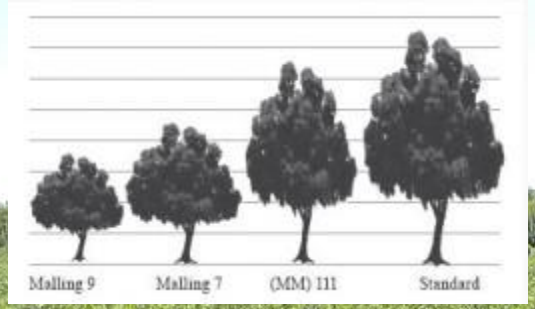


Apple Rootstock Update

2017 Great Plains Growers Conference

Matt Stasiak
Peninsular Agricultural Research Station
UW-Madison CALS

NC140

Current Plantings

2015 Organic Apple Rootstock

2014 Apple Rootstock

2010 Apple Rootstock

Completed plantings

2006 Apple Replant

2003 Apple (Golden Delicious) Physiology

2003 Dwarf Apple Rootstock

2002 Apple (Gala) Rootstock

2002 New Jersey-Massachusetts Cameo

1999 Dwarf Apple (Fuji and McIntosh) Rootstock

1999 Semi-dwarf Apple Rootstock

1998 G.16 Apple Rootstock

1994 Gala Dwarf Apple Rootstock

1994 Gala Semi-dwarf Apple Rootstock

1992-1993 Liberty/CG Apple Rootstock

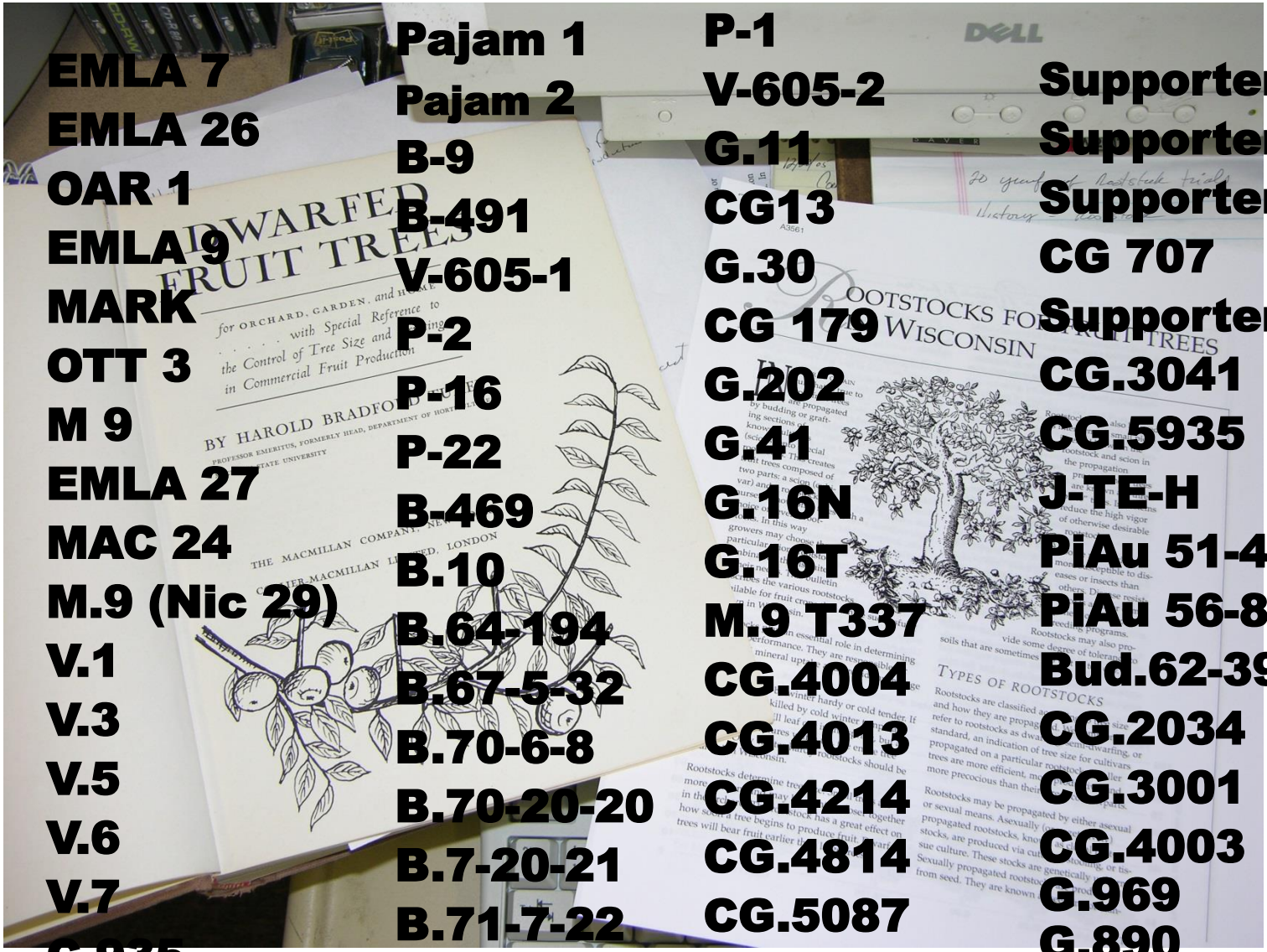
1990 Apple Systems

1990 Gala Apple Rootstock

1990 Apple Cultivar/Rootstock Apple

1984 Apple (Red Delicious) Rootstock

1980/81 Apple (Red Delicious) Rootstock



EMLA 7
EMLA 26
OAR 1
EMLA 9
MARK
OTT 3
M 9
EMLA 27
MAC 24
M.9 (Nic 29)
V.1
V.3
V.5
V.6
V.7
C 935
C 210

Pajam 1
Pajam 2
B-9
B-491
V-605-1
P-2
P-16
P-22
B-469
B.10
B.64-194
B.67-5-32
B.70-6-8
B.70-20-20
B.7-20-21
B.71-7-22
B.7-3-150

P-1
V-605-2
G.11
CG13
G.30
CG 179
G.202
G.41
G.16N
G.16T
M.9 T337
CG.4004
CG.4013
CG.4214
CG.4814
CG.5087
CG.5222

Supporter 1
Supporter 2
Supporter 3
CG 707
Supporter 4
CG.3041
CG.5935
J-TE-H
PiAu 51-4
PiAu 56-83
Bud.62-396
CG.2034
CG.3001
CG.4003
G.969
G.890
G.65

‘Pre-History’

English Paradise

‘Doucin’

French Paradise

Paradise

Over the millennia since the apple’s domestication, growers had tried to exploit spontaneously occurring **genetic mutations** that made the trees shorter and thus easier to harvest, grafting the best fruiting varieties onto these **cloned dwarfing rootstocks**.

History - Selection

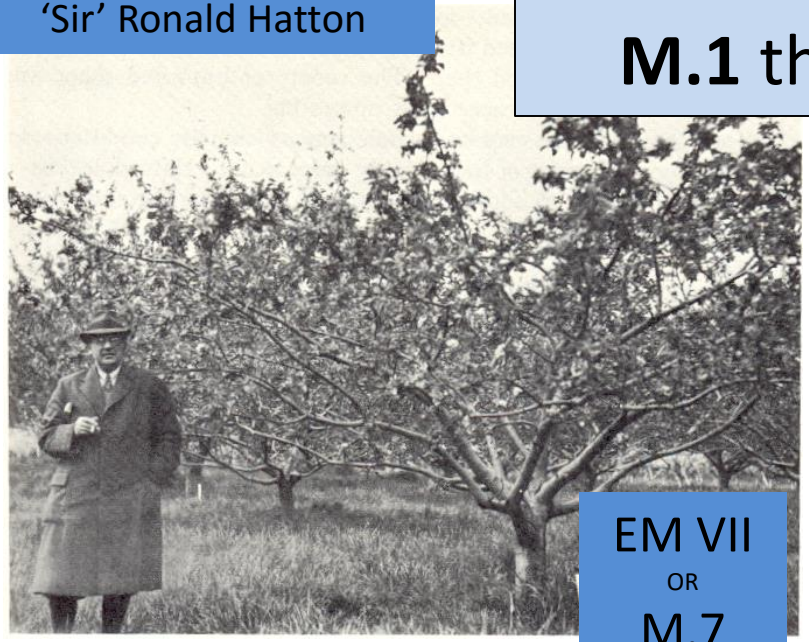
1900's Dawn of the Modern Apple Rootstock

'**M**' Series

Malling

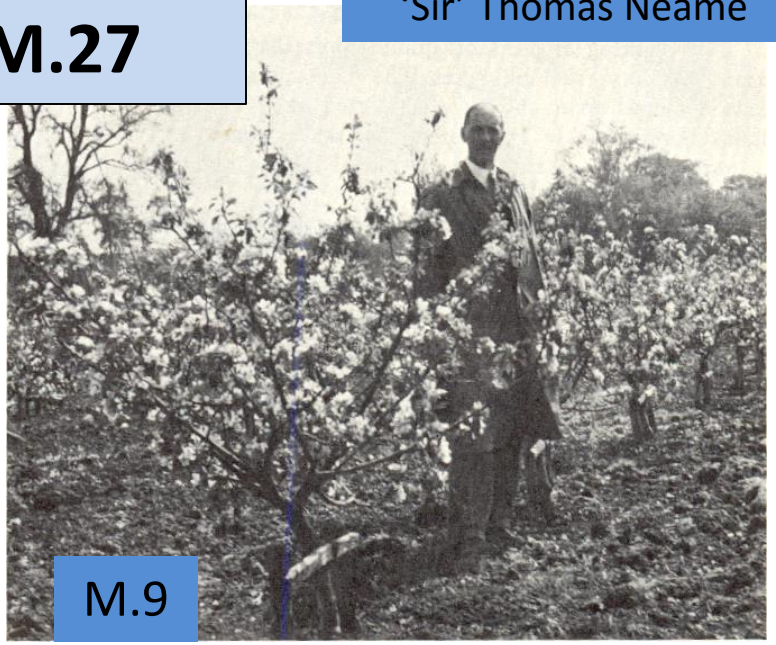
M.1 through **M.27**

'Sir' Ronald Hatton



EM VII
OR
M.7

'Sir' Thomas Neame



M.9

History - Early Breeding

1920's

'MM' Malling-Merton

Malling x Northern Spy

Woolly Apple Aphid resistant

MM.106 & **MM.111**

Photo credit: E. Beers, June 2009, Washington State University

History - Improvement

1960's

'EMLA' East Malling & Long Ashton Stations

Removed viruses

Slightly more vigorous than M's

EMLA 9, **EMLA 26**, etc.

Photos: Mid-Atlantic Orchard Monitoring Guide

History - The Potential

Lower cost per unit of production

High quality fruit and greater % pack-out

Earlier return on investment

Regular & annual production

Quicker & easier adjustment to change

Ability to adjust to various stresses

H.B Tukey 1964

Rootstock of the Future

"Although M.9 has many favorable characteristics, it has some problems, such as poor anchorage in the soil, propagation difficulty, winter injury, brittle roots, and susceptibility to fireblight and crown gall."

"Therefore new dwarfing rootstocks without the shortcomings of M.9 are desirable."

Performance of 'Golden Delicious' Apple on 23 Rootstocks at Eight Locations: A Ten-Year Summary of the 2003 NC-140 Dwarf Rootstock Trial

R.P. MARINI, B. BLACK, R.M. CRASSWELLER, P. A. DOMOTO, C. HAMPSON, R. MORAN, T. ROBINSON, **M. STASIAK**, and D. WOLFE

M.9 ‘Type’

- Bud. 9
- M.9 NAKB 337
- M.9 EMLA
- M.9 Nic RN29

Supporter Series (GER)
Geneva Series (USA)
Budagovski (RUS)
Vineland (CAN)
Polish
Etc…

NC140

Evaluated for

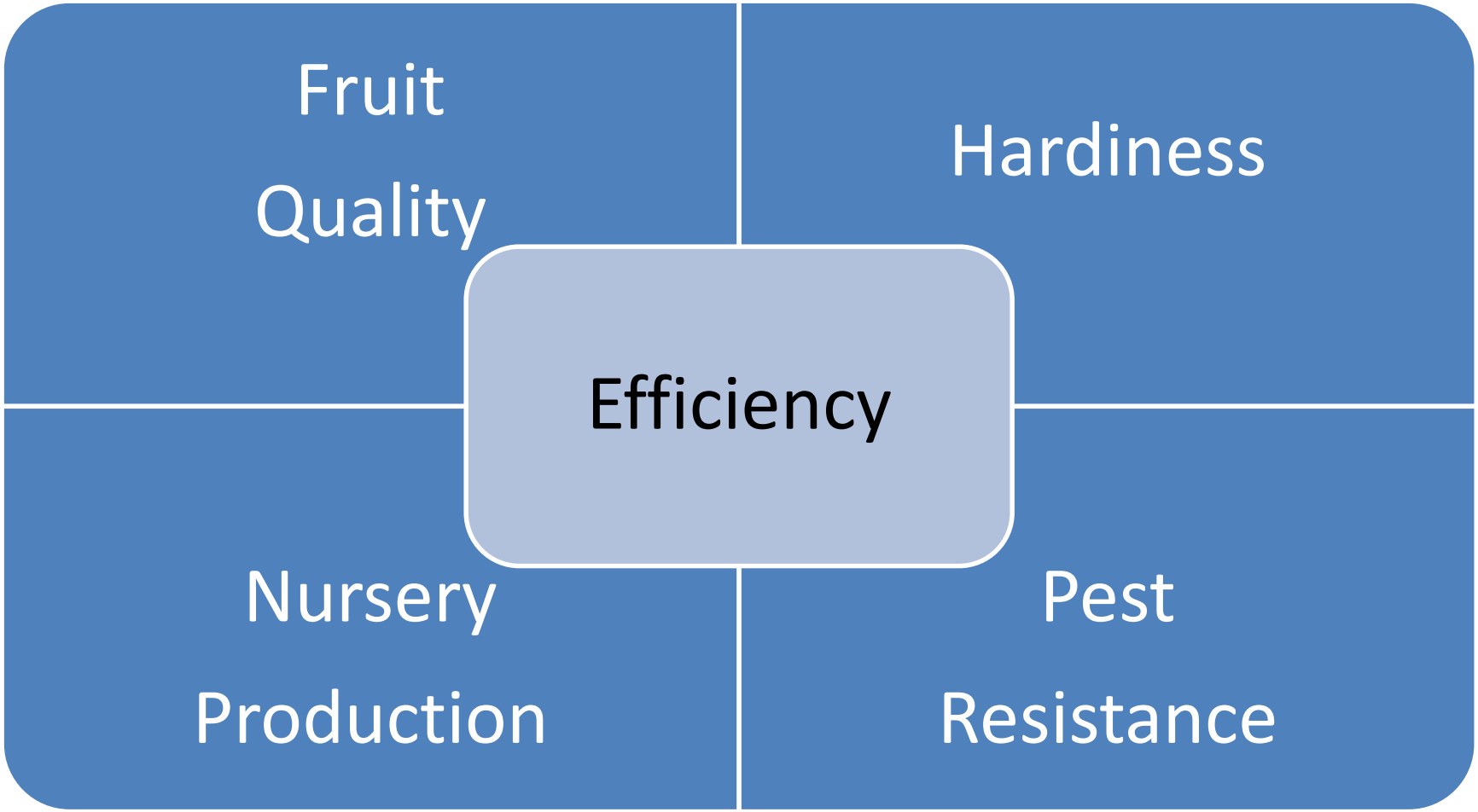
survival
precocity
productivity
size control
anchorage
suckering
pest resistance
adaptability
production efficiency

Trials concluded after 8-10 growing seasons.

Data collected

root suckering
tree growth trunk cross-sectional area
tree height & spread
precocity
yield
yield efficiency
fruit size

Maximizing the Potential

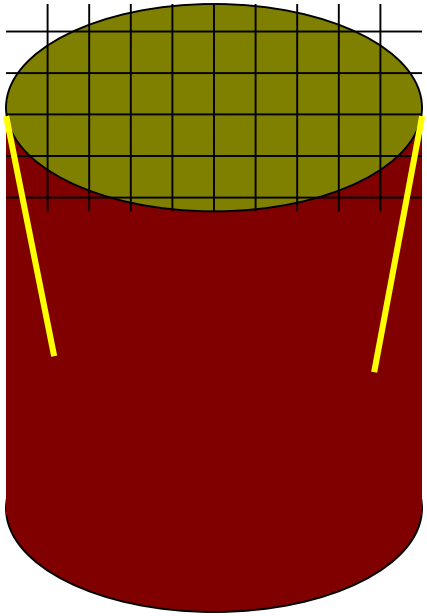


Estimating Tree Size

Trunk Cross Sectional Area

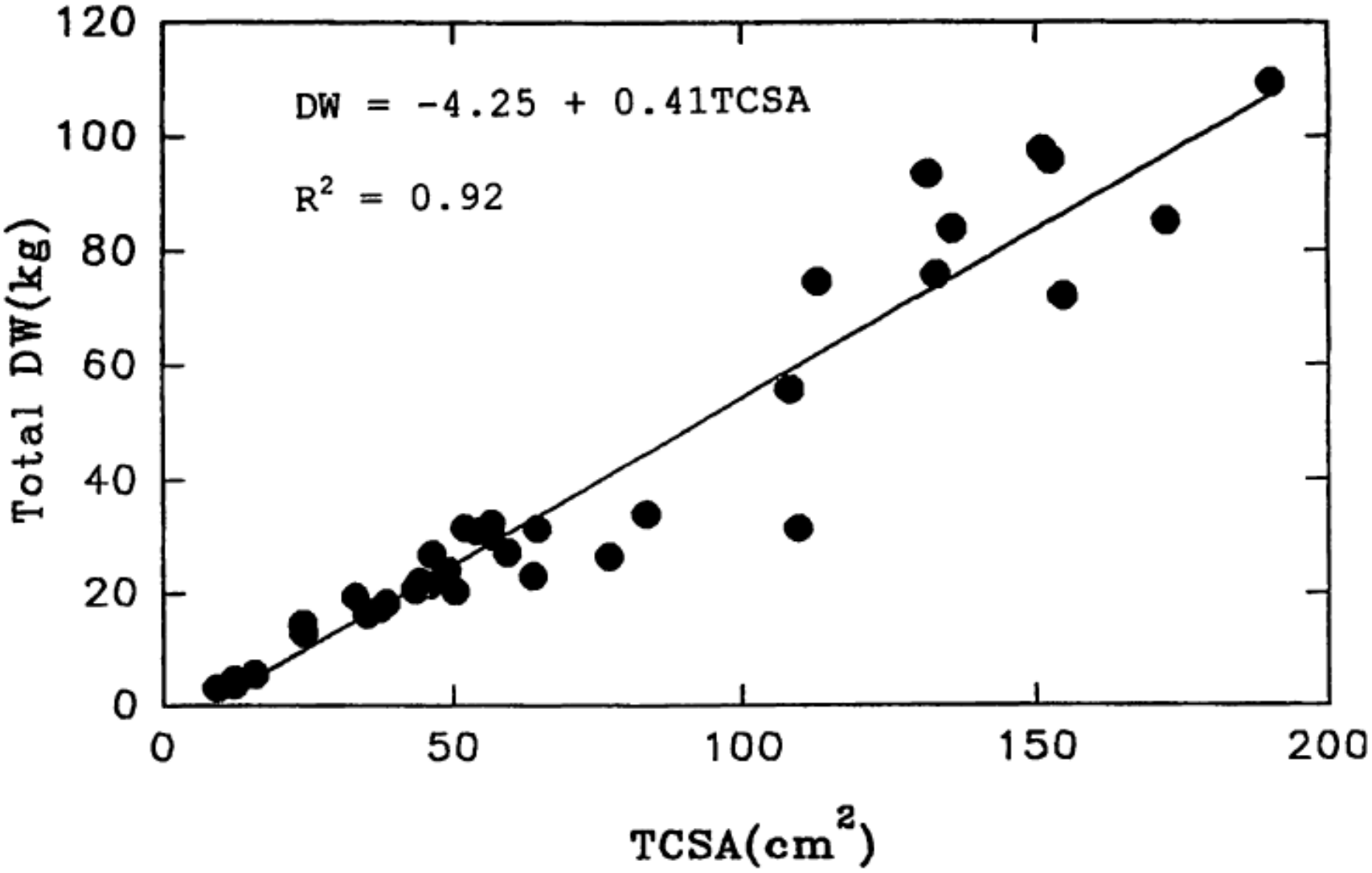
vs.

diameter or circumference



$\Pi r^2 = \text{Area}$

Estimating Tree Size



Measuring Efficiency

$$\text{'YE'} = \frac{\textbf{YIELD}\ \text{Production (kg})}{\textbf{TCSA}\ \text{Tree Size (cm}^2\text{)}}$$

Measuring Efficiency

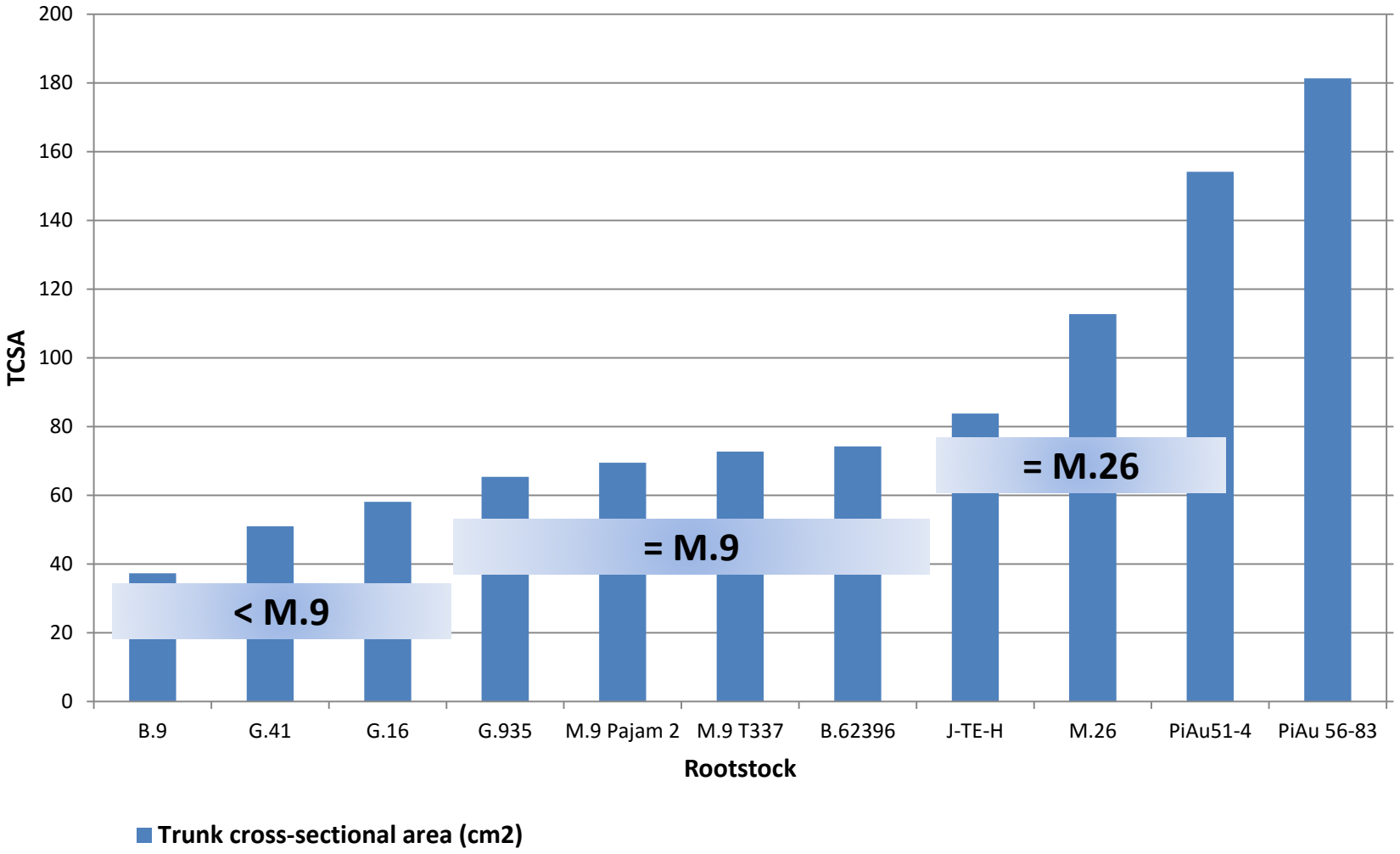
$$\text{'YE'} = \frac{\textbf{YIELD}\ \text{Production (kg})}{\textbf{TCSA}\ \text{Tree Size (cm}^2\text{)}}$$

1990 NC140 Cultivar/Rootstock Trial

Ten year cumulative average for 12 sites

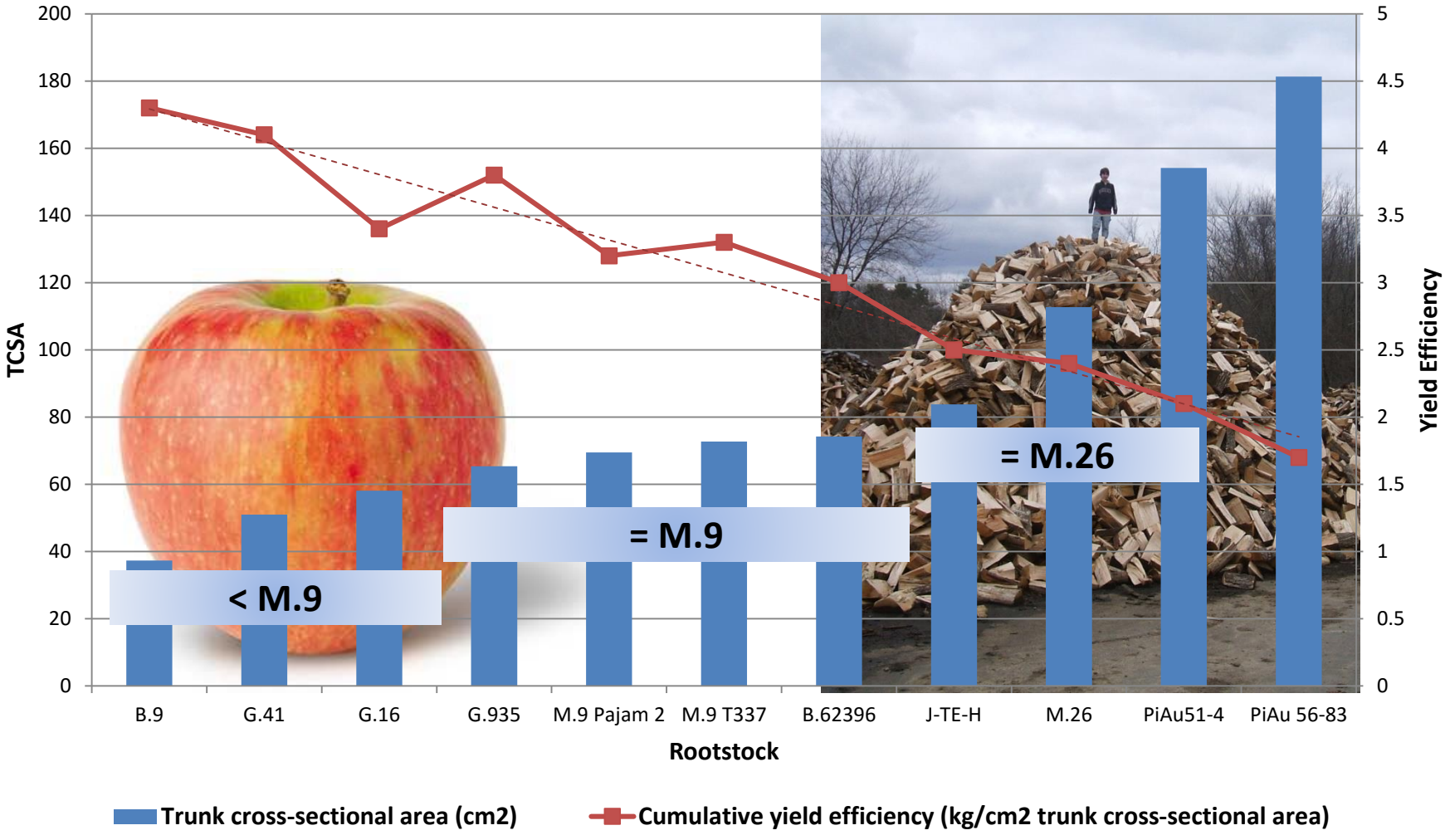
Rootstock	**TCSA** (cm^2)	**Yield**/Tree (kg)	**Yield Efficiency (kg/cm^2 TCSA)**
Mark	46	127	**2.9**
B.9	57	152	**3.0**
M.9 EMLA	88	195	**2.5**
M.26 EMLA	118	210	**2.0**

Tree Size

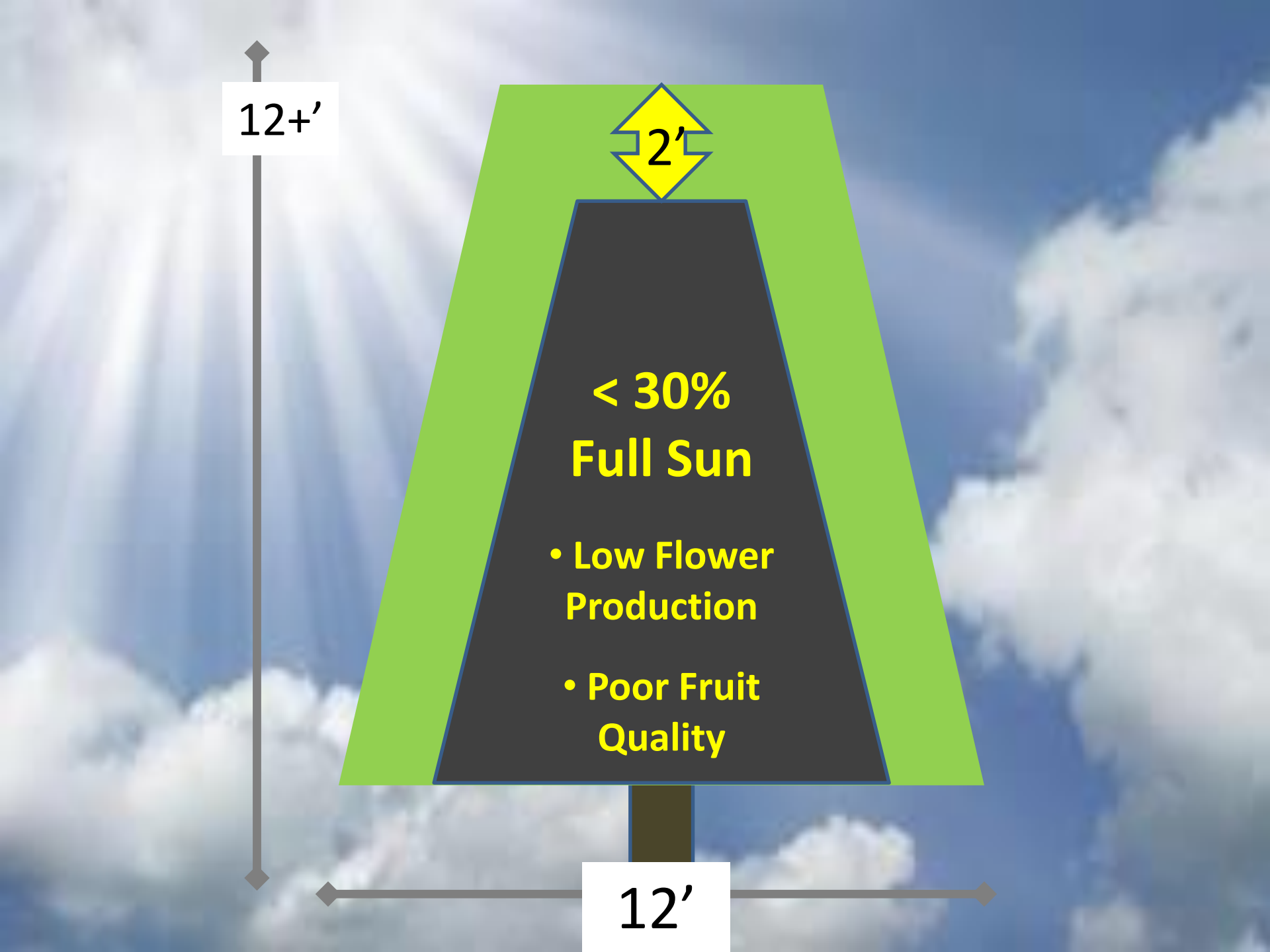


2003 NC140, Sturgeon Bay

Yield Efficiency vs. Tree Size

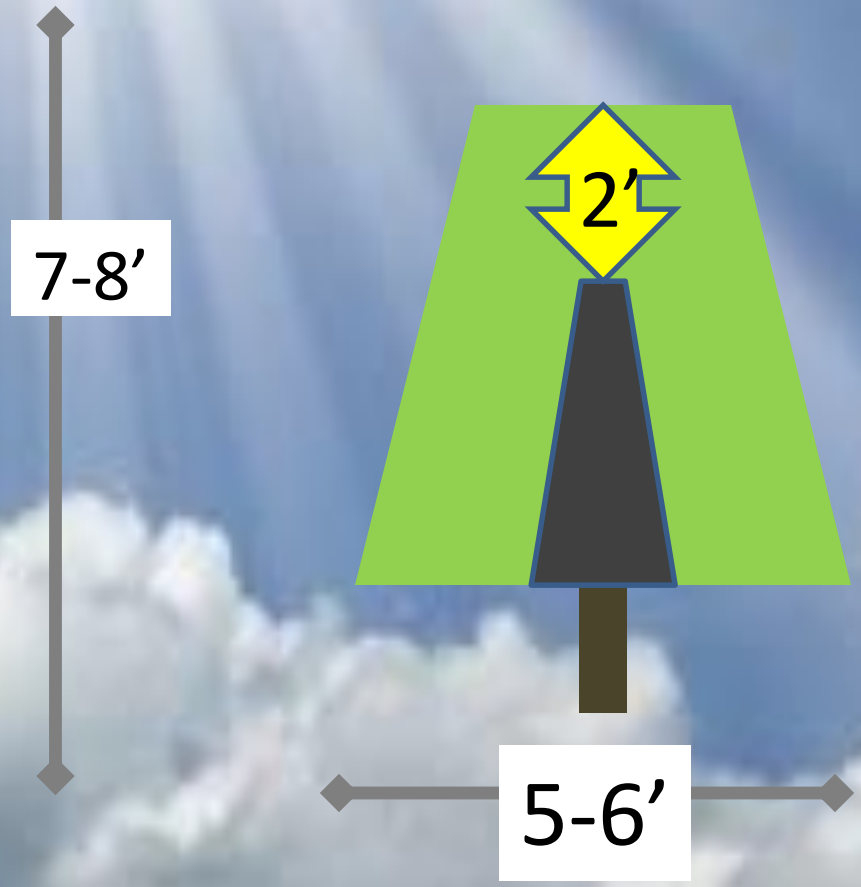


2003 NC140, Sturgeon Bay

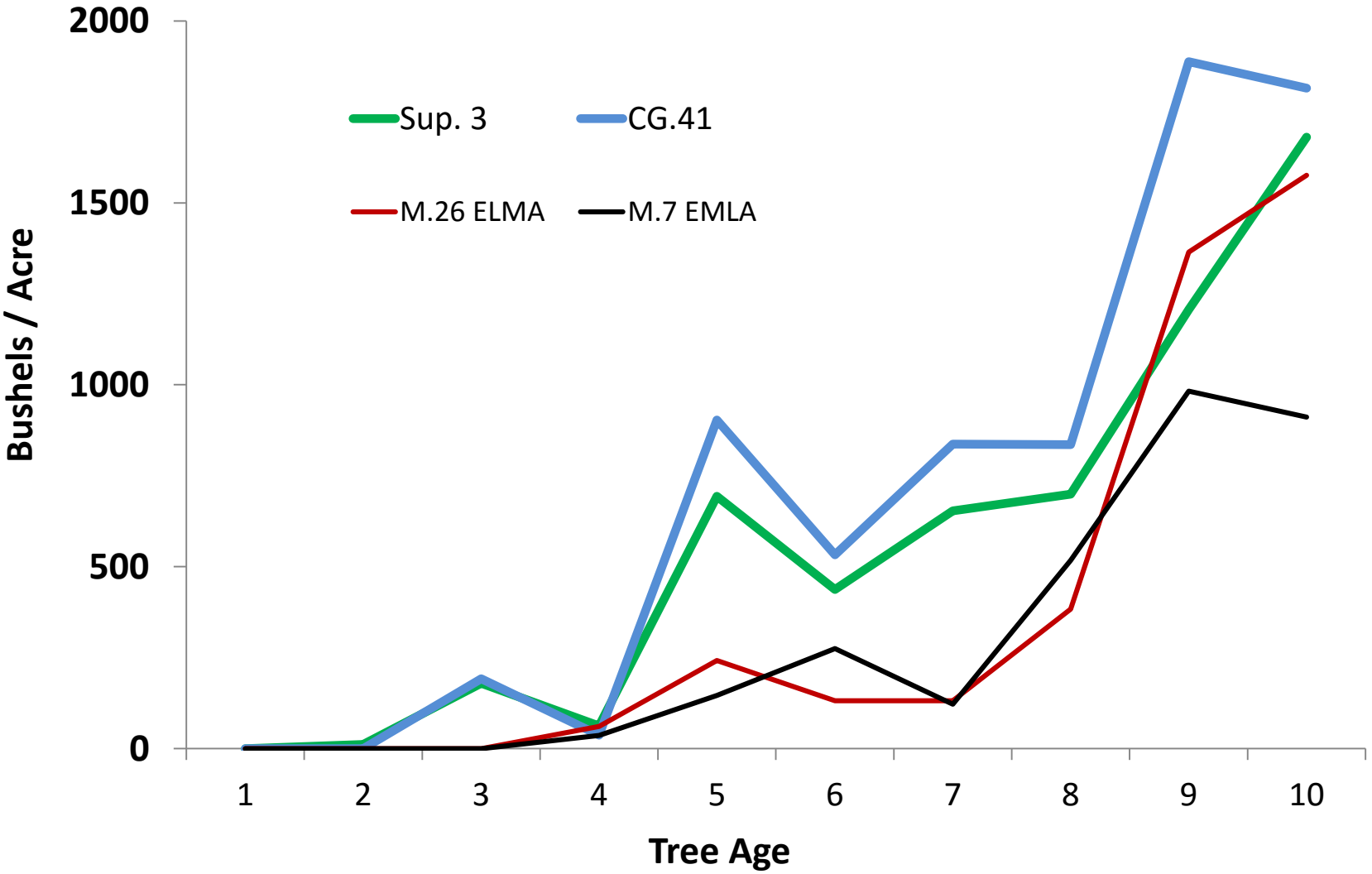

12+’
2’
< 30%
Full Sun
• Low Flower Production
• Poor Fruit Quality
12’

Better Light Distribution!

Dwarfing Rootstocks

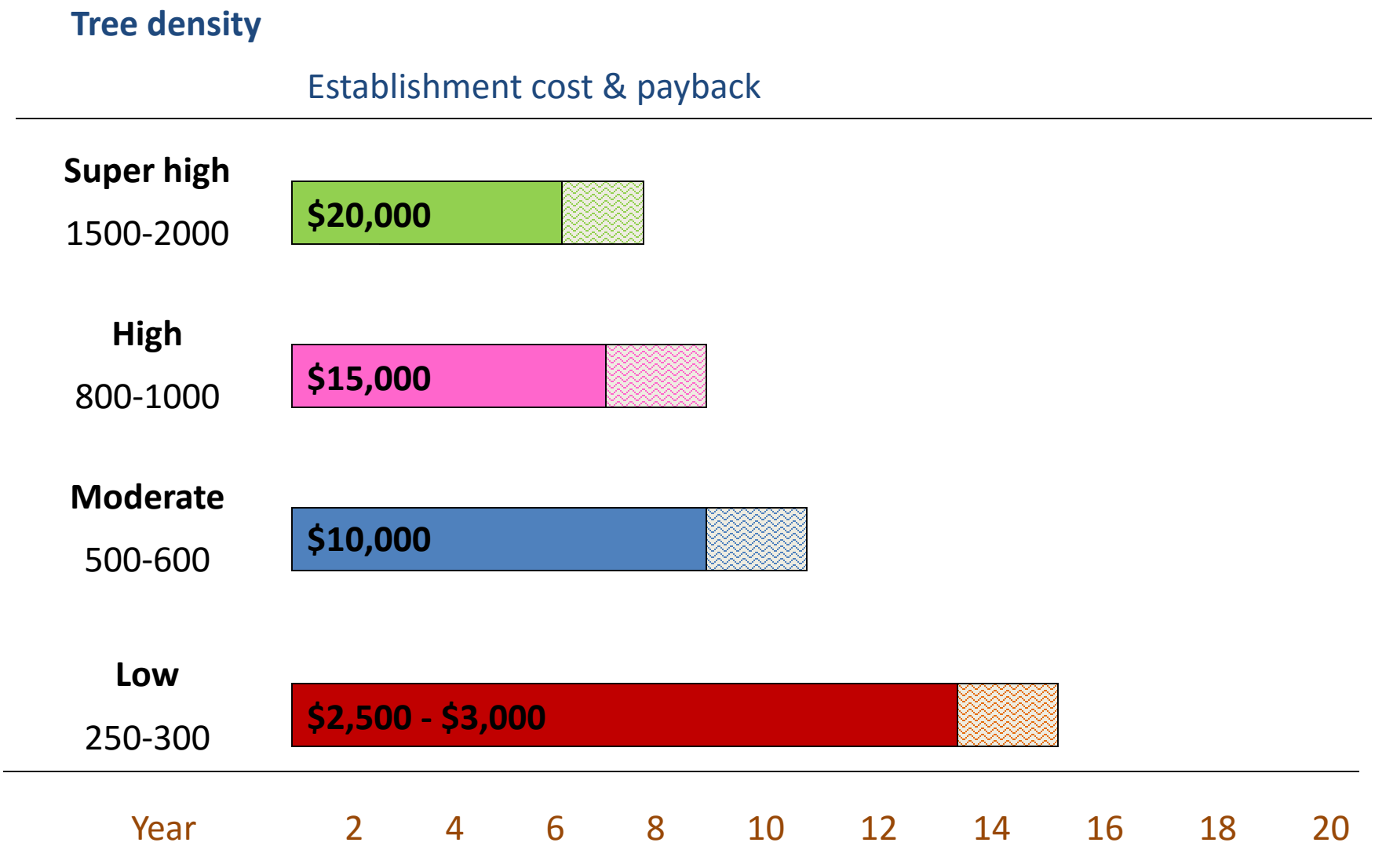


Earlier Return on Investment

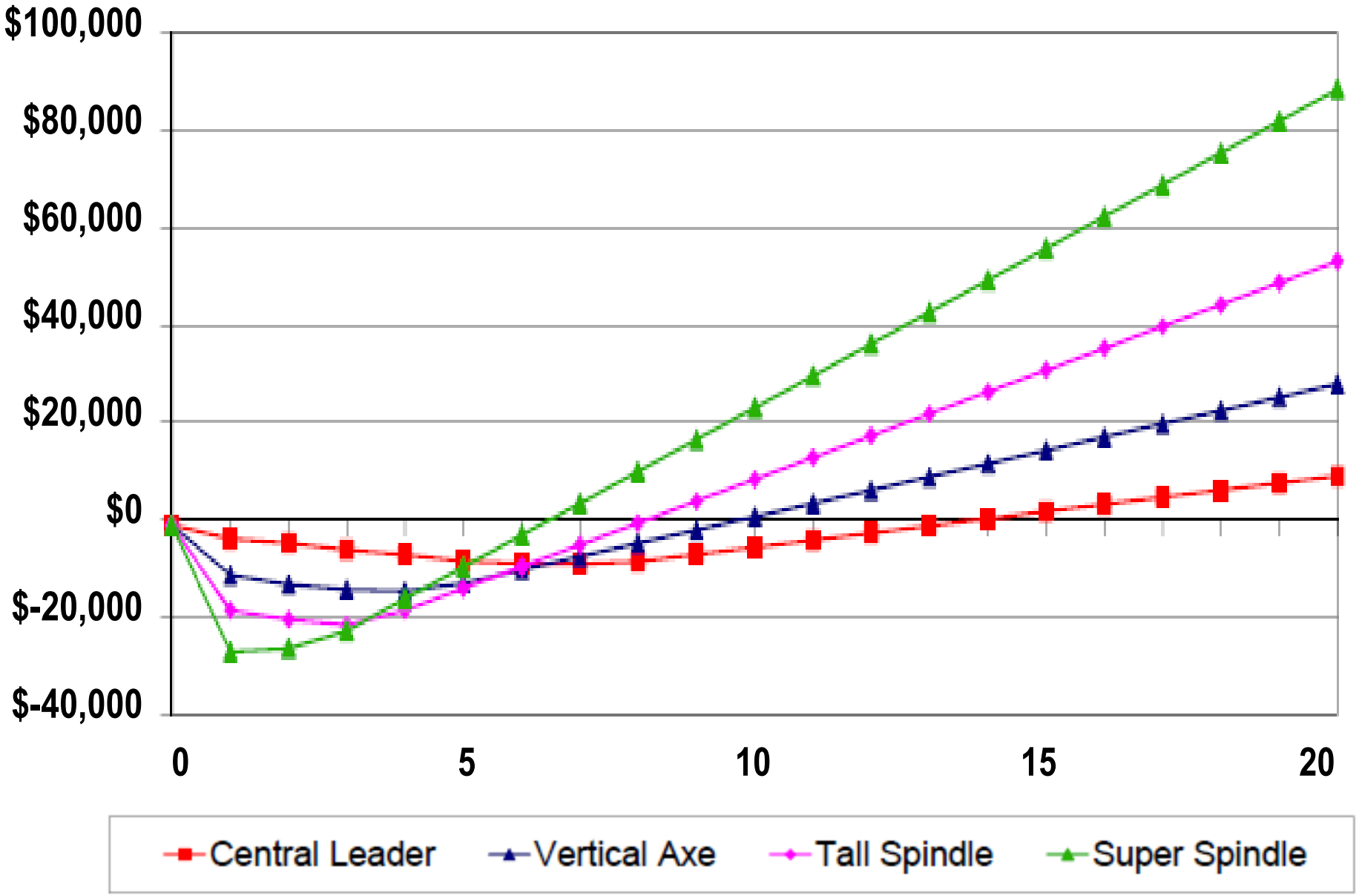


1999 NC140 Apple Rootstock, Sturgeon Bay

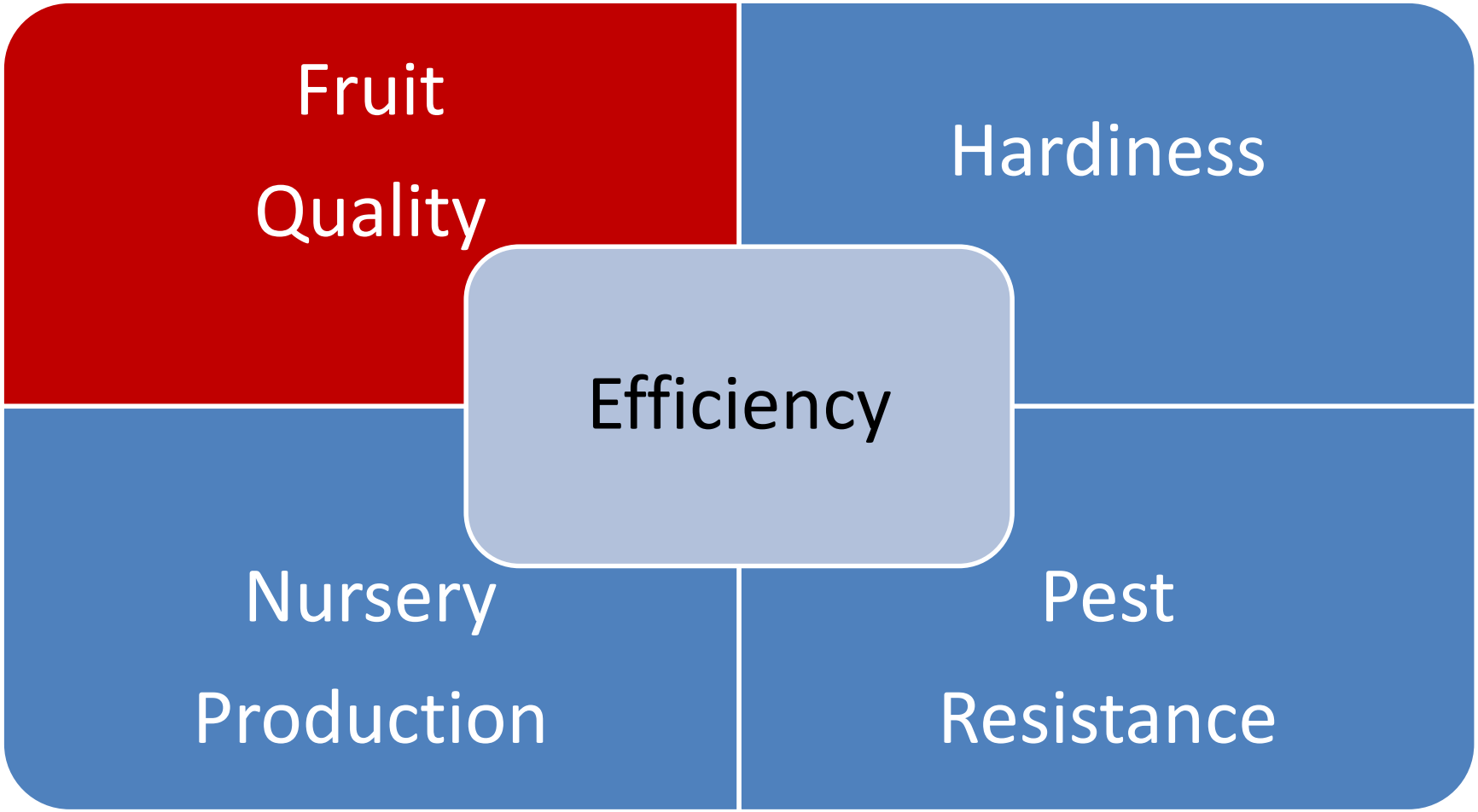
Earlier Return on Investment



20 Year Profit Estimate



Only Part of the Matrix

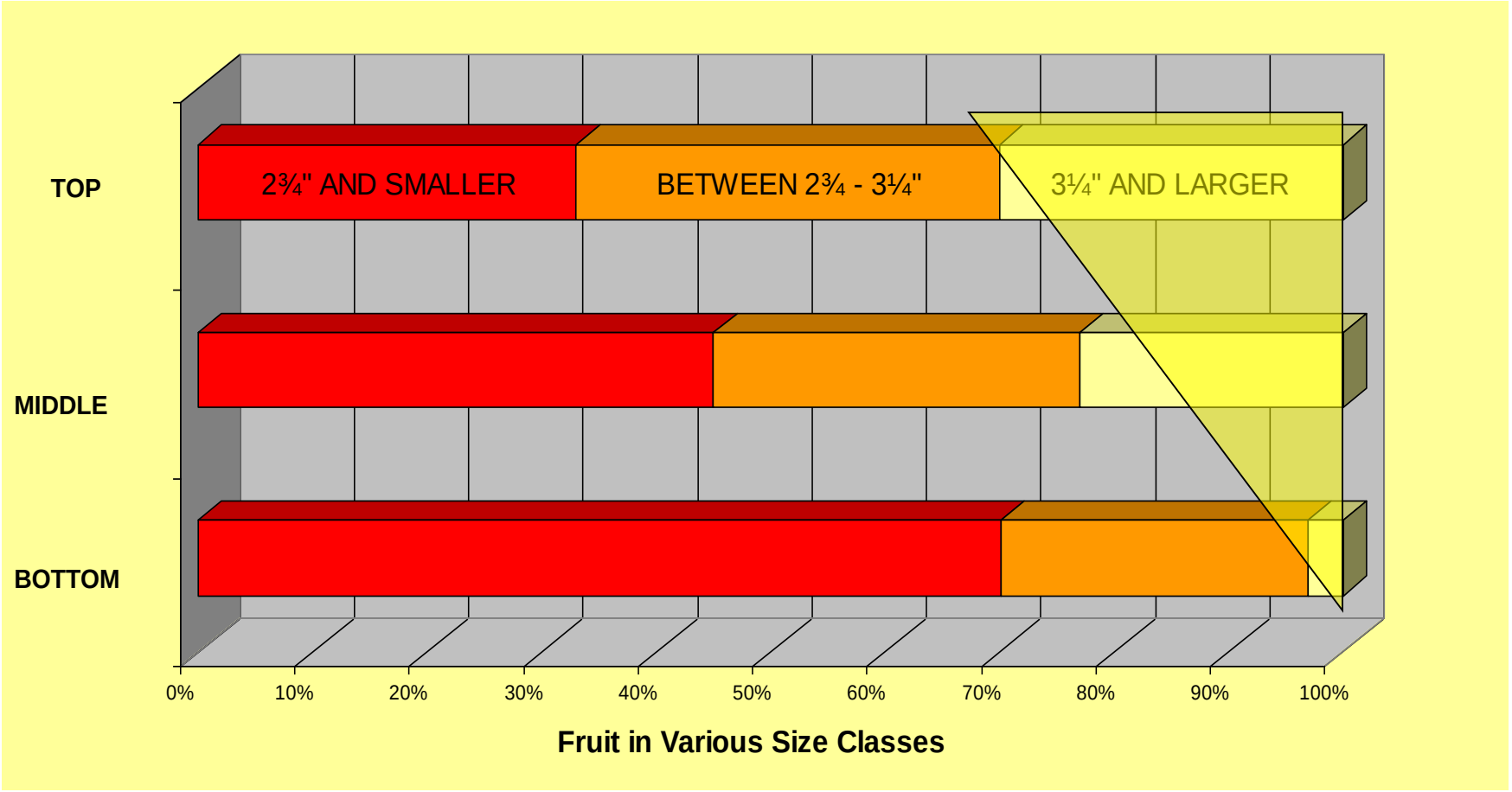


Spur Quality and Canopy Position

Canopy Position	% Full Sunlight	Spur Dry Weight (g/spur)	% Fruit Set	% Red Color
Top	48	0.98	61	88
Middle	23	0.87	54	80
Bottom	9	0.62	42	81
% Reduction from top to bottom	-80%	-37%	-31%	-8%

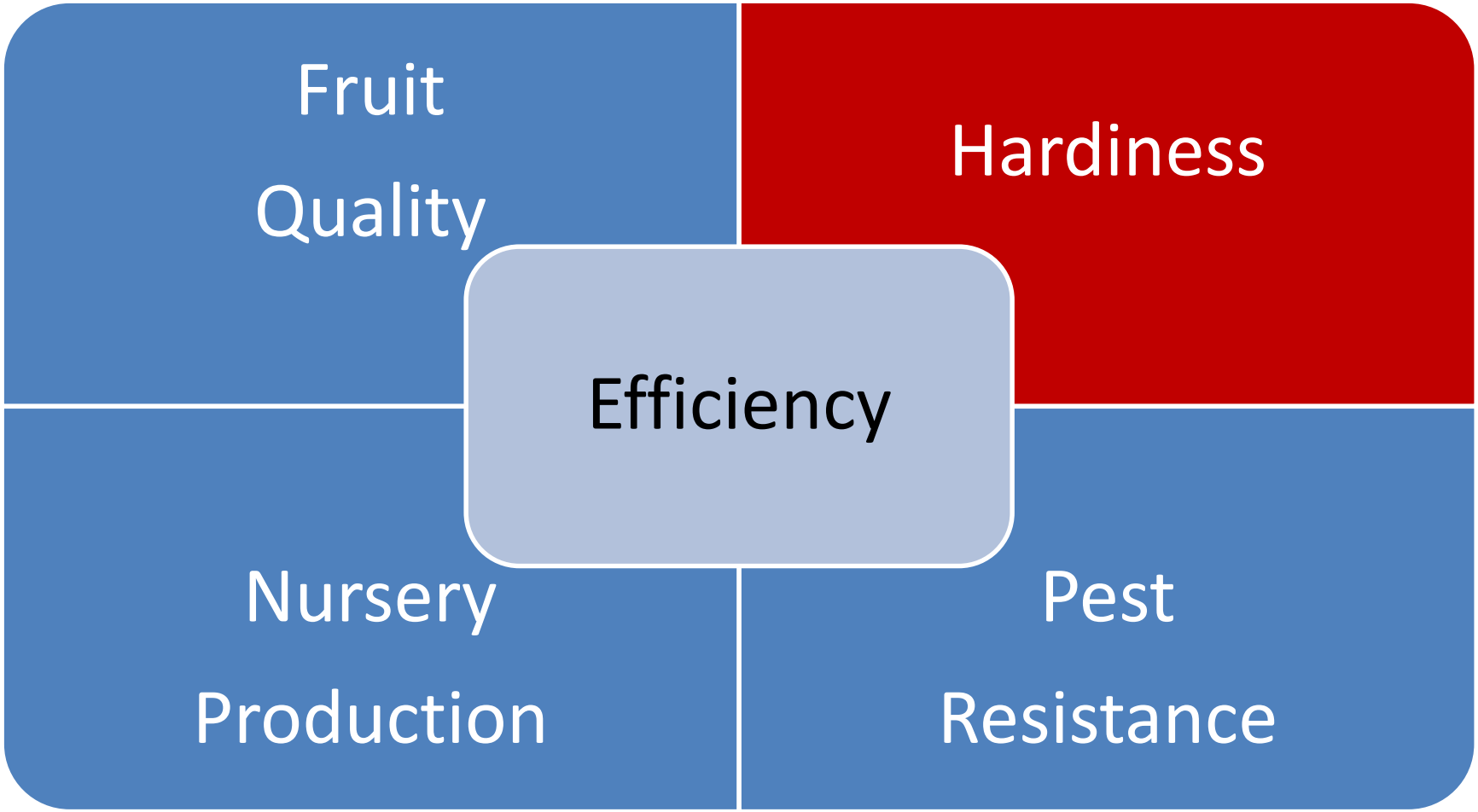
Adapted from: Barritt, B.H., C.R. Rom, K.R. Guelich, S.R. Drake, and M.A. Dilley. **1987**. Canopy Position and light effects on spur, leaf, and fruit characteristics of Delicious apple. *HortScience* 22:402-405.

Fruit Size and Canopy Position



Adapted from: Barritt, B.H., C.R. Rom, K.R. Guelich, S.R. Drake, and M.A. Dilley. **1987**. Canopy Position and light effects on spur, leaf, and fruit characteristics of Delicious apple. *HortScience* 22:402-405.

Only Part of the Matrix



Budagovski

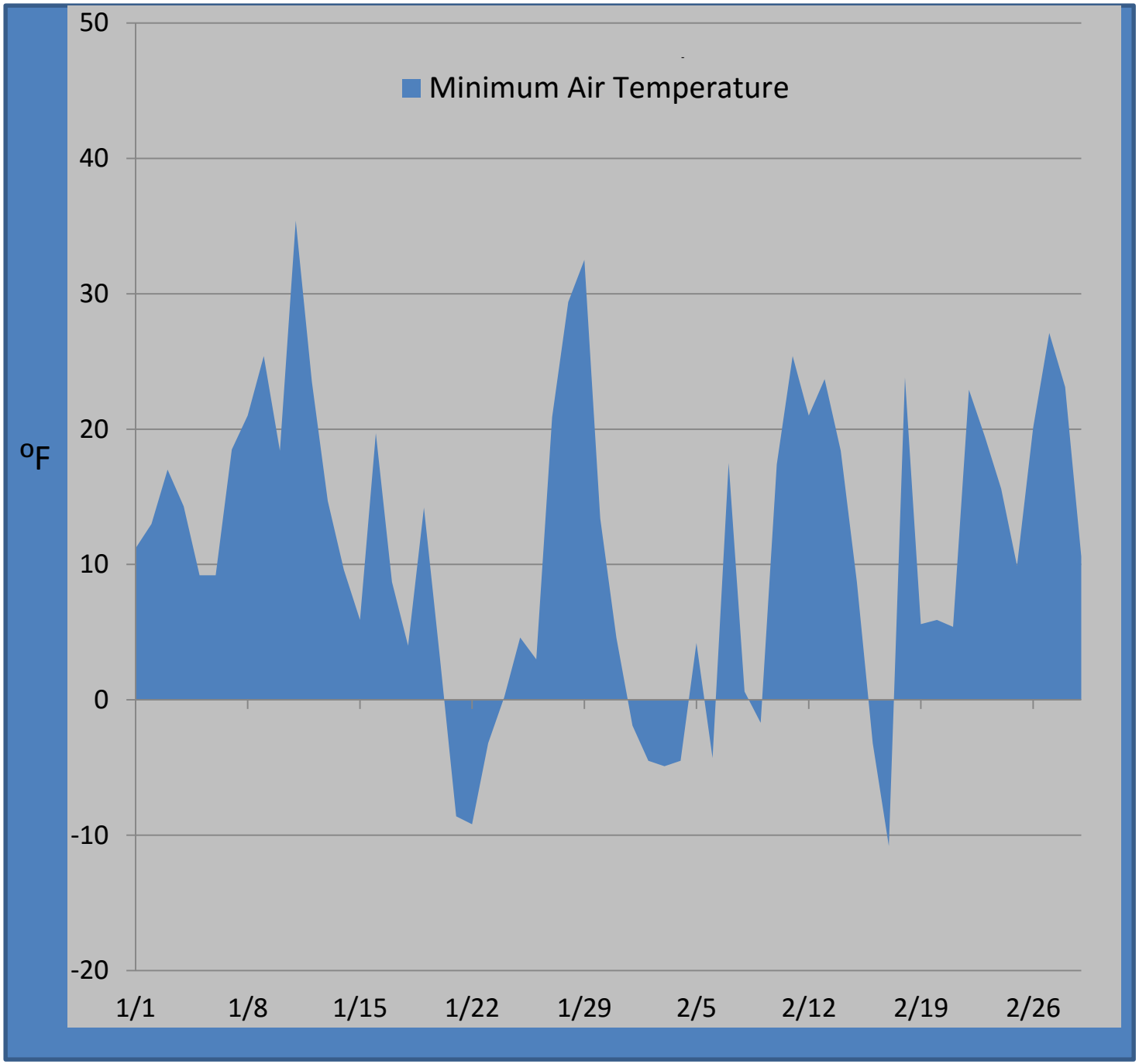
- Breeding program at Michurinski College in Russia.
- Resistance to low temperature stress.
- **B9 an 'M.9' replacement in cold climates.**
  M.8 x Red Standard (Krasnij Standart)
- 2003 planting: **B10** (B62-396) tested.
- 2010 planting: **B9, B10**, B64-194, B67-5-32, B70-6-8, B70-20-20, B7-20-21, B71-7-22, B7-3-150.
- 2014 planting: **B10 & Vineland series (CAN)**

2012-13 Winter Injury - **Root Damage**

2013

January

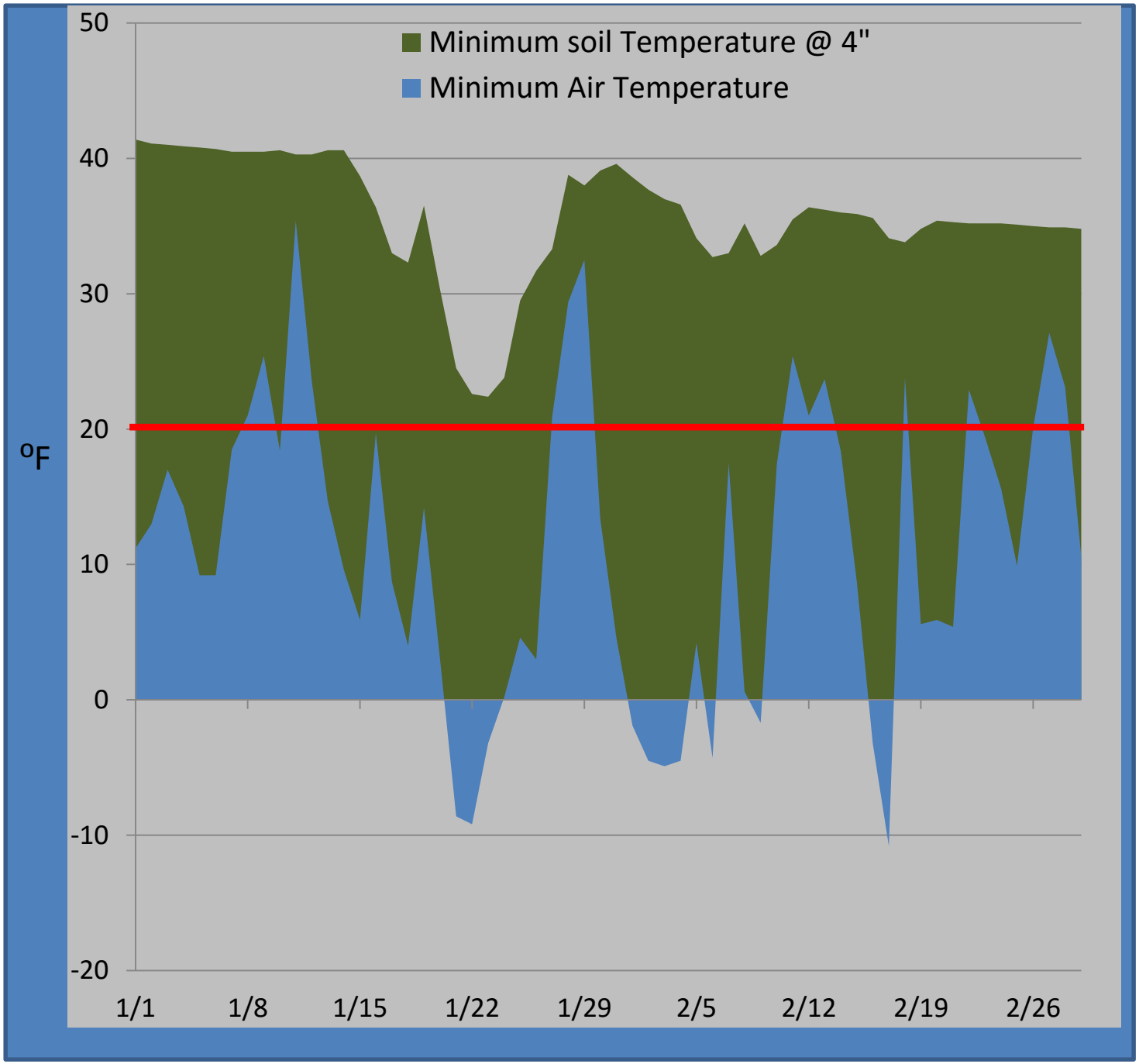
February



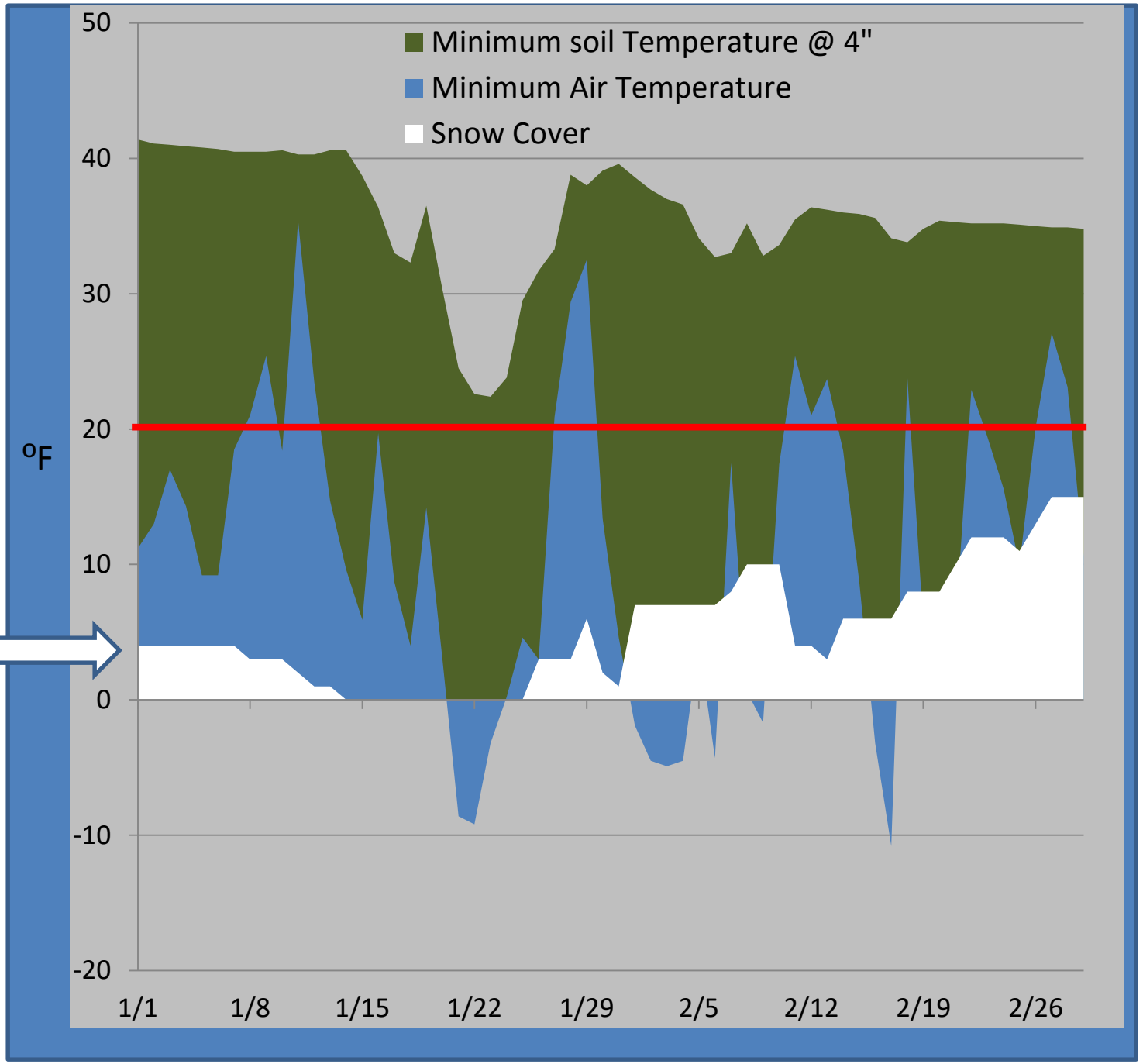
2013

January

February

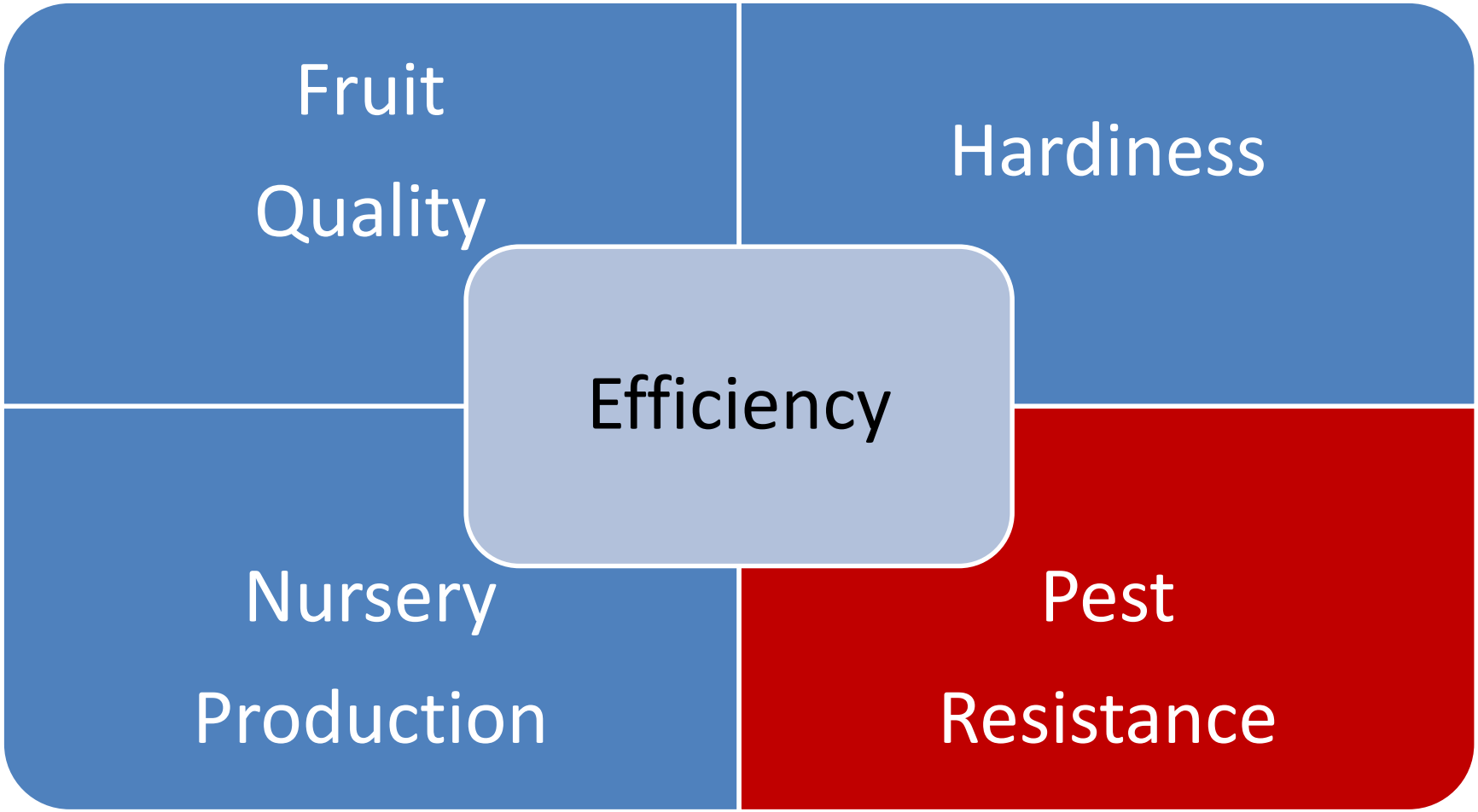


2013
January
February



Snow depth inches

Only Part of the Matrix



Breeding and Developing New Apple Rootstocks

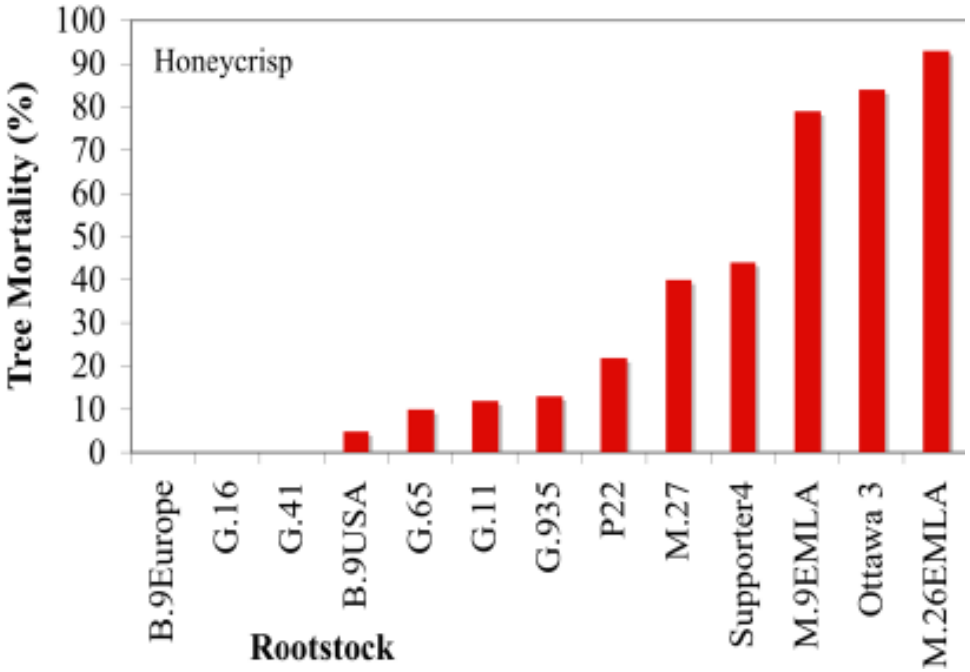
Started in 1968 Geneva, NY

Goals:

- Resistant to Fireblight
- Resistant to Phytophthora
- Resistant to Wooly Apple

As productive and precocious as Malling stocks

Fireblight


Honeycrisp
Tree Mortality (%)
100
90
80
70
60
50
40
30
20
10
0
B.9Europe
G.16
G.41
B.9USA
G.65
G.11
G.935
P22
M.27
Supporter4
M.9EMLA
Ottawa 3
M.26EMLA
Rootstock

G & CG (Geneva and Cornell Geneva)

- Cornell-Geneva breeding program located in Geneva, NY, USA.
- Selected for horticultural characteristics and resistance to **fire blight, crown rot & WAA**.
- **G** released to the commercial market.

  Earlier releases - G**11**, G**16**, G**41**, G**935**, G**202**, G**30**

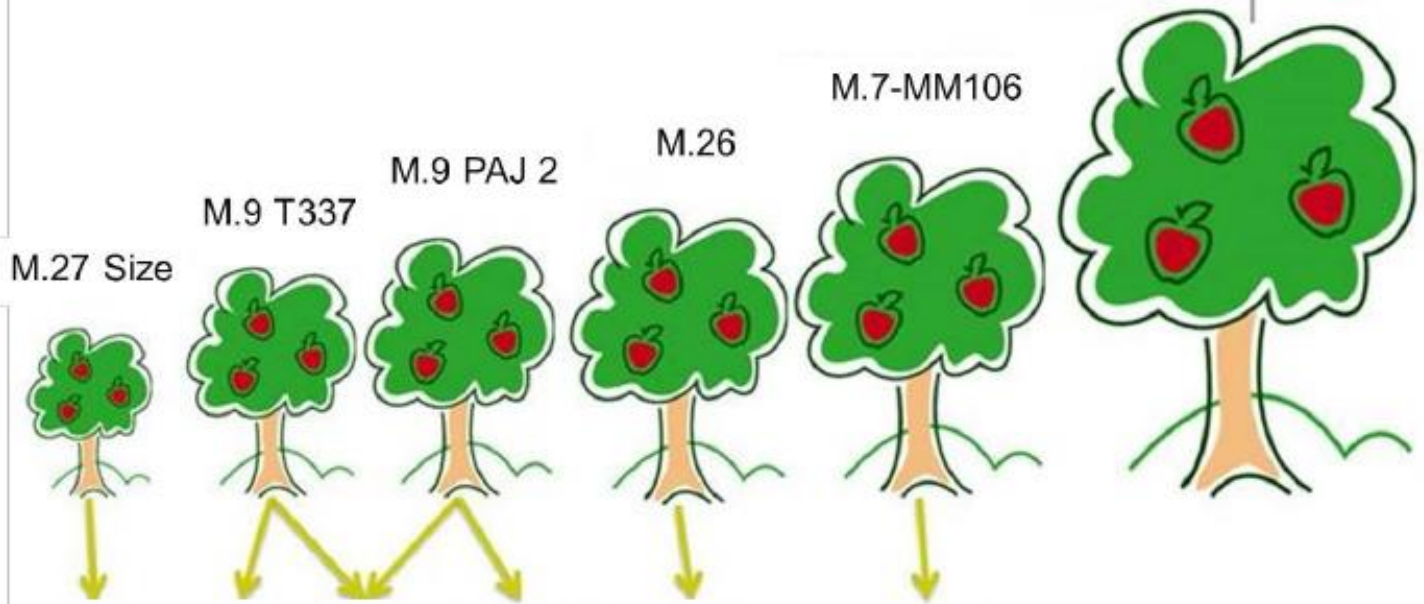
  Recent releases - G**213**, G**214**, G**814**, G**969**, G**210**, G**890**
- CG are still in test.
  - CG.2034, CG.3001, CG.4003, CG.4004, CG.4013, CG.5087, CG.5222 etc….

CTL CENTER FOR TECHNOLOGY LICENSING AT CORNELL UNIVERSITY

GENEVA® APPLE ROOTSTOCKS COMPARISON CHART v.2

Released GENEVA® Apple Rootstocks Arranged by Tree Size

USDA ARS Agricultural Research Service



M.27 Size	M.9 T337	M.9 PAJ 2	M.26	M.7-MM106	Seedling Size
G.65	G.11	G.41	G.214	G.935	G.969
		G.16	G.814	G.222	G.30
New Releases		G.213		G.202	G.210
					G.890

The GENEVA® Apple Rootstocks perform differently in Washington State conditions in comparison to the data displayed here that was collected in New York State.

Please contact your local extension agent for growing predictions for these varieties in your region.

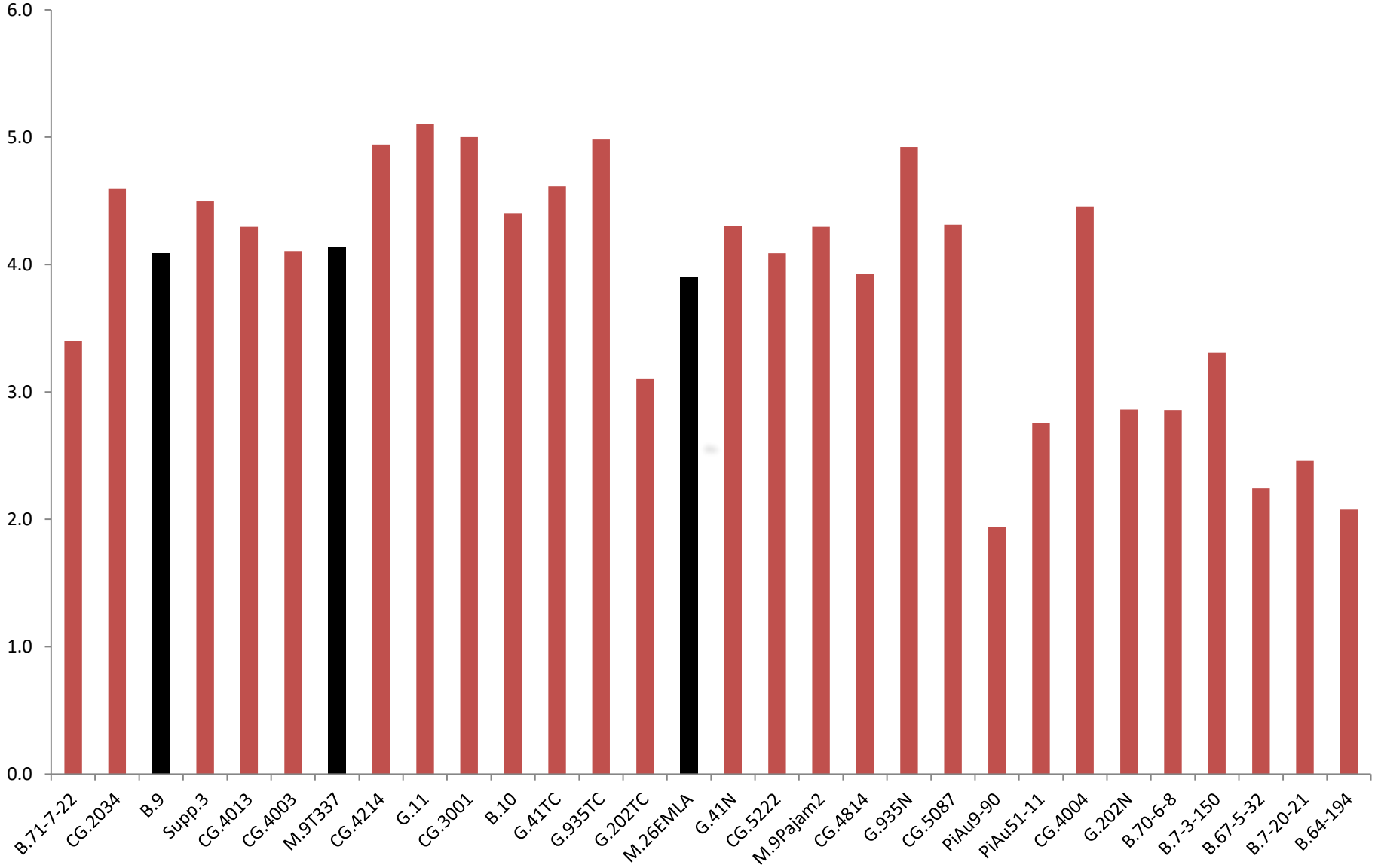
Contact:
Jessica Lyga,
Plant Varieties & Germplasm Licensing Officer

Office: 607-255-0270

E-mail:
JML73@cornell.edu

www.ctl.cornell.edu

2010 NC140 Apple Rootstock, Wisconsin
- Yield Efficiency



M.9

Rootstock	Fireblight Resistance	Crown Rot Tolerance	Wooly Apple Aphid	Replant Tolerance
G.11	✓	✓	✓	✓
G.16	Hypersensitive to at least one latent virus			
G.41	✓	✓	✓	✓

G.41

NC-140 Trial	Tree Size TCA (% of M.9)	Yield Eff. (% of M.9)	Fruit Size (% of M.9)
1996 Gala	150*	124*	109*
1998 Jonagold	96	155*	93*
1999 McIntosh	126	124	105
2003 Goldens-WI	70 *	120*	91*
2010 Honeycrisp	**106**	**103**	**107***

G.41 - vigor like larger M.9 clones (NIC29)

Resistant to Fire Blight and Crown Rot

Resistant to Wooly Apple Aphid

Tolerant to Replant Disease Complex

- Very precocious
- Very cold hardy
- Tends to be less biennial on Honeycrisp.
- In the USA new stoolbeds planted in 2009 and 2010.

M.9

Rootstock	Fireblight Resistance	Crown Rot Tolerance	Wooly Apple Aphid	Replant Tolerance
G.11	✓	✓	✓	✓
G.16	Hypersensitive to at least one latent virus			
G.41	✓	✓	✓	✓

M.9 < M.26

Rootstock	Fireblight Resistance	Crown Rot Tolerance	Wooly Apple Aphid	Replant Tolerance
G.11	✓	✓	✓	✓
G.16	Hypersensitive to at least one latent virus			
G.41	✓	✓	✓	✓
B.10	✓	✓	?	✓
G.213	✓	✓	✓	✓
G.214	✓	✓	✓	✓
G.814	✓	✓	-	✓

M.9

Rootstock	Yield Efficiency (kg/cm² TCSA)
M.9 T337	3.0
G.11	3.4*
B.10	3.2*
G.41	3.1
G.213	??

< M.26

Rootstock	Yield Efficiency (kg/cm² TCSA)
G.214	3.2*
G.814	2.6*
M.26 EMLA	2.4

$1,000 - $5,000/A

2010 NC140 Apple Rootstock, Sturgeon Bay

M.26

Rootstock	Fireblight	Crown Rot	Wooly Apple Aphid	Replant Tolerance
G.935	✓	✓	-	✓
G.202	✓	✓	✓	✓
G.222	✓	✓	✓	-

G.935 - vigor slightly smaller than M.26

Resistant to Fire Blight and Crown Rot

Susceptible to Wooly Apple Aphid

Tolerant to Replant Disease Complex

- More productive than M.26, like M.9.
- Very cold hardy.
- Fruit size is smaller than M9 in some trials; **not in WI**.

Questions about compatibility/latent virus?

G.935

NC-140 Trial	Tree Size TCA (% of M.9)	Yield Eff. (% of M.9)	Fruit Size (% of M.9)
1991 Empire	138 *	122	---
1998 Gala	207 *	112 *	101
1999 McIntosh	177*	111	95
2010 Honeycrisp	**116***	**122***	**100**

G.202 - vigor similar to M.26

Resistant to Fire Blight and Crown Rot

Resistant to Wooly Apple Aphid

Tolerance to Replant Disease Complex

- Precocious, productive.
- Cold hardy.
- Good choice for weak growing cultivars like Honeycrisp.

G.202

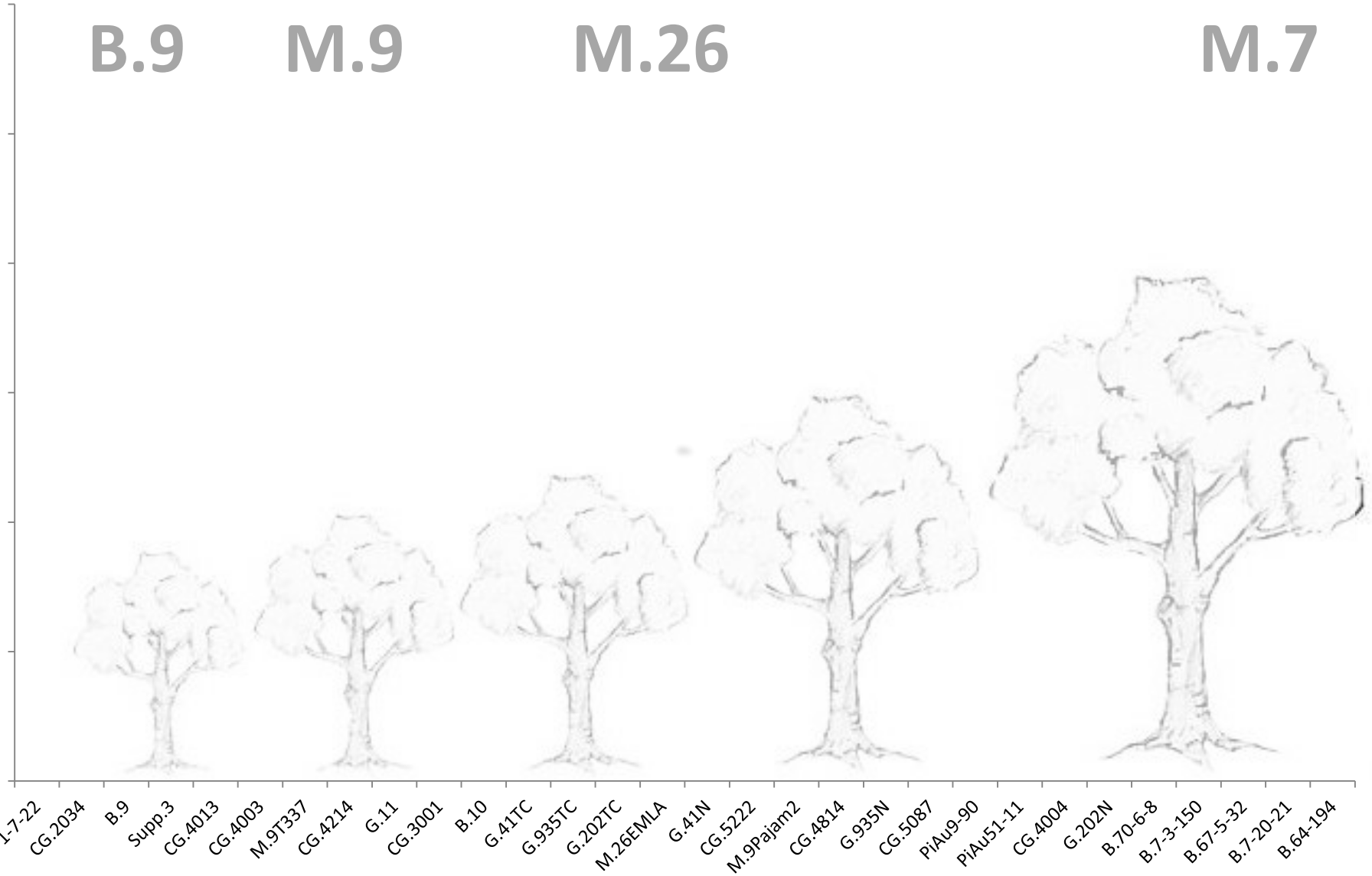
NC-140 Trial	Tree Size TCA (% of M.9)	Yield Eff. (% of M.9)	Fruit Size (% of M.9)
1991 Empire	153*	101	---
1996 Delicious	171*	103	108*
1999 McIntosh	200*	76*	101
2010 Honeycrisp	**120**	**93**	**96**

M.7 < MM.106

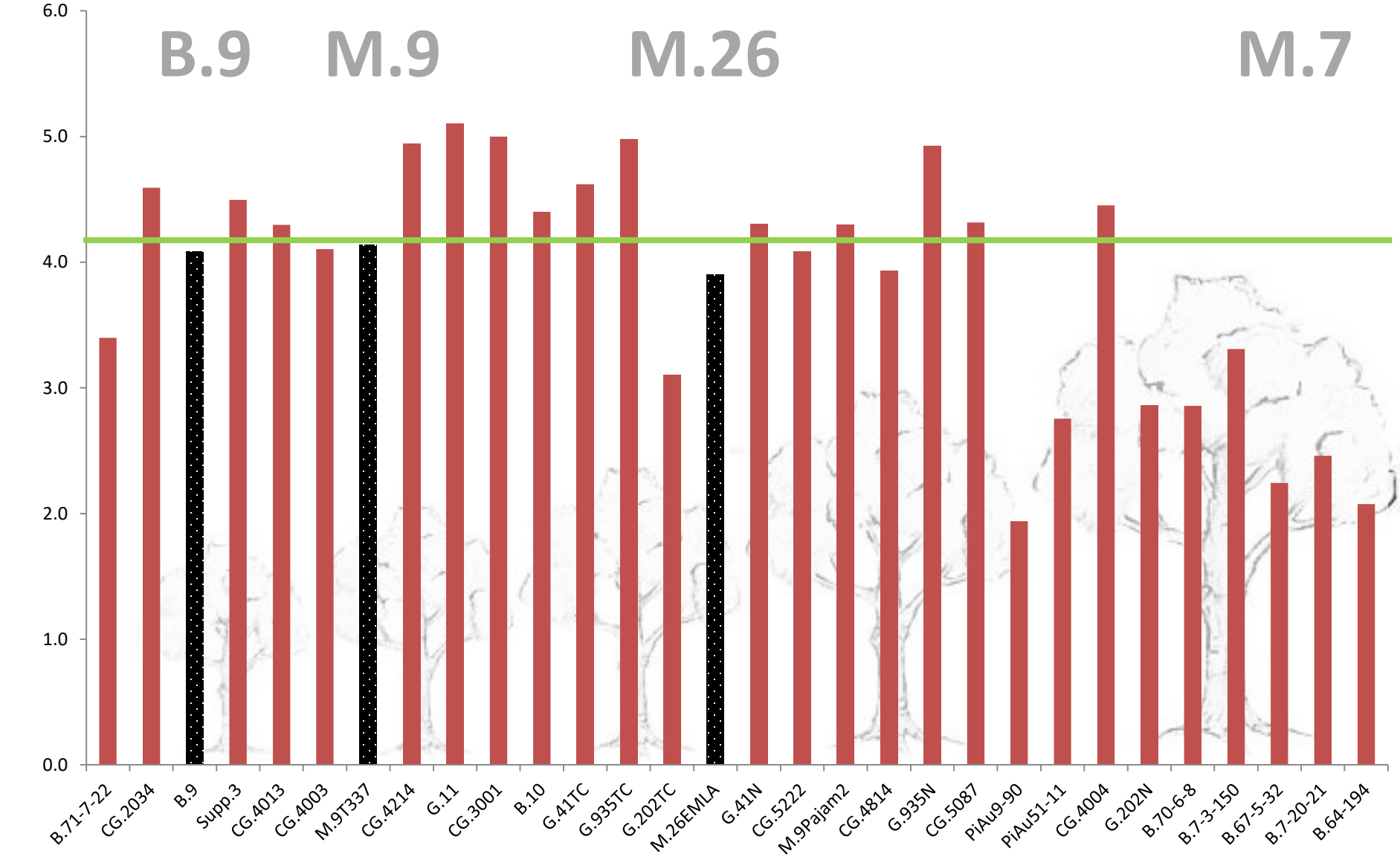
Rootstock	Fireblight	Crown Rot	Wooly Apple Aphid	Replant Tolerance
G.30	✓	✓	-	✓
G.210	✓	✓	✓	✓
G.969	✓	✓	✓	✓
G.890	✓	✓	✓	✓

‘YE’ > M.26!!

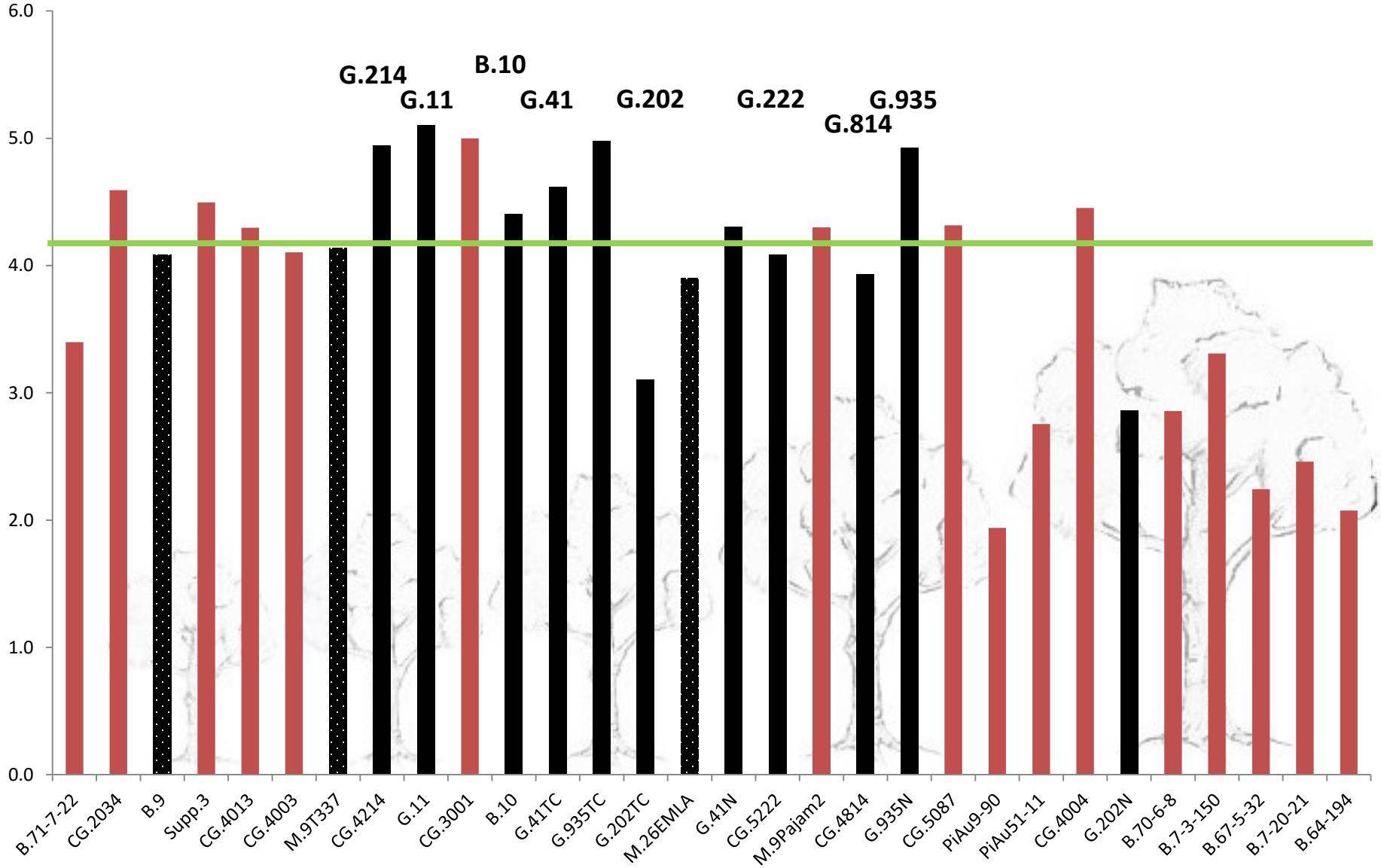
2010 NC140 Apple Rootstock, Wisconsin



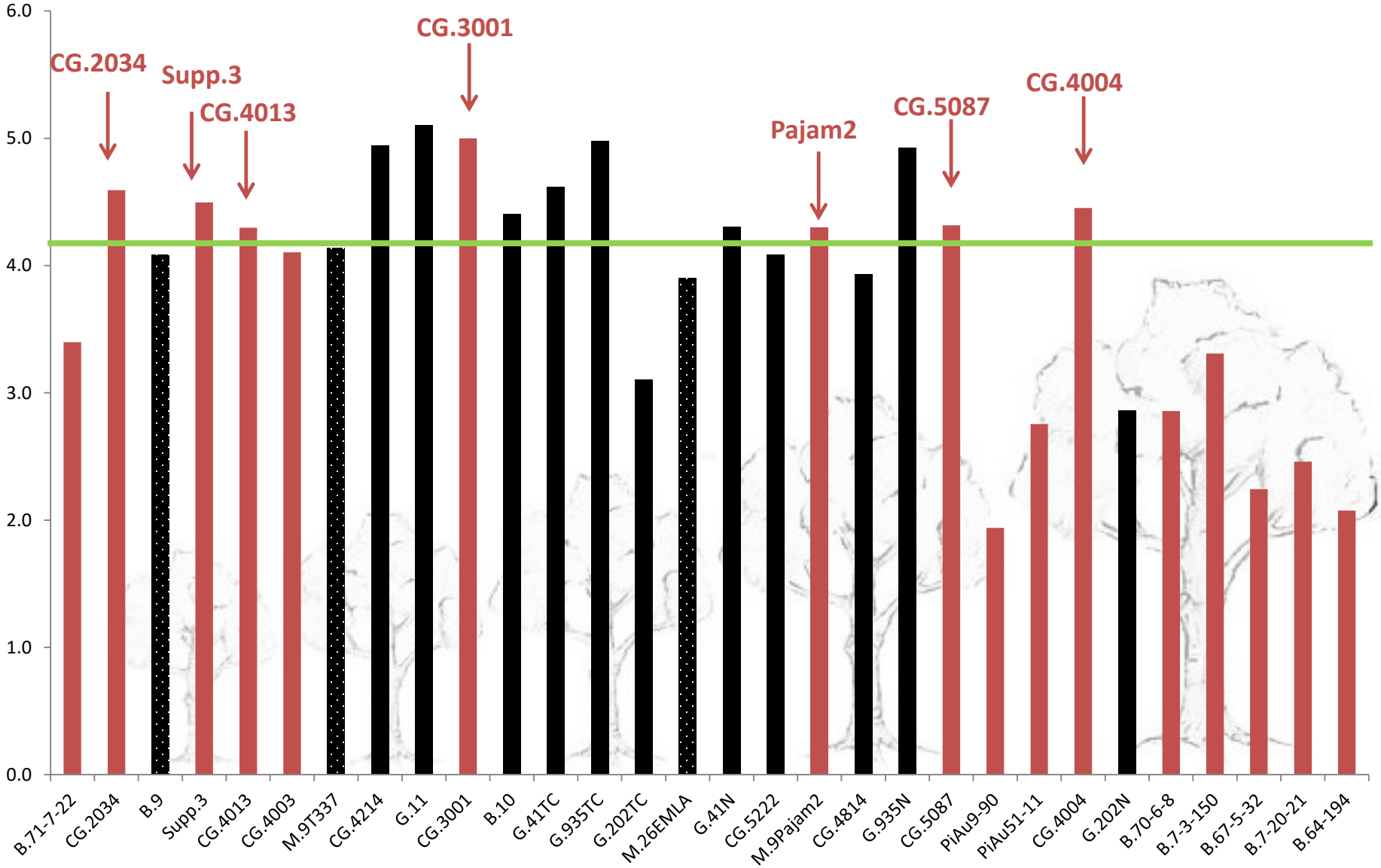
2010 NC140 Apple Rootstock, Wisconsin
- Yield Efficiency



2010 NC140 Apple Rootstock, Wisconsin - Yield Efficiency



2010 NC140 Apple Rootstock, Wisconsin
- Yield Efficiency



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GENEVA® APPLE ROOTSTOCKS COMPARISON CHART v. 2

Google:

NC140 rootstock

-or-

Geneva rootstock

GENEVA® Apple Rootstocks

Traits	D1148 G.11	D1147 G.16	D3610 G.41[a]	D3539 New! G.213	D4950 G.214	D6263 New! G.814	D3609 G.935	D4190 G.222	D2737 G.202	D4951 G.969	D3785 G.30	D3540 G.210	D5107 G.890
Arranged in order by size (smallest to largest)	M.9 T337	M.9 T337	M.9 T337	M.9 T337	M.9/M.26	M.9/M.26	M.26	M.26	M.26	M.7	M.7	M.7	M.7/ MM.106
Woolly Apple Aphid Resistance	No	No	High	High	High	No	No	High	High	High	No	High	High
Fire Blight Resistance	Resistant	Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant
Replant Disease Complex Resistance	Partial	Partial	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	No	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant
Crown and Root Rots (Phytophthora)	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant
Cold Hardiness	Yes	Partial: Good Mid-winter, Bad early-cold	Yes	TBD	Yes	Yes	Yes	Yes	Yes-Good, Mid-winter	Yes	Yes	Yes	Yes
Productivity/Yield Efficiency- as good or better than M.9	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Low suckering and burr knots	TBD	Yes	Yes	Yes	Yes	Medium	Yes	Medium	Yes	Yes	Yes	Yes	Yes
Susceptibility to latent viruses	No	Yes	No	No	No	Yes	Yes	No	No	No	No	No	No

TBD: To Be Determined.

(a) Remarks: G.41 has presented weak graft unions with the following scions: Cripps Pink, Scilate, and Honeycrisp. The well feathered trees are prone to breakage in strong winds in the first 2-3 years and additional care needs to be taken to prevent breakage. Breakage risk decreases with time.

Recommendation: Use plant materials that have been tested and are "clean" of viruses.

Licensing for all varieties is available as exclusive or non-exclusive in selected Domestic and International Territories.

Chart data valid as of July 22, 2016, and supplied by Cornell University apple rootstock breeding team members, Gennaro Fazio, PhD., USDA Breeder, Terence Robinson, PhD, Cornell Breeder, and Herb Aldwinckle, PhD., Professor Emeritus.

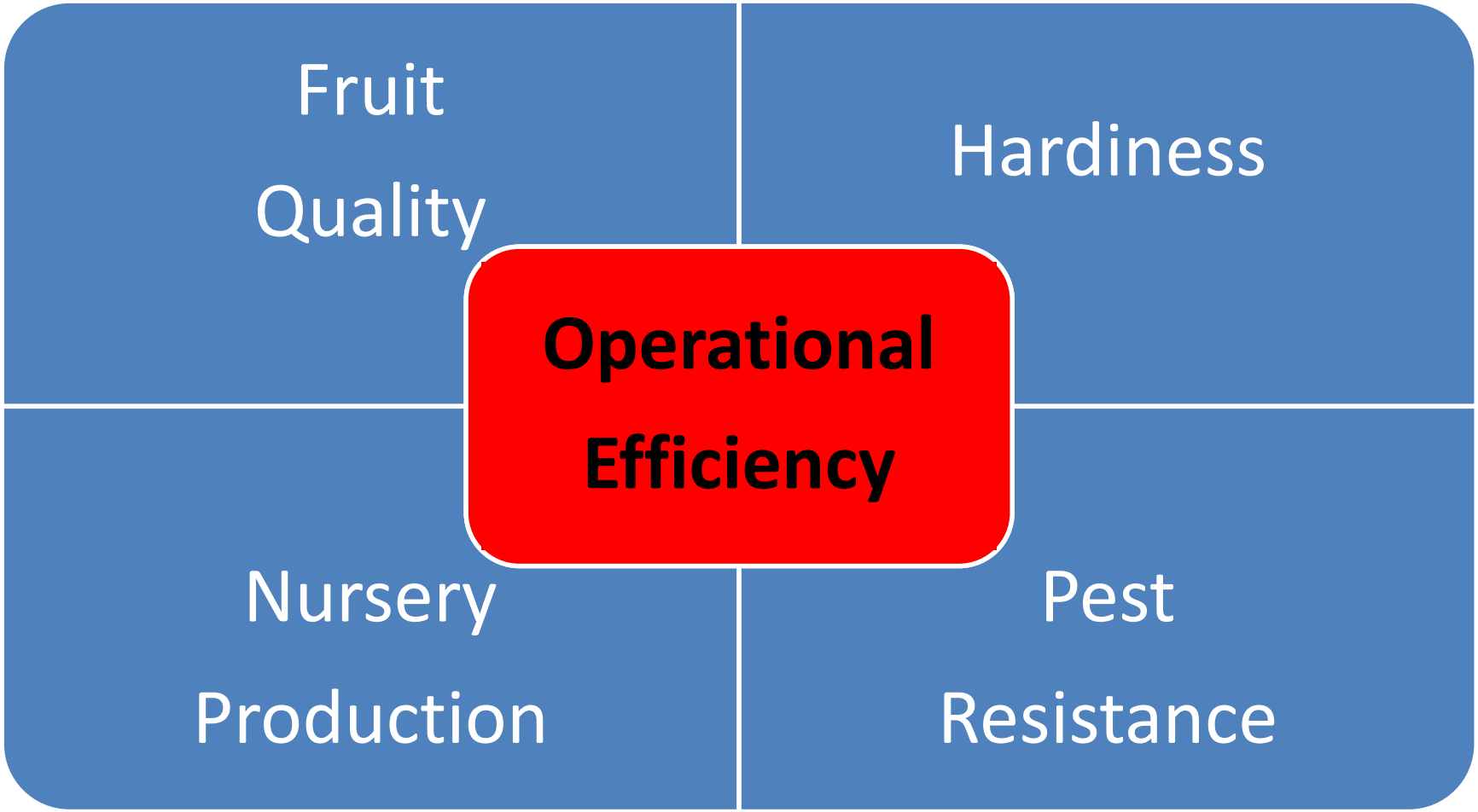
USDA ARS Agricultural Research Service

Contact:
Jessica Lyga, Plant Varieties & Germplasm Licensing Officer

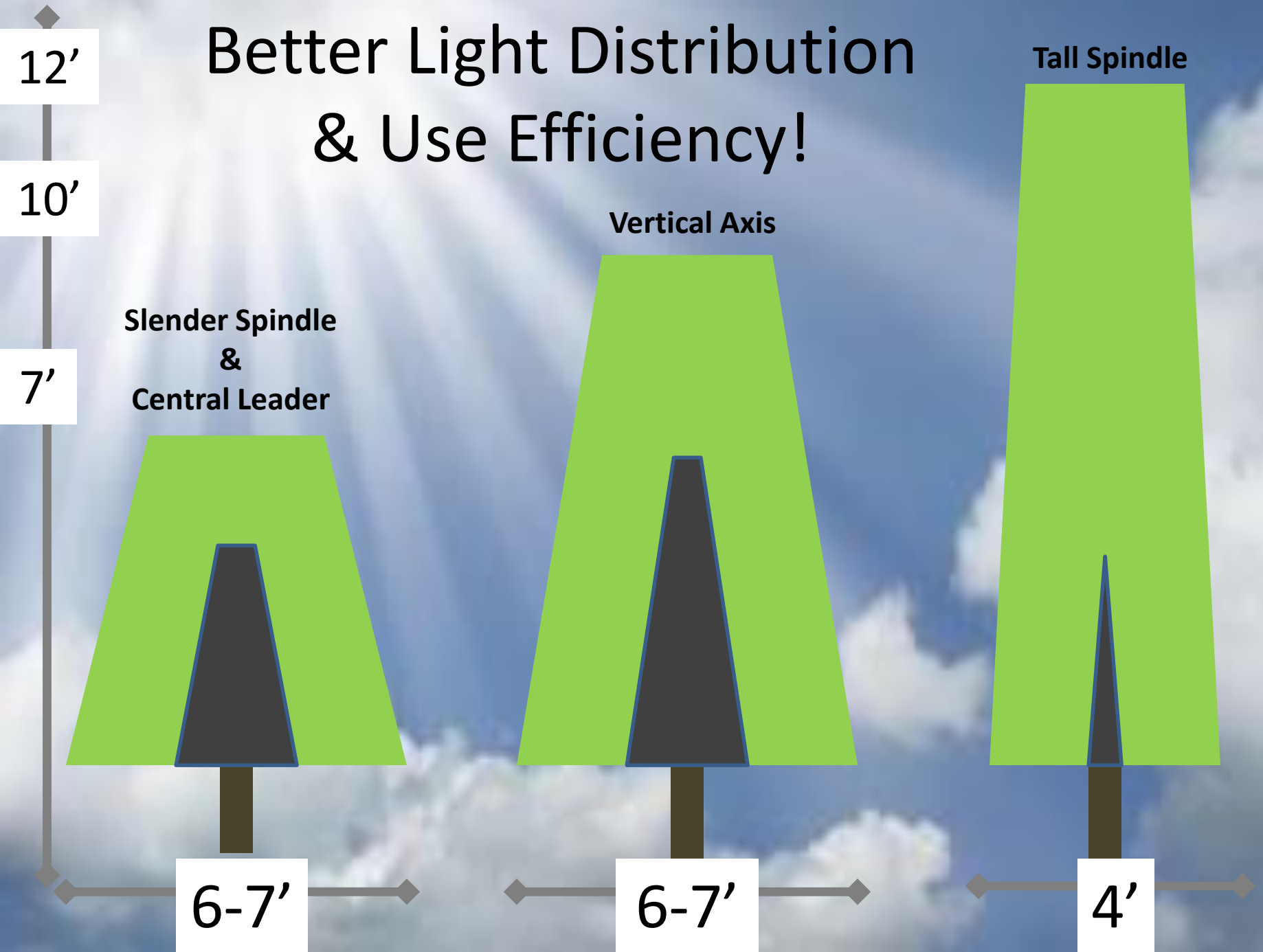
Office: 607-255-0270

E-mail: JML73@cornell.edu

Only Part of the Matrix



Better Light Distribution & Use Efficiency!



Early Yields – Honeycrisp, NY

Modern Apple Training Systems. 2005, Robinson

Bushels / Acre

Slender Spindle

2nd	0
3rd	33
4th	117
Cum.	**150**

444 T/A

Vertical Axis

2nd	.1
3rd	111
4th	277
Cum.	**388**

726 T/A

Tall Spindle

Potential	
2nd	**200**
3rd	**500**
4th	**800**
Cum.	**1,500**
2nd	3
3rd	132
4th	578
Cum.	**713**

908 T/A

2010 NC140 Apple Rootstock- Wisconsin

Density 908 T/A

Bushels / Acre

	M.9T337	G935	CG4004
2nd	0	0	0
3rd	479	359	563
4th	568	1061	1264
Cum.	1,047	1,420	1,827

Rootsto

What is a Tall Spindle?

Optimum Economic Density
900 - 1,200 trees/acre

High Early Production
Feathered trees, minimal pruning & branch tying
Cumulative yield 1,500 bu/a first 4 years

High Mature Yields (5+ yrs.)
High light interception 70-75%
Sustained yields of 1,200 - 1,500 bu/a

High Fruit Quality
Good light distribution in the canopy
Thin conical canopy
No permanent branches
Simplified (columnarized) fruiting branches
Balance vigor 'calm trees'

Improved Labor Efficiency
Simplified pruning steps
Possible mechanization of dormant pruning
Mechanized summer hedging

Tall Spindle

- Closer **in-row spacing of 3' for weak** growing varieties (Honeycrisp)
- In-row spacing of **4' for vigorous** varieties and tip bearing varieties. (McIntosh, Fuji, Gala, Gingergold)
- **Between row 10-12’**
- **Tree Height = 10-11’**

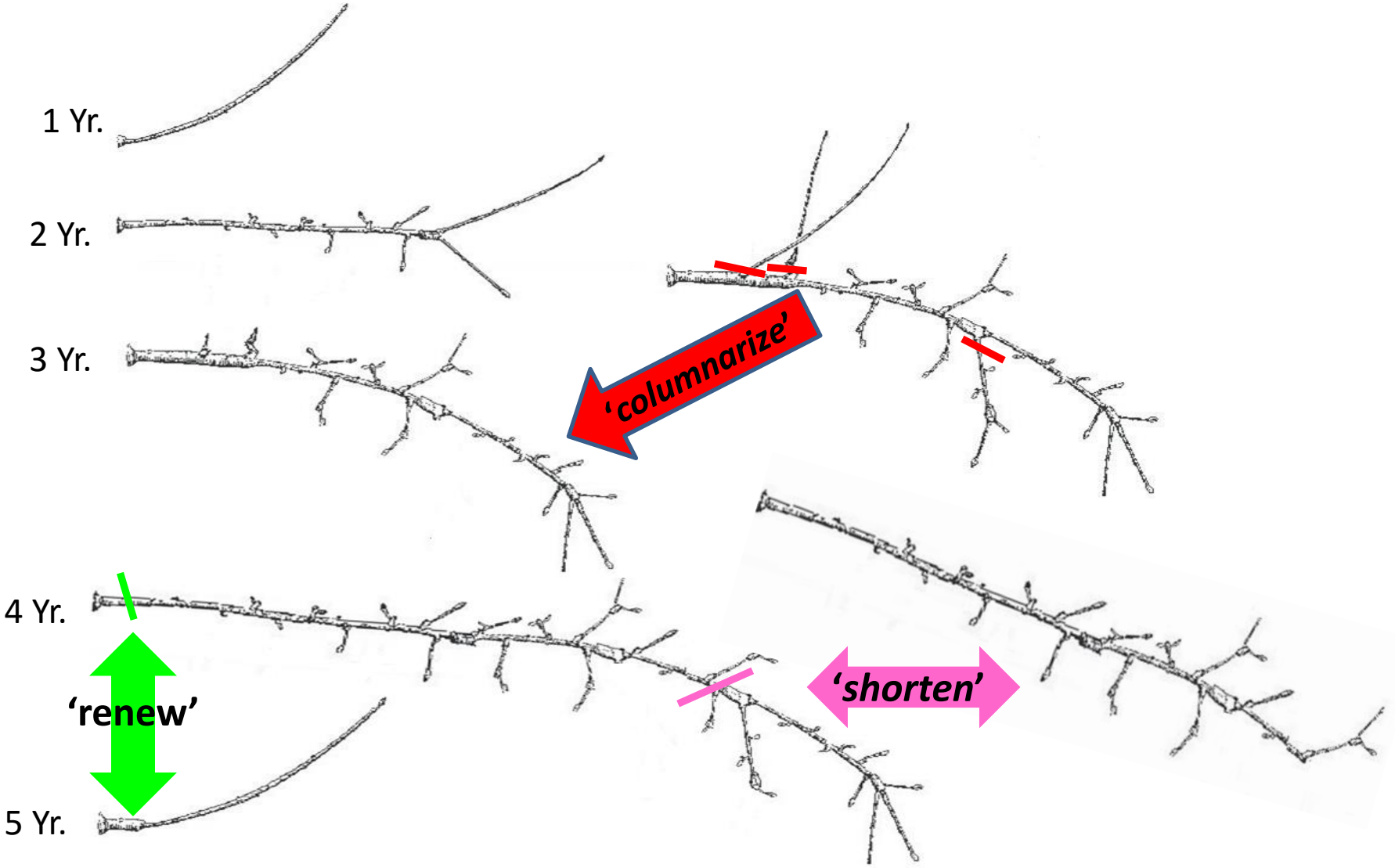
Simple Pruning Steps for Mature Tall Spindle

1. Limit tree height by cutting leader back to fruitful side branch.

2. Remove 2-3 large branches (>3/4”)
   “large branches create large trees”

3. Simplify or ‘*columnarize*’ remaining branches so a single axis is left

Branch Growth Progression and Pruning



Mechanical Pruning Mature Tall Spindle?

Benefits

- Reduced pruning costs ½
- Improved fruit quality

Goal

- Narrow fruiting wall
- Good light distribution
- Avoid vigorous response

1yr & 2yr hedge

3yr corrective pruning

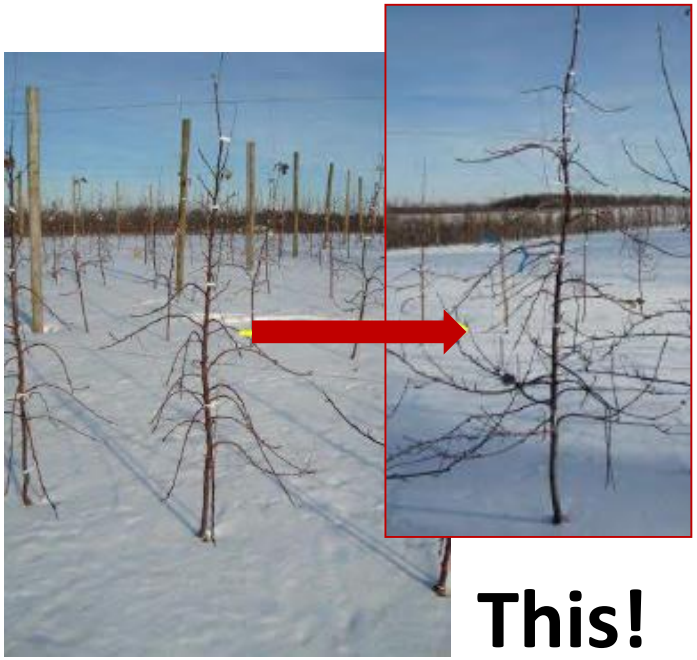
- – remove large caliper
- – ‘crows feet’

Angled wall

Tall Spindle Common Mistakes

Biggest mistakes:

- Not tying initial branches down
- Excessive cropping years 2-4
- Not growing tree to top wire fast enough
- Retaining too many large branches on mature trees



This!

Not This!

"large branches create large trees"

Tall Spindle Common Mistakes

Avoid excessive cropping in the first 5 years

4 fruit/cm²TCSA biennial varieties (Honeycrisp)

5 fruit/cm²TCSA non-biennial varieties

YEAR - #FRUIT

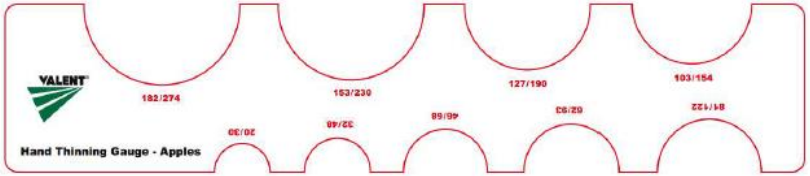
1……0

2……20

3……40

4……80

5……100



WI Funding for NC140 Plantings

Door & Kewaunee County

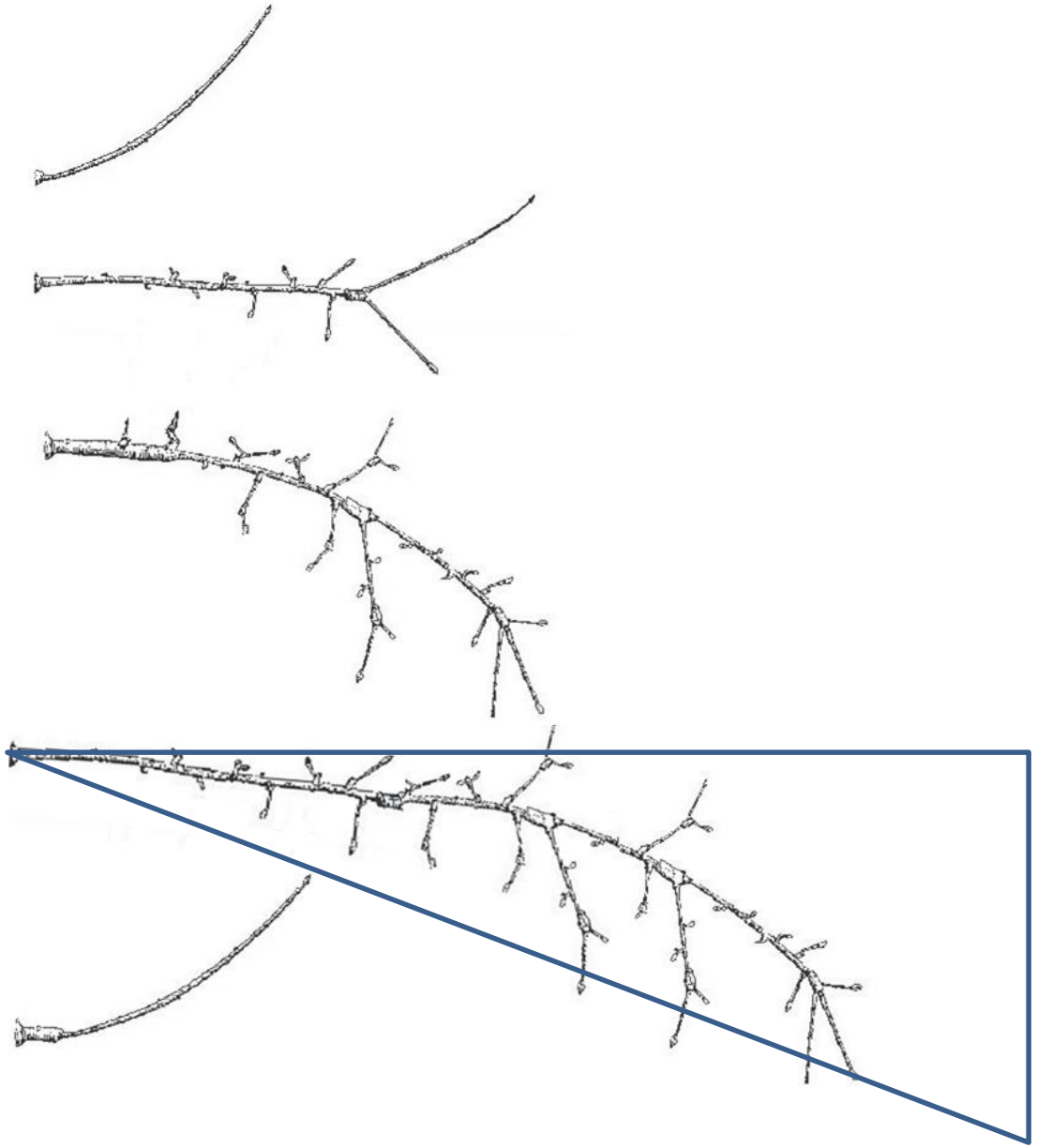
USDA United States Department of Agriculture
National Institute of Food and Agriculture

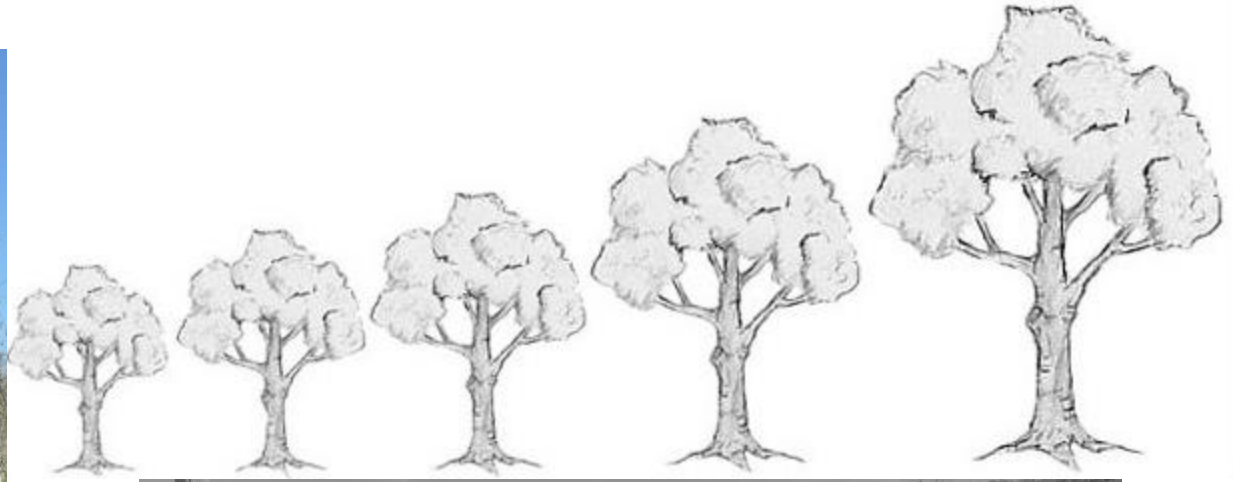
UW Extension COOPERATIVE EXTENSION

2014 & 2015 Planting

UW Extension COOPERATIVE EXTENSION

Wisconsin Apple Growers Association






Lets talk about efficiency

Current and Future PARS

2010 NC140 Apple

Russia	USA - advanced	USA - commercial	Germany	CONTROLS
B.9	CG.2034	**G.11**	PiAu 51-11	**M.9T337**
Bud 10 (62-396)	CG.3001	**G.41 Normal**	PiAu 9-90	**M.9Pajam2**
Bud 64-194	CG.4003	**G.41 TC**	Supporter 3	**M.26EMLA**
Bud 67-5-32	CG.4004	**G.935 Normal**		
Bud 70-6-8	CG.4013	**G.935 TC**		
Bud 70-20-20	CG.4214	**G.202 Normal**		
Bud 70-20-21	CG.4814	**G.202 TC**		
Bud 71-7-22	CG.5087			
Bud 7-3-150	CG.5202 (222)			

Current and Future PARS

2014 NC140 Apple

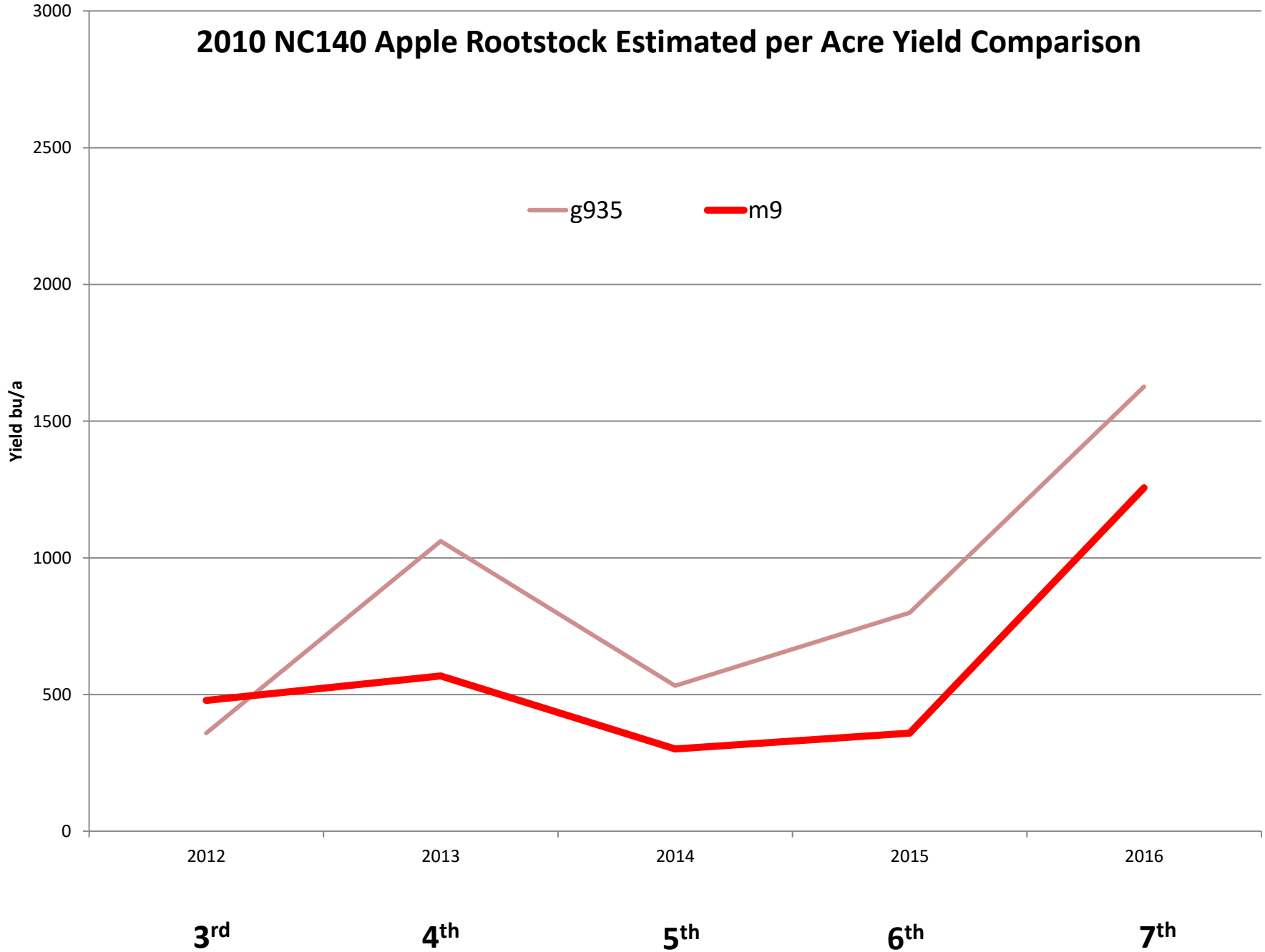
Russia	USA	Canada	CONTROLS
B.10	G.11 ★	V.1	M.26 EMLA
	G.202 ★	V.5	M.9 T337
	G.214 ★	V.6	
★	G.30 ★	V.7	
	G.41		
★	G.5890		
	G.935		
★	G.969		

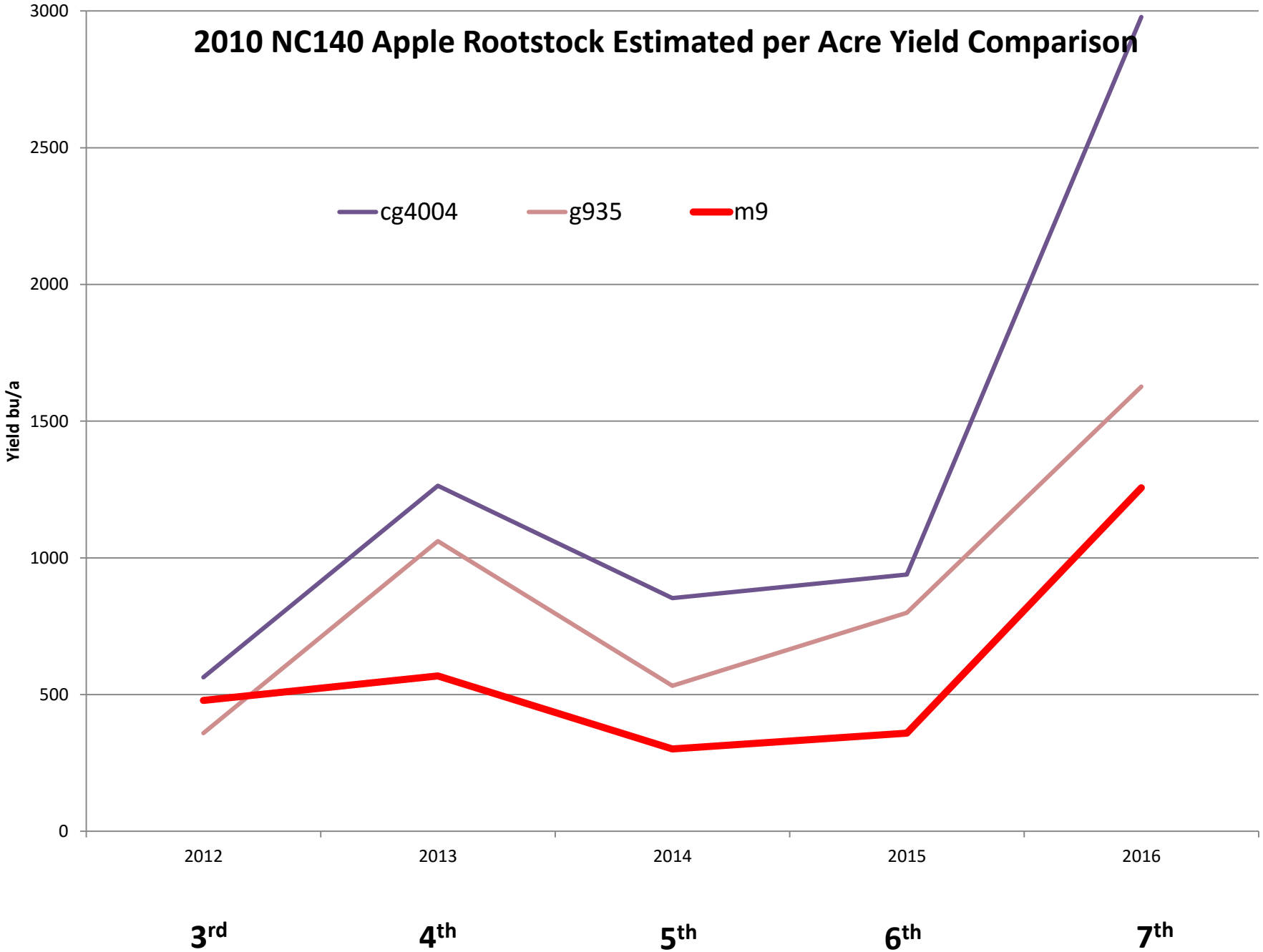
The Vineland ('V.') series

- Dr. Aleck Hutchinson
- Horticultural Experiment Station Canada, Vineland Station in 1958.
- Open-pollinated hybrids of 'Kerr' crabapples x M.9 rootstock
- Dwarf growth habit, cold hardiness, ease of propagation, and disease and insect resistance Resistance to low temperature stress.

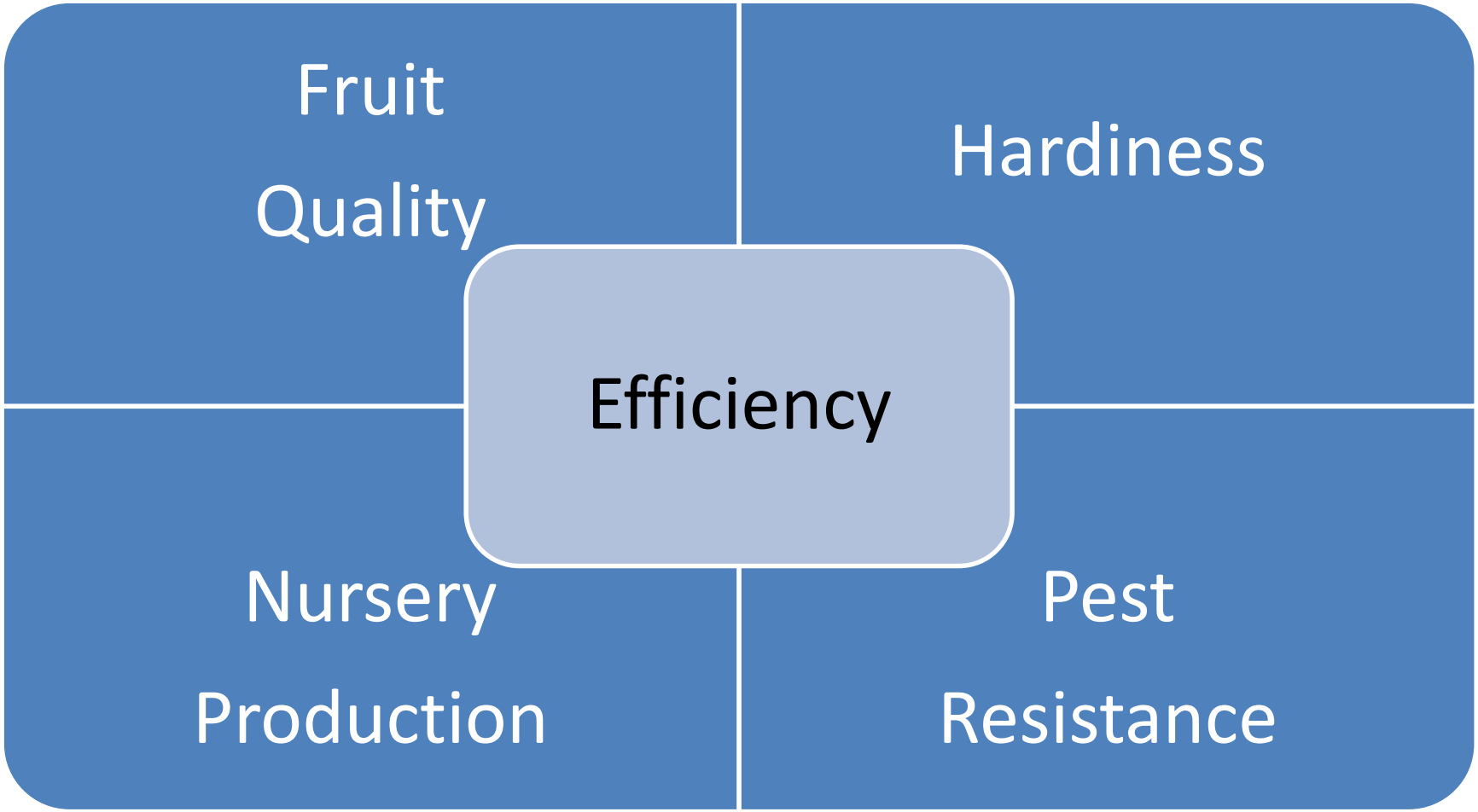
Size Class

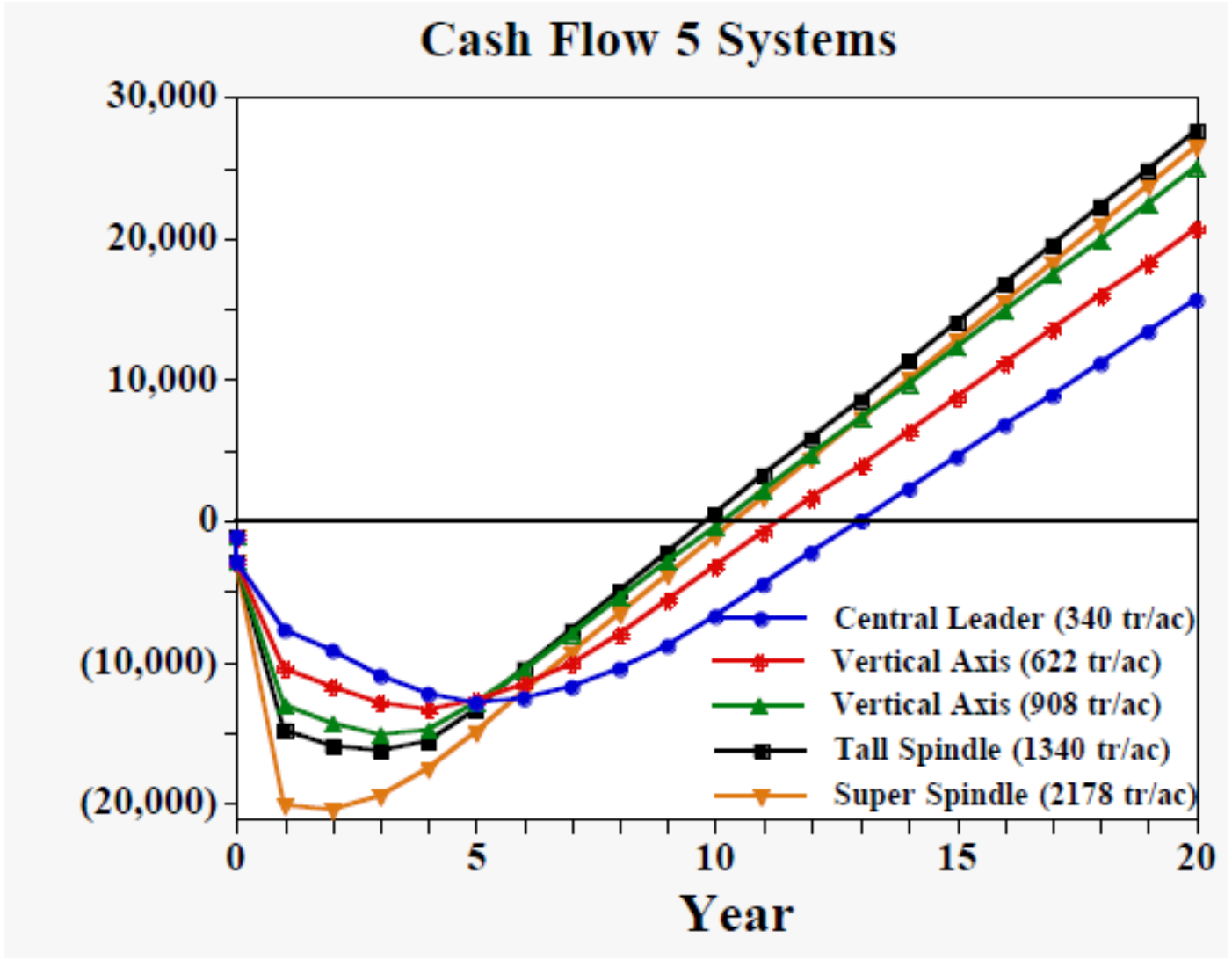
V.5 & V.6	**≤ M.9**
V.3	**= M.9**
V.1 & V.2	**= M.26**
V.7	**= M.7**


2010 NC140 Apple Rootstock Estimated per Acre Yield Comparison
g935
m9
Yield bu/a
3000
2500
2000
1500
1000
500
0
2012
2013
2014
2015
2016
3rd
4th
5th
6th
7th


2010 NC140 Apple Rootstock Estimated per Acre Yield Comparison
cg4004
g935
m9
Yield bu/a
3000
2500
2000
1500
1000
500
0
2012
2013
2014
2015
2016
3rd
4th
5th
6th
7th

Maximizing the Potential




Cash Flow 5 Systems
30,000
20,000
10,000
0
(10,000)
(20,000)
0
5
10
15
20
Year
Central Leader (340 tr/ac)
Vertical Axis (622 tr/ac)
Vertical Axis (908 tr/ac)
Tall Spindle (1340 tr/ac)
Super Spindle (2178 tr/ac)

Google:

NC140 rootstock

-or-

Geneva rootstock