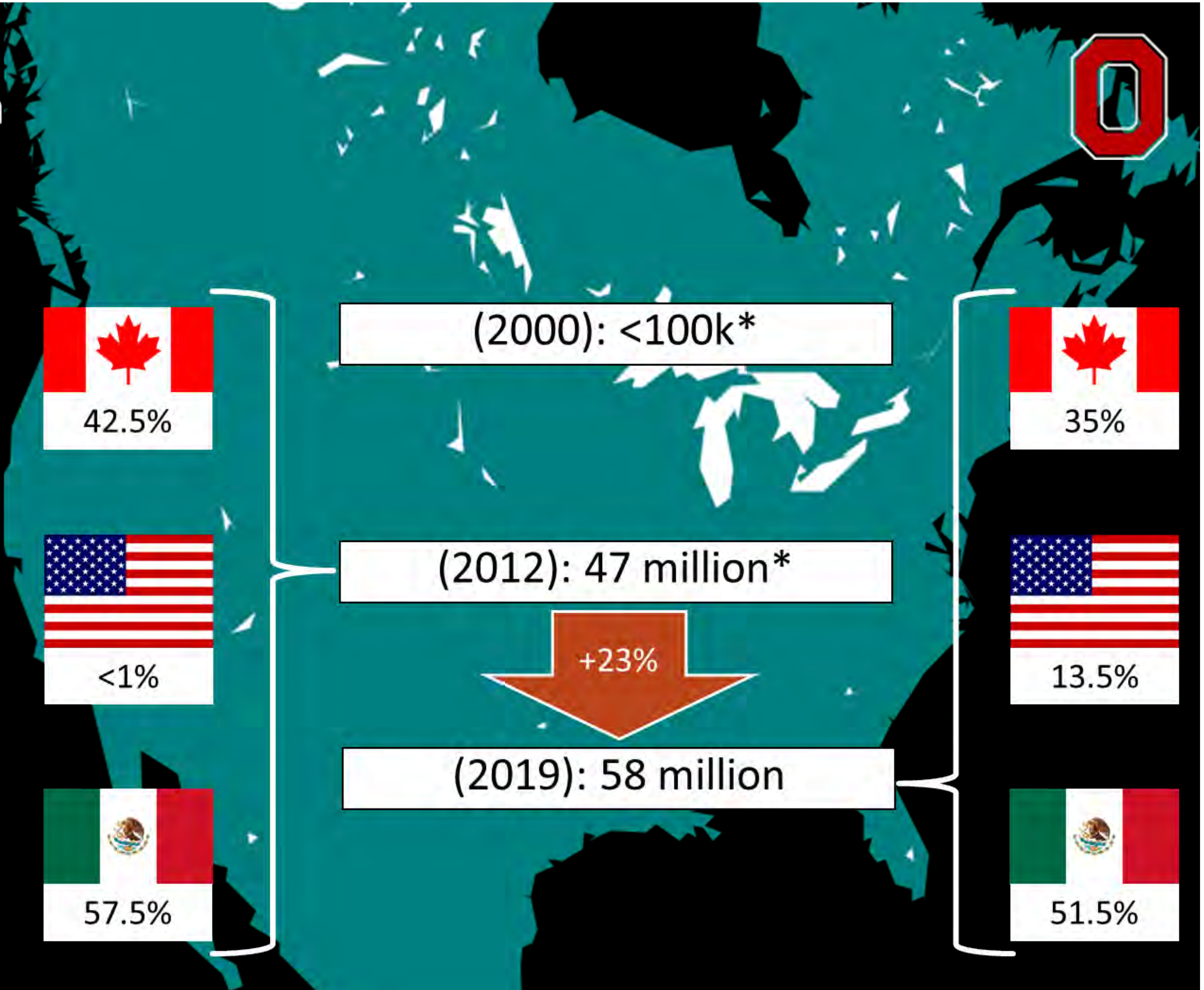
Added yield per plant (lb) needed to compensate for higher transplant prices

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

Olya Rysin & Frank Louws North Carolina State University

Grafting Production in North America





Ertle, J., and C. Kubota. 2020. North American Grafting Survey. <u.osu.edu/cepptlab/extension>.

Grafting: Where will it serve you best?

System Simplicity

Scale neutral but system specific

Limited rotation + organic
Soilborne pathogens
Indeterminate
Heirloom

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

Market Niche

Length of Harvest

Production Issues