Overview of Vegetable Grafting in the United States

Chieri Kubota &

SCRI-Grafting PIs

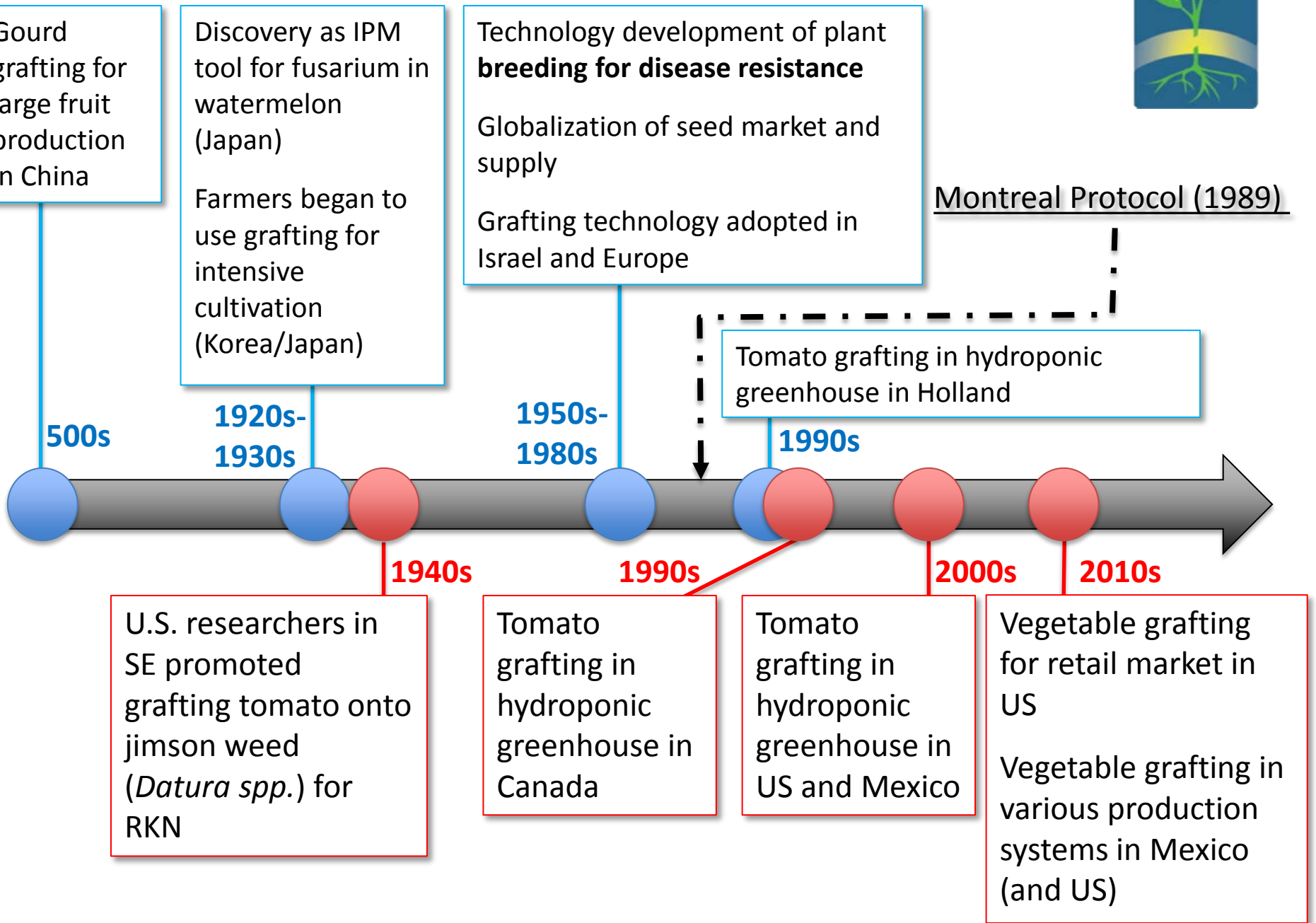
ARIZONA
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
CONTROLLED ENVIRONMENT AGRICULTURE CENTER

Overview of Vegetable Grafting in the U.S.

- A bit of history
- Current status, opportunities , and challenges
  - Greenhouses
  - High tunnels
  - Open fields
  - Retail
  - Costs and economics


Photo by Carol Miles

Vegetable grafting timeline



US vegetable production

Diversity in climates, soil, systems, etc…

Commercial production and use of grafted vegetable plants in North America

Table. Estimate in 2012

Country	Production (plants per year)	Use (plants per year)	Crop species (commercial use)
U.S.A.	< 0.1 million	~10 million	Tomato (Greenhouse)
Canada	~20 million	~10 million	Tomato (Greenhouse)
Mexico	>20 million >7 million	>20 million >7 million	Tomato (Greenhouse) Watermelon (Open-field)

- ✓ US greenhouse growers are buying millions of grafted plants from Canada.
- ✓ Main purpose of using grafted plants in greenhouse is to increase yield.

Use of grafted vegetable plants in the U.S. (all sectors)

Table. 2015 estimate (USA usage)

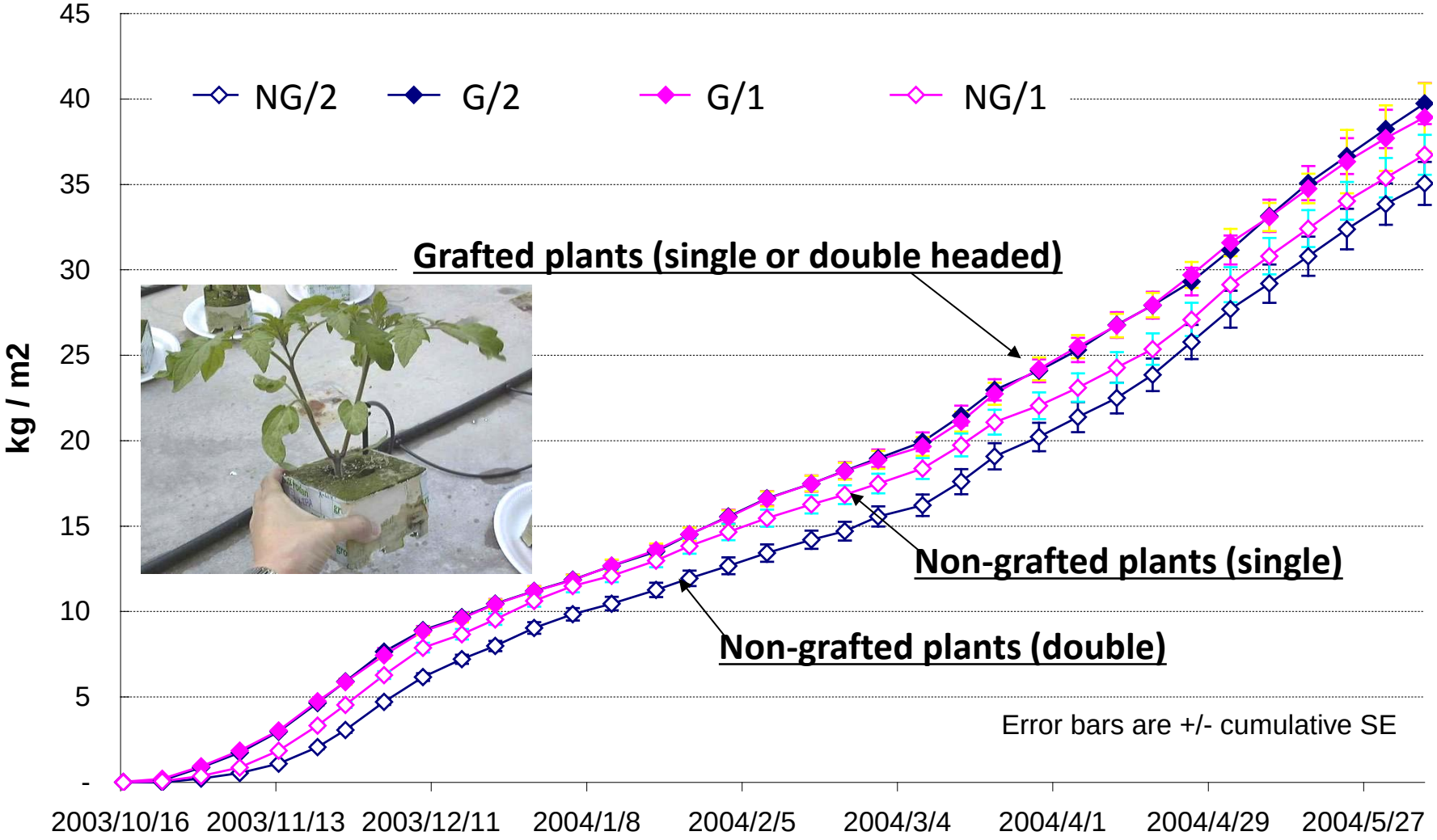
Use	Tomato	Watermelon	Other crops grafted	Sources
Greenhouses	~10 million	None	cucumber	Canada, Mexico, US
High tunnels	~1 million?	None	melon, eggplant	US, Canada
Open fields	~6 million	~200K?	melon, eggplant	US, Canada, Israel
Retail	~1 million	None	eggplant, pepper, potato	US

Greenhouses

Vegetable grafting in US Greenhouses

- **Hydroponic/soilless tomato**
- Introduced by Dutch/Canadian growers in early 2000s.
- Use of strong rootstocks (interspecific hybrid) for **vigor** to support long cultivation cycle (10-12 months)
- Typical yield increase: 10-20% (increase by 5-10 kg/m^2 or 22-44 ton/acre)
- Use of two-headed grafted plants to reduce the plant costs (12000 → 6000 plants/acre)
- ~10 million grafted plants used (estimate as of 2012)

One double-head (twin leader) plant can yield the same as two-single head plants



(Data by Pat Rorabaugh, 2004)

Commercial nurseries in Canada

Technology-rich propagation

Transplant types used in US Greenhouses

- Substrate (Rockwool)
- Young seedling plugs ($0.50-$1.00 per plant)
- Mature 1-ft plants at flowering stage (~$1.50 per plant)
- Use of two-headed (twin leader) grafted plants to reduce the plant costs
- Low grafting (close to substrate surface)

Photo by Ray Breedveld

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

Importation of tomato plants in US

- Importation ban of tomato plants due to ToTV and ToSLCV (APHIS, 2009)
- Exempt: Canada
- Importation of tomato plants growing in **soilless medium** from Mexico to US **greenhouses** is approved (APHIS, 2015)

High Tunnels

Photo by Cary Rivard

Vegetable grafting in US high tunnels

- Unheated or minimally heated structure, typically with soil
- 4600 acres (estimated in 2009)
- High Tunnel System Initiative (USDA NRCS)
- Rapidly increasing sector of US vegetable industry
- Strong support for locally grown fresh vegetables
- **Intensive cultivation**
- **Early adaptors** of grafting technologies (tomato, eggplant and melon)


USDA NRCS (www.nrcs.usda.gov)


Univ. of Vermont Extension

Typical objectives of grafting in HTs

- Disease and pest management due to the intensive cultivation (without rotations)
- Abiotic stress tolerance for season extension (cold soil temperature)
- Vigor for less vigorous cultivars (e.g., heirloom)

Heirloom tomatoes

- Old tomato cultivars maintained for many generations in North America and Europe
- Specialized market
- Low productivity
- Little or no resistance to soil-borne disease
- *Emerging ToMV compatibility issue in grafting (Rosskopf, 2013)*

Photos by Seed Savers Exchange (http://www.seedsavers.org)

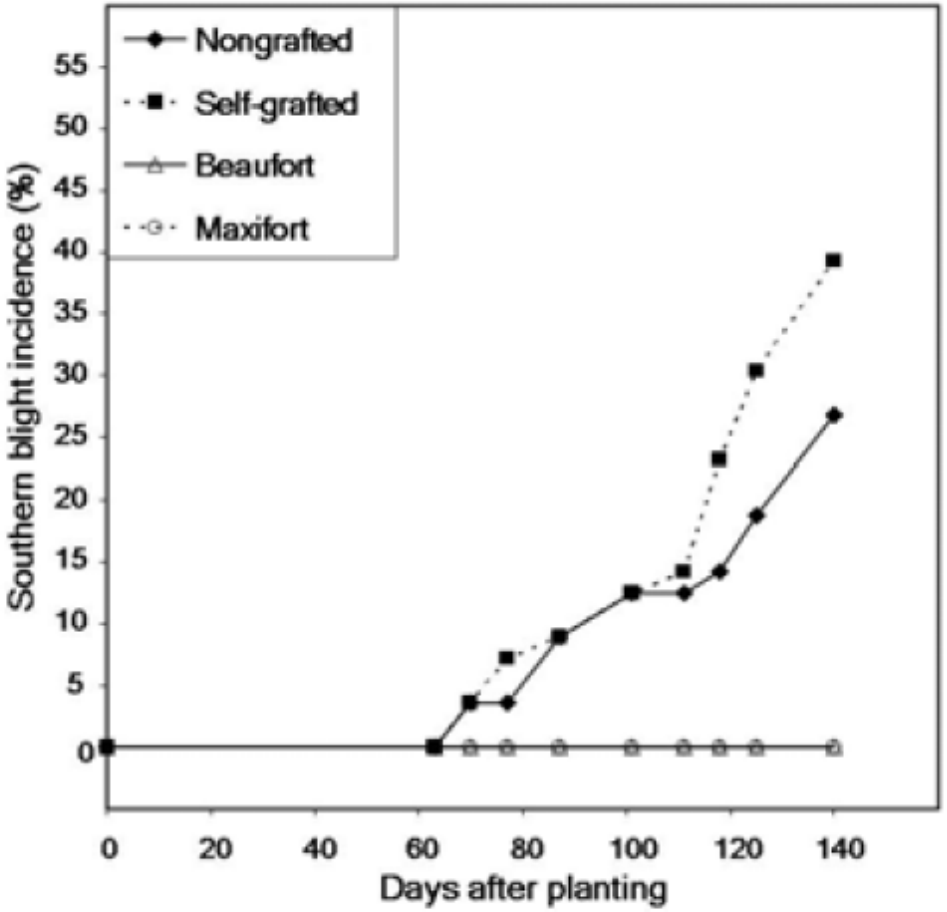


Fig. 1. Mean southern blight incidence on non-grafted and self-grafted tomato cultivar Cherokee Purple as well as Cherokee Purple grafted onto rootstock cultivars Beaufort and Maxifort at the Alamance County location in 2007 and 2008.

Rivard et al. (2010)

Vegetable grafting in US retail (for home gardening)

Gardenharvestsupply.com

Unique product lines for retail market

Photo by Alice Doyle

Log House Plants

Photo by Hishtil

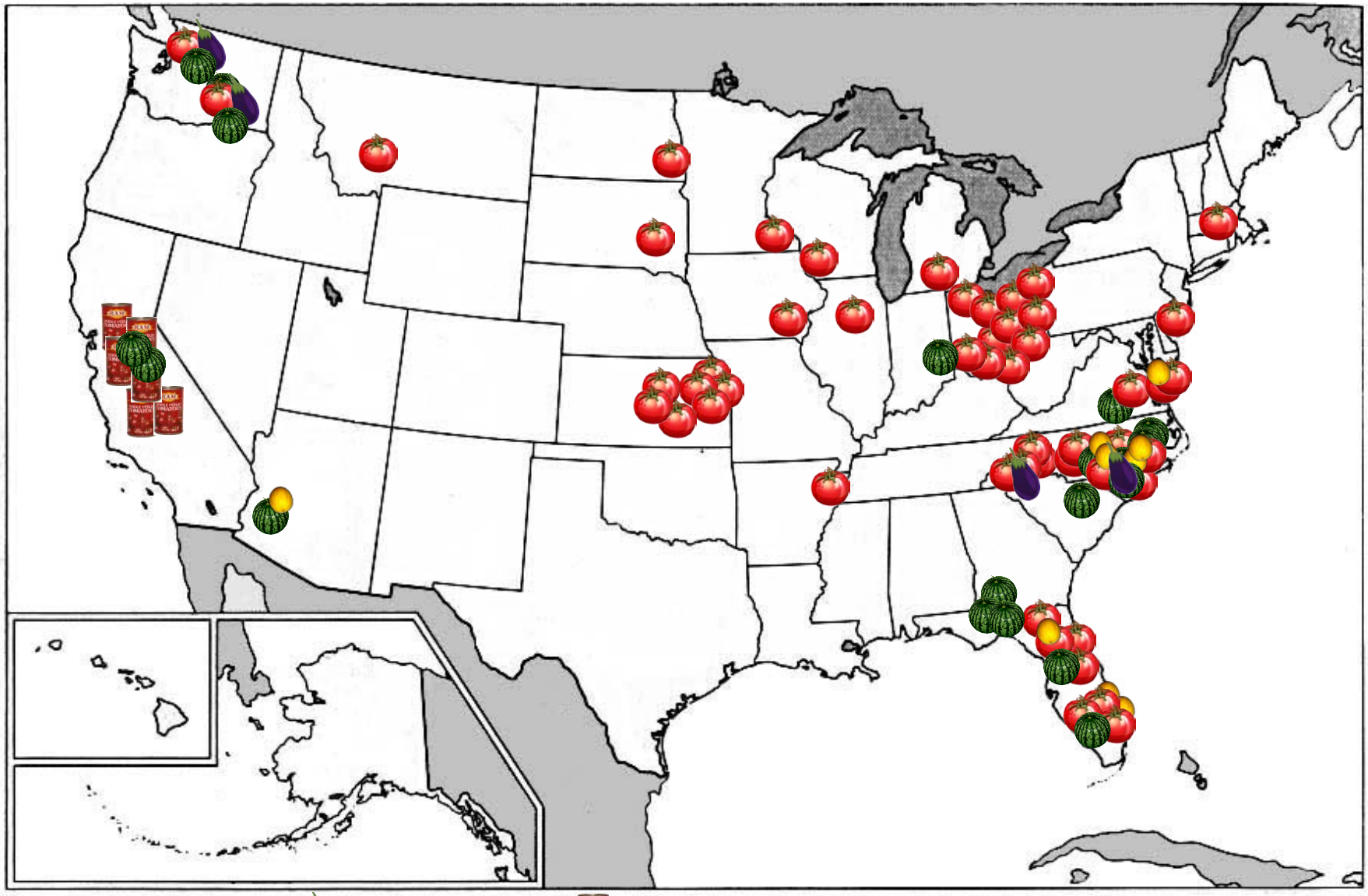
Grafting workshops for home gardeners


Photo by Carol Miles

- Grafting workshops are very popular programs for master gardeners

Open Fields

Trial introduction of grafting to open-fields



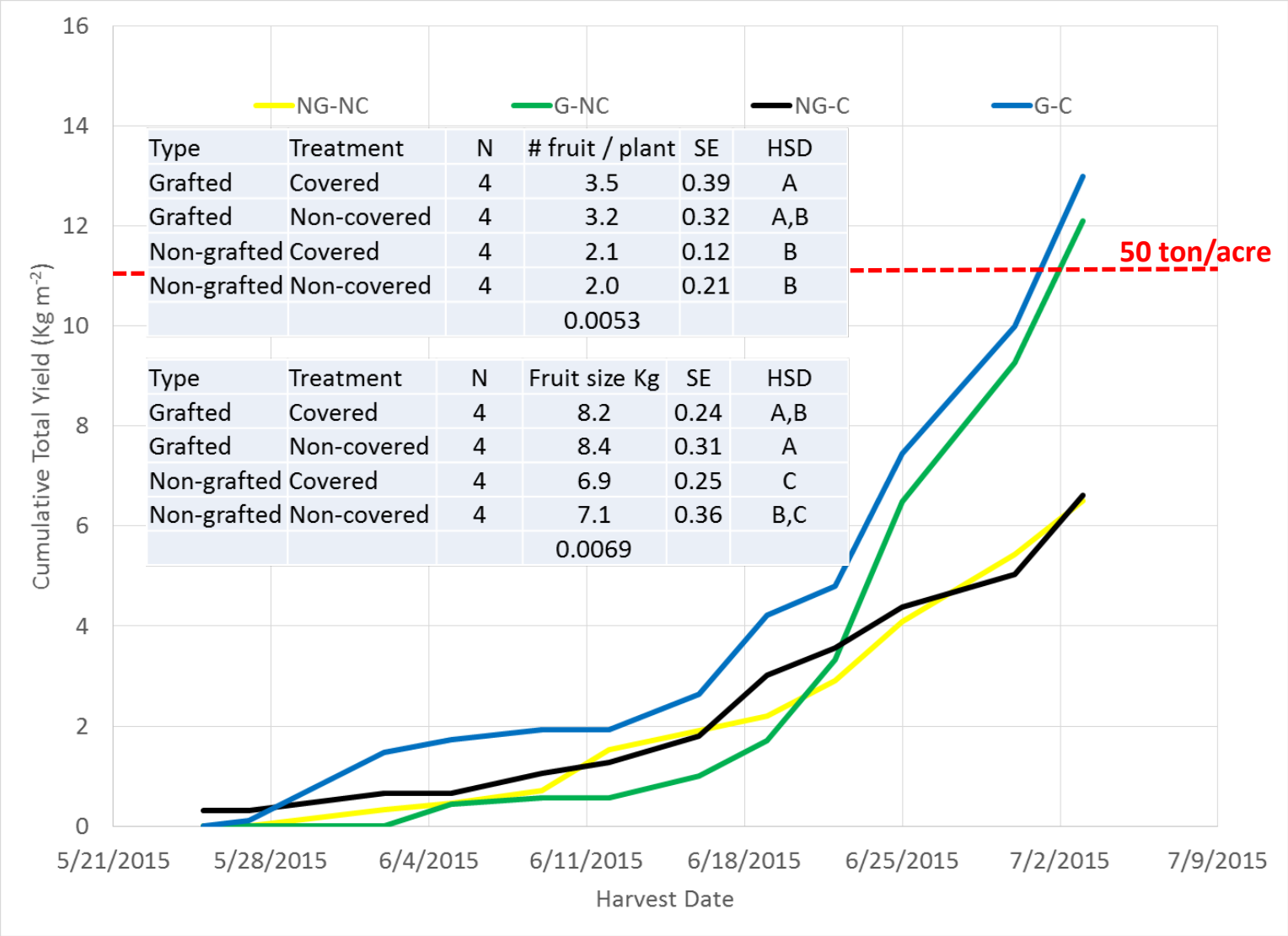
Tomato (F) Eggplant Tomato (P) Watermelon Melon

Grafted cantaloupe seedlings prepared in Texas for Arizona trials (2007-2010)

Grafting trial for bacterial wilt

Photo by Dr. Josh Freeman (Univ. of FL)

Watermelon grafting trial (2015, AZ)



Type	Treatment	N	# fruit / plant	SE	HSD
Grafted	Covered	4	3.5	0.39	A
Grafted	Non-covered	4	3.2	0.32	A,B
Non-grafted	Covered	4	2.1	0.12	B
Non-grafted	Non-covered	4	2.0	0.21	B
			0.0053		

Type	Treatment	N	Fruit size Kg	SE	HSD
Grafted	Covered	4	8.2	0.24	A,B
Grafted	Non-covered	4	8.4	0.31	A
Non-grafted	Covered	4	6.9	0.25	C
Non-grafted	Non-covered	4	7.1	0.36	B,C
			0.0069		

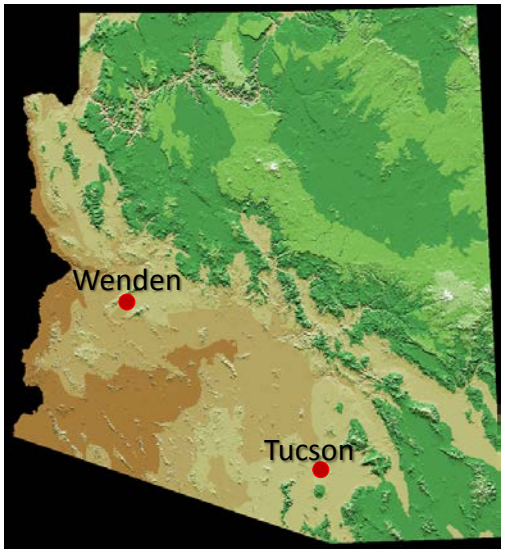
1800 plants per acre

Muskmelon grafting trial (2010, AZ)

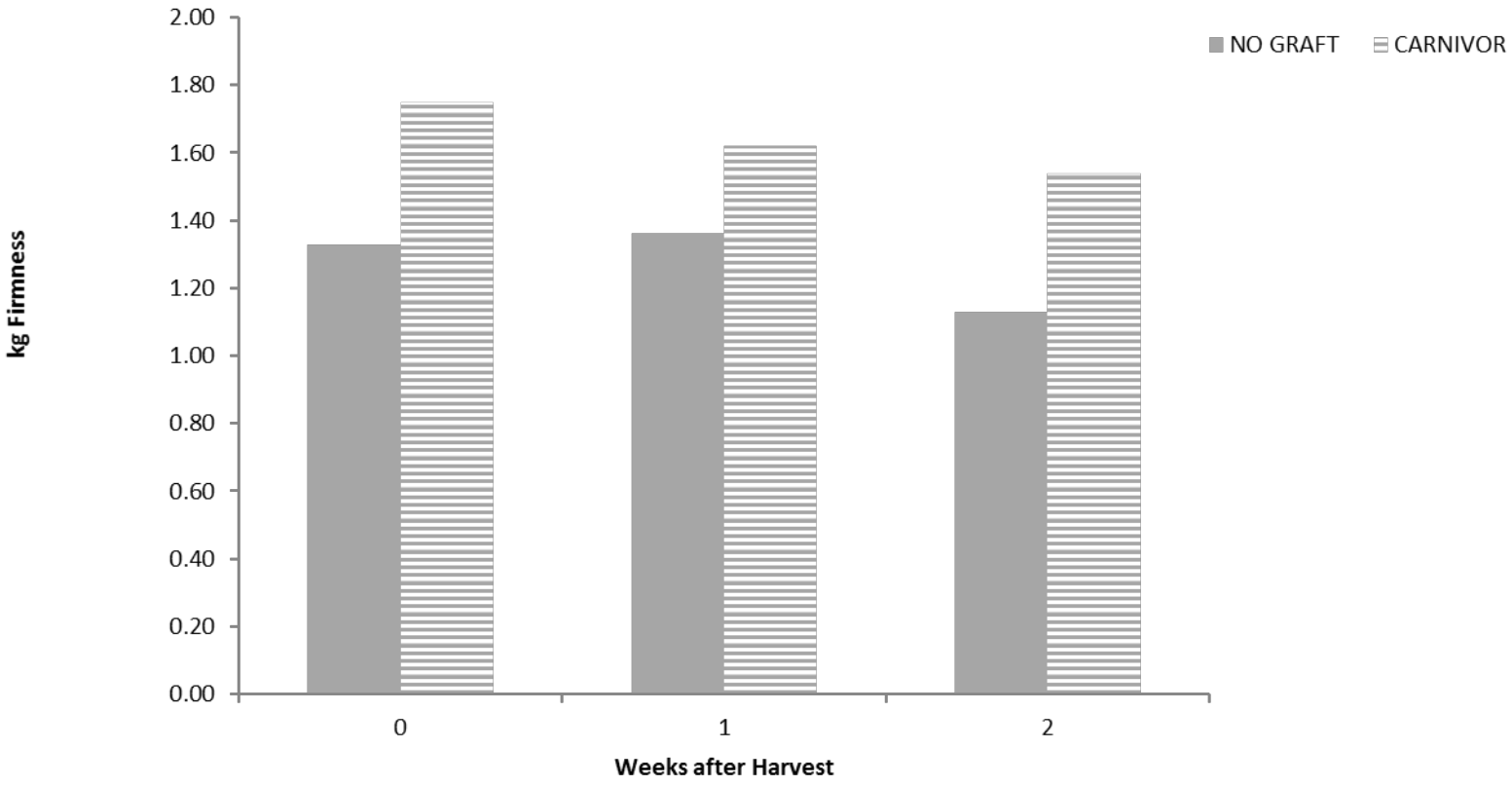
✓Grafted plants yielded more than non-grafted or direct seeded plants.

Plant type	Total harvestable number of fruit (#/plant)	Total harvestable fruit yield (kg/plant)
Grafted plants	4.3a	6.5a
Non-grafted plants	2.4b	3.9b
Direct-seeded plants	2.5b	3.8b
ANOVA	<0.0001	<0.0001

5606 plants per acre

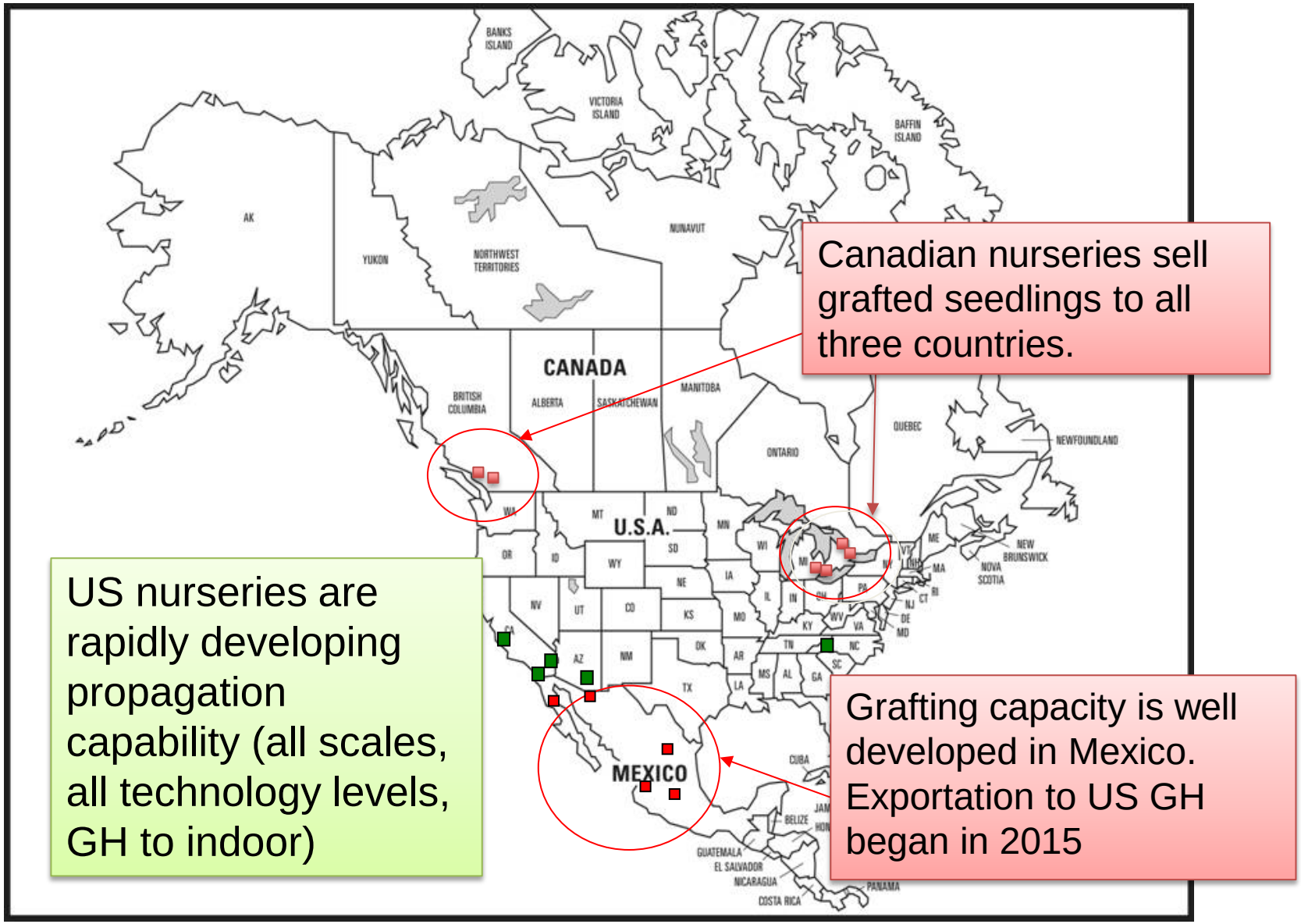


Grafting effect on fruit quality - watermelon



Fruit firmness (kgf) as affected by grafting (Data by Richard Hassell)

Dynamic market of US grafted tomato seedlings in North America



Grafting for processing tomato

Emerging application

Processing tomato trial in CA (photo by Gene Miyao)

Grafting for processing tomato

Emerging application

5.5 million plant production using semi-automated grafting machines over 3 months (processing tomato grafting trials in California)

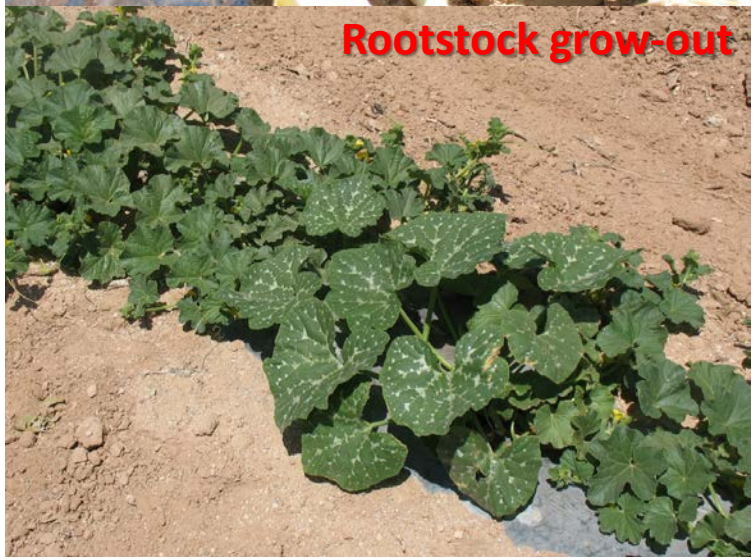
AgriVest 2015 –Part-6-Rootility
https://www.youtube.com/watch?v=koXNA3Qkdp4

Promotional factors for open fields

- Prolonged drought
- Lack of lands for rotation
- Limited fumigation tools
- New rootstocks (for biotic and abiotic stress management)
- Vigor and more yield in marginal lands

Challenges

A few as example, but more…

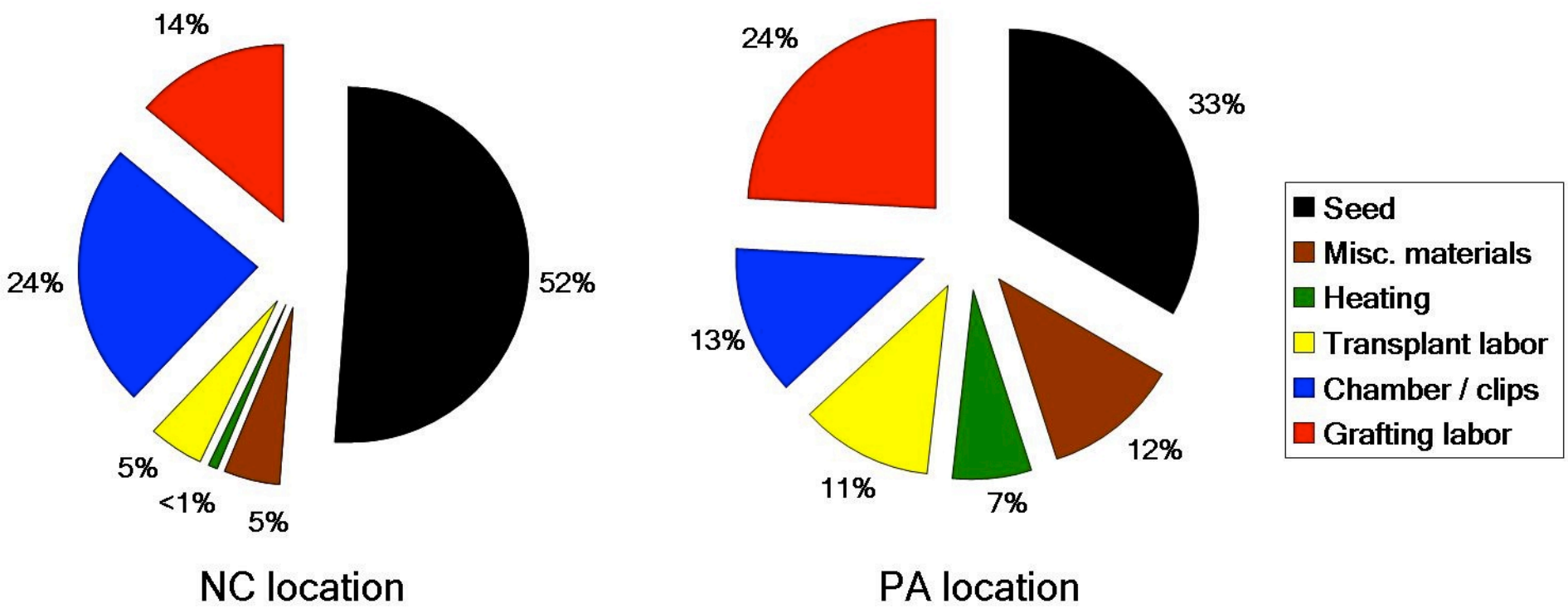


Key technology – transportation and distribution

Plug Connection

Cost analysis for grafting propagation

- 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 grafting propagation

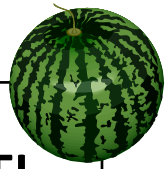
Scenario-based theoretical analysis

Variable costs per plant for low and high volume tomato grafting in FL				
Item	**Low Vol - Manual**		**High Vol - Automation**	
	20,000 plants/week		2,000,000 plants/week	
Depreciation	$0.008	5.5%	$0.030	25.3%
Materials	$0.031	20.9%	$0.019	16.3%
Utilities	$0.049	33.5%	$0.050	42.9%
Labor	$0.059	40.1%	$0.018	15.4%
Variable Cost / plant (not including seeds)	$0.148		$0.116	
	Grafting speed = 300/h		Grafting speed = 1000/h	

Lewis et al. (2014)

Cost analysis for grafting propagation

Scenario-based theoretical analysis



Variable costs per plant for low and high volume watermelon grafting in FL				
Item	**Low Vol - Manual**		**High Vol - Automation**	
	20,000 plants/week		2,000,000 plants/week	
Depreciation	$0.009	4.4%	$0.022	22.6%
Materials	$0.037	19.0%	$0.022	24.2%
Utilities	$0.032	16.3%	$0.032	35.3%
Labor	$0.118	60.4%	$0.016	17.8%
Variable Cost / plant (not including seeds)	$0.195		$0.089	

Grafting speed = 150/h Grafting speed = 800/h

Lewis et al. (2014)

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 (NCSU)

Figure 1. Estimated profit given different yields of grafted seedless watermelon.

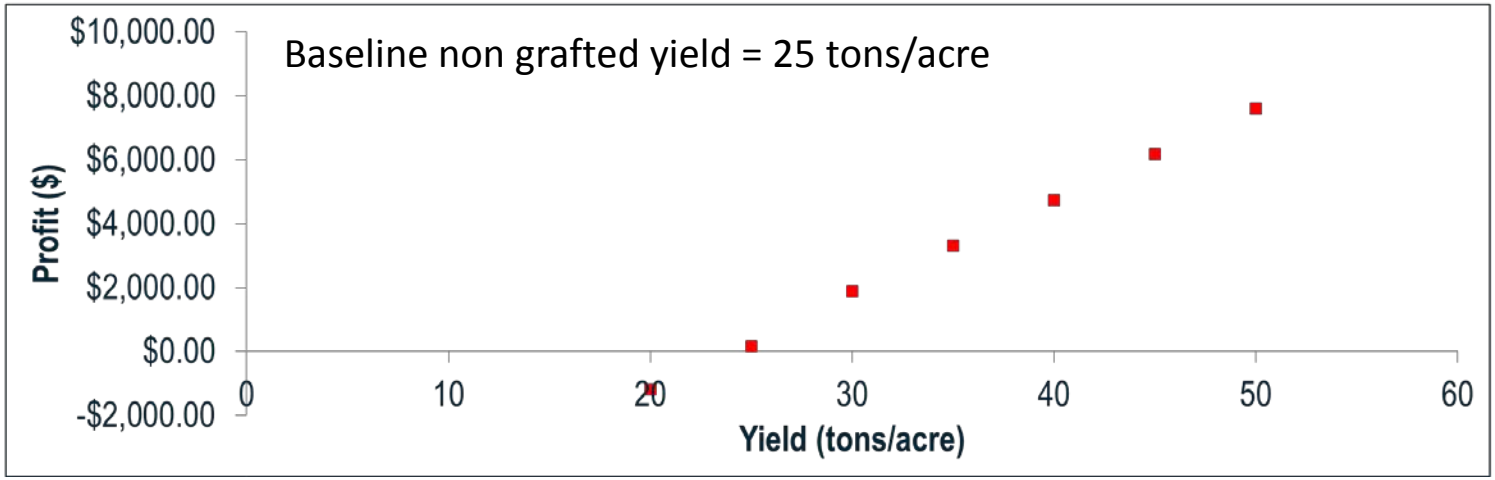
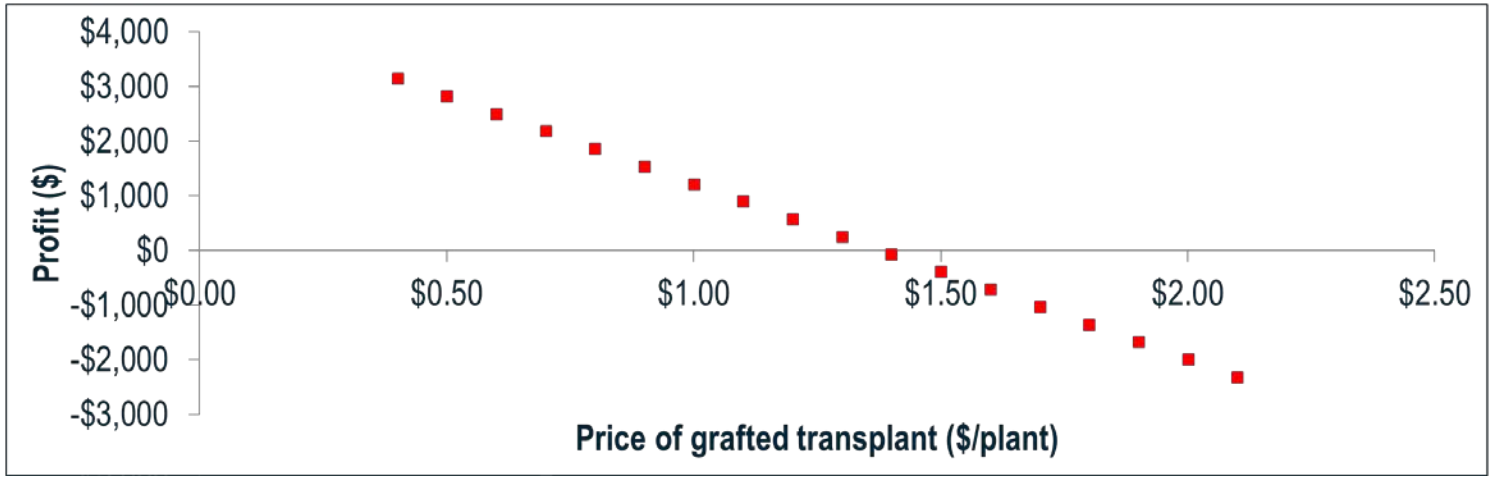


Figure 2. Estimated profit given different prices of grafted watermelon transplants.



Source: Non-grafted and Grafted Seedless Watermelon Transplants: Comparative Economic Feasibility Analysis

Galinato et al. 2015, Washington State University Extension Publication TB08E

More grafting innovation needed!

- Automation for seedless watermelon
- Rootstocks for abiotic stress management (drought, salinity, heat)
- “Postharvest” technologies for seedling transportation
- Integration with other farm management technologies
- Value added crop production with enhanced quality

http://www.rikou.ryukoku.ac.jp/~nomura/HRS2012/

Grafted Growers LLC, photo by UA Alumni Association

Thank you!
(www.vegetablegrafting.org)