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Rootstock Selection to Mitigate Stress in the Long Run

December 8, 2022

Moderator: Sebastian Saa (ABC)
Speakers: Katherine Jarvis-Shean (UC ANR)
Roger Duncan (UC ANR)
Greg Browne (UC ANR)
Cameron Zuber (UC ANR)

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Session Details

Rootstock Selection to Mitigate Stress in the Long Run

Moderators
Sebastian Saa, ABC, Session Moderator
Cameron Zuber, UCCE - Merced County, Q&A Moderator

Speakers
Katherine Jarvis-Shean, UCCE
Avoiding Production Flaws Via Rootstock Selection

Roger Duncan, UCCE
The Relationship Between Rootstock Vigor and Yield (and $$)

Andreas Westphal, UC Riverside
Reducing losses due to Nematodes

Greg Browne, USDA-ARS (Natalia J. Ott, PhD Candidate)
Use of Rootstocks to Mitigate Soilborne Diseases

THE ALMOND CONFERENCE

50 YEARS

Avoiding Production Flaws Via Rootstock Selection

Katherine Jarvis-Shean, UCCE Orchard Advisor, Sac, Solano & Yolo Counties

UNIVERSITY OF CALIFORNIA
Agriculture and Natural Resources

UC Cooperative Extension

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Almond Board of California

Outline

Intro to Rootstocks

Salts

Boron

Nitrogen

Potassium

Anchorage

What do rootstocks do?

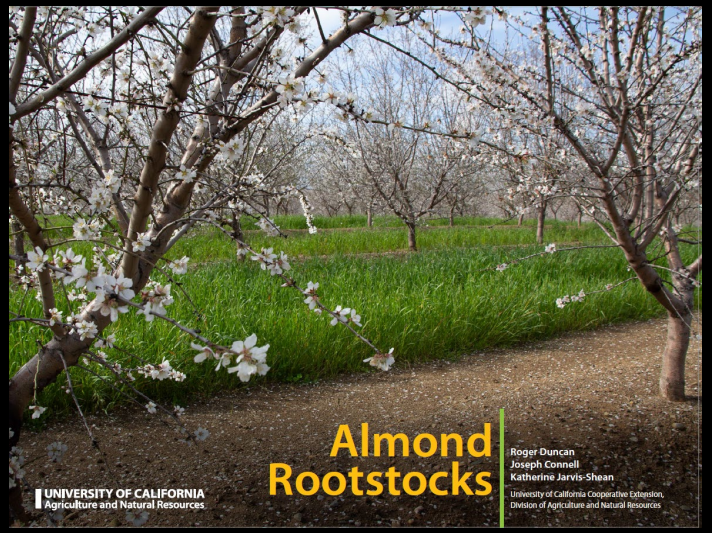
✓Take up water

✓Take up nutrient, salts

✓Anchor tree in the soil

✓Store carbohydrates, nutrients overwinter

✓Live and grow in the soil



				Horticultural Characteristics				Abiotic Conditions					Diseases						Nematodes		
Parentage	**Rootstock**	**Genetic Background[1]**	**Comments**	**Compatibility**	**Anchorage**	**Vigor[2]**	**Suckering**	**Excessive Sodium**	**Excessive Chloride**	**Lime-Induced Chlorosis**	**Excessive Boron**	**In-season Waterlogging[3]**	**Oak Root Fungus**	**Crown Gall**	***Phytophthora***	**Verticillium Wilt**	**Replant Disease**	**Bacterial Canker**	**Rootknot[4]**	**Ring[5]**	**Root Lesion[6]**
Peach	Guardian®	*P. persica*	Similar to Nemaguard but with good resistance to ring nematode and bacterial canker.	Good	Fair	Moderately high	Low	Susceptible	Susceptible	Susceptible	Susceptible	Sensitive	Susceptible	Susceptible	Moderately susceptible	Susceptible	Unknown	Tolerant	Resistant	Tolerant	Susceptible
	Lovell®	*P. persica*	Historical standard in Sacramento Valley heavier soils due to perceived better asphyxia tolerance than Nemaguard. Susceptible to rootknot nematode.	Good	Fair	Moderate	Low	Susceptible	Highly susceptible	Susceptible	Highly susceptible	Sensitive	Susceptible	Susceptible	Moderately susceptible	Highly susceptible	Highly susceptible	Tolerant	Susceptible	Tolerant	Susceptible
	Nemaguard®	*P. persica*	Historical standard rootstock for the San Joaquin Valley in well-drained soil. Being replaced by newer, better-suited rootstocks. Prone to zinc deficiency.	Good	Good	Moderately high	Low	Highly susceptible	Susceptible	Susceptible	Susceptible	Sensitive	Susceptible	Moderately susceptible	Moderately susceptible	Susceptible	Highly susceptible	Susceptible	Resistant	Susceptible	Susceptible
Peach Hybrids	Cadaman®	*P. persica* × *P. davidiana*	Similar to Nemaguard but better tolerance of alkaline and saline conditions.	Good (limited experience)	Good	Moderately high	Low	Moderately tolerant	Moderately tolerant	Moderately tolerant	Highly susceptible	Sensitive	Susceptible	Unknown	Moderately susceptible	Highly susceptible	Unknown	Moderately tolerant	Resistant	Susceptible	Highly susceptible
	Empyrean 1® (Barrier 1®)	*P. persica* × *P. davidiana*	High vigor and salt tolerance similar to peach × almond hybrids but less susceptible to ring nematode. Fair anchorage may limit use in windy areas.	Good (limited experience)	Fair	Very high	Low	Tolerant	Moderately tolerant	Moderately tolerant	Susceptible	Sensitive	Susceptible	Unknown	Moderately susceptible	Susceptible	Low susceptibility	Assumed tolerant[7]	Resistant	Tolerant	Highly susceptible
Peach × Almond Hybrids	Brights 5®	*P. dulcis* × *P. persica*	Similar to Hansen but with more moderate vigor.	Good	Good	High	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Sensitive	Susceptible	Moderately susceptible	Highly susceptible	Susceptible	Low susceptibility	Highly susceptible	Resistant	Highly susceptible	Susceptible
	Cornerstone®	*P. dulcis* × *P. persica*	Similar to Hansen but with more moderate vigor.	Good (limited experience)	Good	High	Low	Tolerant	Tolerant	Moderately tolerant	Assumed moderately tolerant	Sensitive	Susceptible	Highly susceptible	Highly susceptible	Susceptible	Unknown	Assumed susceptible	Resistant	Highly susceptible	Susceptible
	Flordaguard × Alnem (F×A®)	*P. dulcis* × *P. persica*	Similar to Hansen. New release by USDA-ARS. Limited experience.	Good (limited experience)	Excellent	Very high	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Unknown	Unknown	Highly susceptible	Unknown	Highly susceptible	Unknown	Unknown	Unknown	Unknown	Unknown
	Hansen 536®	*P. dulcis* × *P. persica*	Standard peach × almond hybrid rootstock developed by the University of California. High vigor, excellent anchorage, high salt and alkalinity tolerance. Highly susceptible to ring nematode and bacterial canker.	Good	Excellent	Very high	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Sensitive	Highly susceptible	Highly susceptible	Highly susceptible	Highly susceptible	Low susceptibility	Highly susceptible	Resistant	Highly susceptible	Moderately tolerant
	Nickels®	*P. dulcis* × *P. persica*	Similar to Hansen but better adapted to nursery propagation and storage practices. More tolerant of wet spring soils due to higher chilling requirement.	Good	Very good	Very high	Low	Moderately tolerant	Moderately tolerant	Tolerant	Moderately tolerant	Sensitive	Susceptible	Highly susceptible	Highly susceptible	Susceptible	Unknown	Highly susceptible	Resistant	Highly susceptible	Susceptible
	Titan Hybrids (Titan II®, SG 1®, etc.)	*P. dulcis* × *P. persica*	More vigorous than Hansen with possibly better wet-soil tolerance.	Good	Good	Very high	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Sensitive	Susceptible	Unknown	Moderately susceptible	Susceptible	Unknown	Highly susceptible	Resistant	Unknown	Unknown
Plum Hybrids	Krymsk 86® (plum × peach)	*P. cerasifera* × *P. persica*	Excellent anchorage and general tolerance to root diseases. Lower vigor in sandy soil. Susceptible to sodium, chloride, boron, and all nematodes. Incompatible with Independence.[8]	Good with Nonpareil. Incompatible with Independence.[8] Marginal with Monterey and Shasta	Excellent	Moderate	Low / Moderate	Susceptible	Highly susceptible	Susceptible	Susceptible	Tolerant[3]	Moderately Resistant	Susceptible	Resistant	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible
	Marianna 40® (plum × plum)	*P. cerasifera* × *P. munsoniana*	Better vigor and anchorage and less suckering than Marianna 2624. Assumed resistance to oak root fungus and *Phytophthora* but experience is limited.	Assumed similar to M 2624	Very good	Moderate	Low	Unknown	Unknown	Unknown	Assumed susceptible	Tolerant[3]	Resistant	Unknown	Assumed resistant	Unknown	Unknown	Assumed susceptible	Resistant	Susceptible	Susceptible
	Marianna 2624® (plum × plum)	*P. munsoniana* × *P. cerasifera*	Standard in soils infested with oak root fungus and *Phytophthora*. Incompatible with Nonpareil and Independence. Root suckering and low vigor are common.	Incompatible with Nonpareil and Independence. Marginal with Monterey	Good	Moderately low	High (variable)	Tolerant	Tolerant	Susceptible	Susceptible	Tolerant[3]	Resistant	Moderately tolerant	Resistant	Unknown	Highly susceptible	Highly susceptible	Resistant	Susceptible	Susceptible
	Rootpac 20® (plum × sand cherry)	*P. besseyi* × *P. cerasifera*	Dwarfing rootstock (about 65% of Nemaguard) used in Super High-Density plantings in Spain. Limited experience in California.	Variable (limited experience)	Unknown	Very low	High	Unknown	Unknown	Unknown	Assumed susceptible	Unknown	Unknown	Susceptible	Resistant	Unknown	Unknown	Assumed susceptible	Unknown	Unknown	Unknown
	Rootpac R® (plum × almond)	*P. cerasifera* × *P. dulcis*	Best suited for alkaline, heavy soils high in chloride. Not well suited for sandy soils (low vigor) or where excess sodium and boron are a problem. Performance has been variable in UC trials.	Good with Nonpareil (limited experience)	Good	Moderate to low	Moderate	Susceptible	Tolerant	Tolerant	Susceptible	Tolerant[3]	Unknown	Unknown	Resistant	Susceptible	Highly susceptible	Assumed susceptible	Resistant	Highly susceptible	Susceptible
Complex Hybrids (peach, almond, plum, apricot)	Atlas®	*P. persica* × (*P. dulcis* × (*P. cerasifera* × *P. mume*))	Similar to Nemaguard but may have higher yield efficiency. Intolerant to cold storage or dehydration when planted bare root.	Good	Fair	Moderately high	Low	Susceptible	Susceptible	Moderately tolerant	Highly susceptible	Sensitive	Susceptible	Moderately tolerant	Highly susceptible	Tolerant	Unknown	Susceptible	Resistant	Susceptible	Highly susceptible
	Viking®	*P. persica* × (*P. dulcis* × (*P. cerasifera* × *P. mume*))	Slightly more vigorous than Nemaguard but good tolerance to ring nematode, bacterial canker, salt, and alkaline conditions. Excellent anchorage. Intolerant to cold storage or dehydration when planted bare root.	Good	Excellent	Moderately high	Low	Moderately tolerant	Moderately tolerant	Moderately tolerant	Moderately tolerant	Sensitive	Susceptible	Moderately tolerant	Highly susceptible	Susceptible	Unknown	Tolerant	Resistant	Tolerant	Susceptible

What's the Perfect Rootstock?

High early vigor

Low later vigor

Heavy soil, wet feet tolerance

Low suckering

No negative impact to bloom or harvest timing

Good anchorage

Root disease resistance

Nematode resistance

Mid-to-high pH tolerance

B, Cl, Na exclusion

Compatibility with all cultivars

Select based on biggest site limitation(s)

Remembering…

Some ‘limitations’ are average conditions

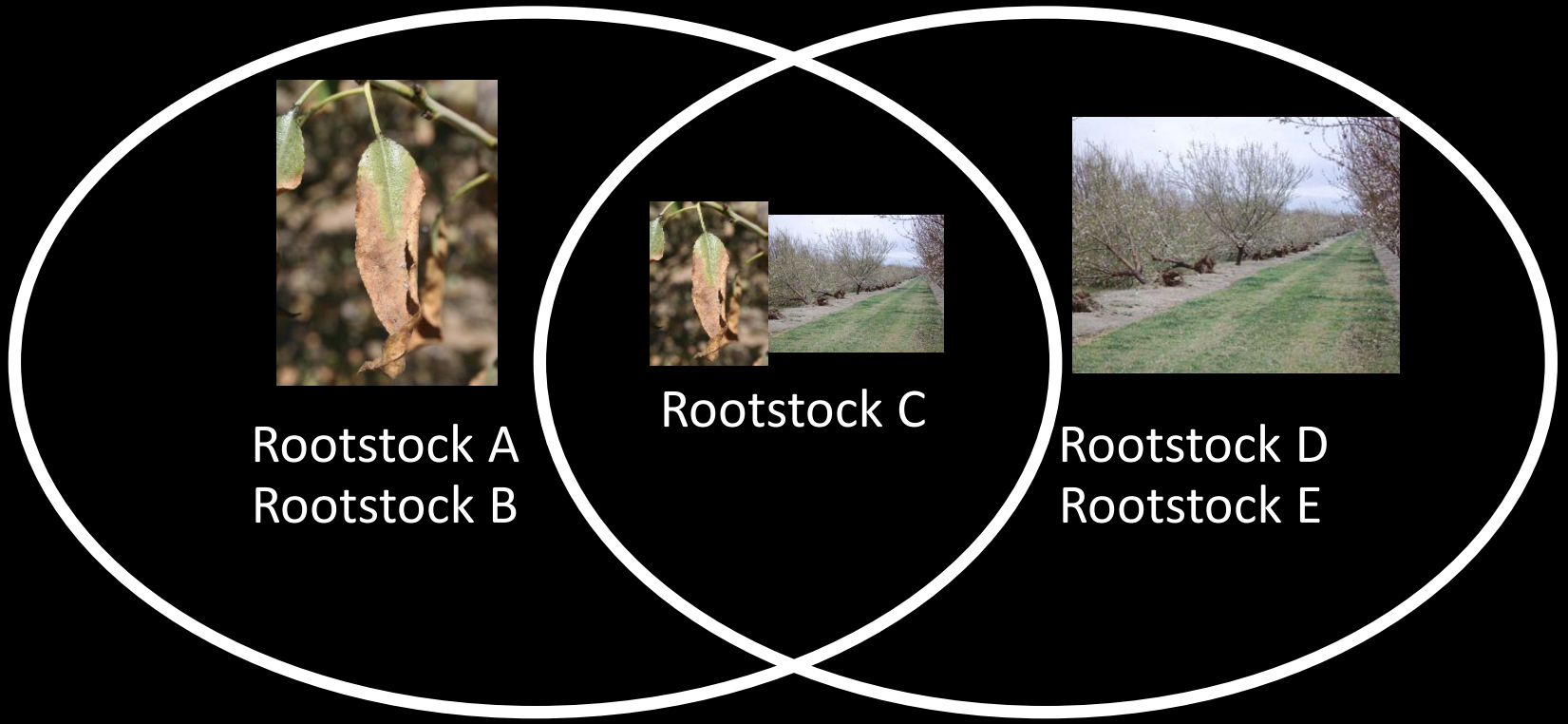
Some ‘limitations’ are rare, but guaranteed eventually

Select based on biggest site limitation(s)

Rootstock A
Rootstock B
Rootstock C

Rootstock C
Rootstock D
Rootstock E

Select based on biggest site limitation(s)



Toxic Ions

- Chloride, Sodium
- Boron

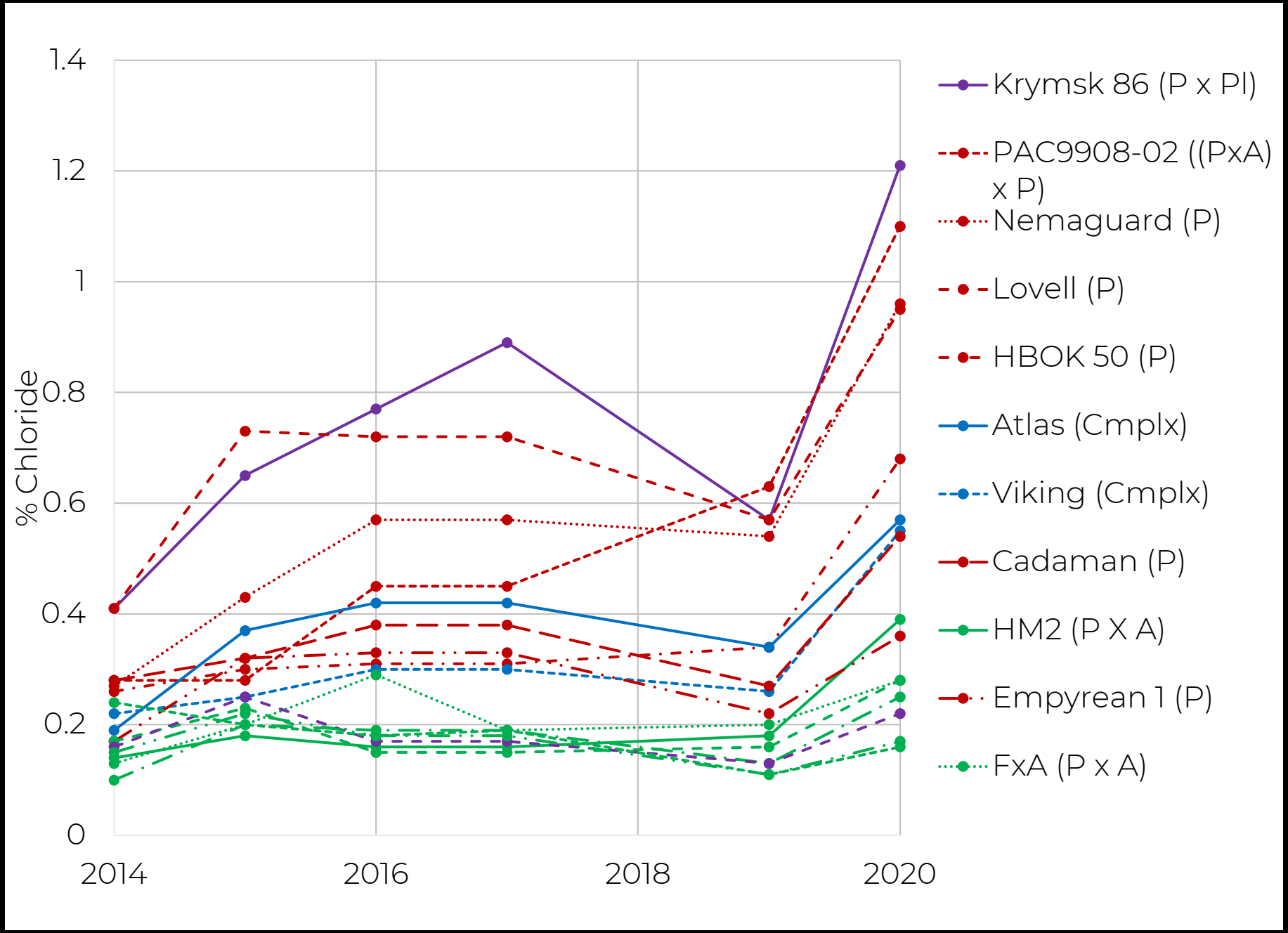
Toxic Ions

Chloride kills leaf tissues

- ↓ photosynthesis, carbs
- ↓ tree temp regulation
- ↑ premature leaf drop

Chloride

- Roger Duncan Westside Trial
- 2012-2020
- Irrig water often high in chloride
- Often, more almond heritage = better at excluding Chloride



Sodium

- Roger Duncan Eastside Trial
- 2013 = 10th Leaf
- Often, more almond heritage = better at excluding Sodium

Leaf Levels of Sodium and Chloride in Nonpareil & Carmel Almonds on Various Rootstocks. September, 2013				
	Carmel		Nonpareil	
	% Sodium	% Chloride	% Sodium	% Chloride
Nemaguard (P)	0.99 a	0.51 a	0.76 a	0.28 b
Atlas (Cmplx)	0.94 a	0.29 b	-	-
Guardian (P)	0.76 a	0.41 a	-	-
Lovell (P)	0.70 a	0.50 a	-	-
Cadaman (P)	0.38 b	0.25 b	-	-
Julior (P x *P. insititia*)	0.35 b	0.16 bc	-	-
Empyrean 2 (Pl)	0.30 b	0.41 a	0.34 b	0.53 a
Viking (Cmplx)	0.29 b	0.21 bc	-	-
Nickels (P x A)	0.28 b	0.15 cd	-	-
Hansen (P x A)	0.09 c	0.07 d	-	-
Paramount (P x A)	0.04 c	0.05 d	-	-
Empyrean 1 (P)	-	-	0.09 c	0.07 c
Cornerstone (P x A)	-	-	0.04 c	0.05 c
Krymsk 86 (P x Pl)	-	-	0.60 a	0.32 b

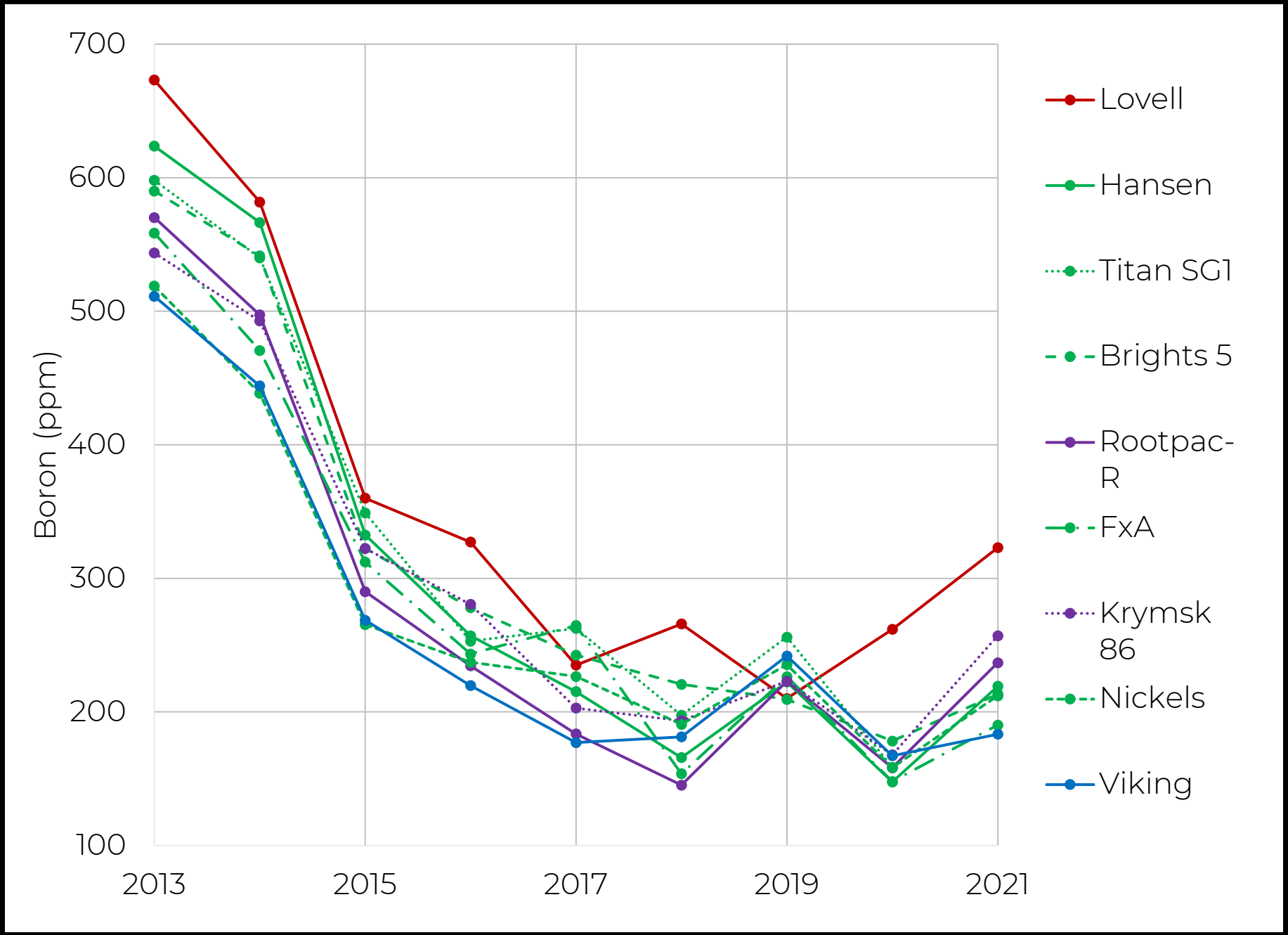
High Boron → Gumming → Infection

High Boron → Dead Shoots

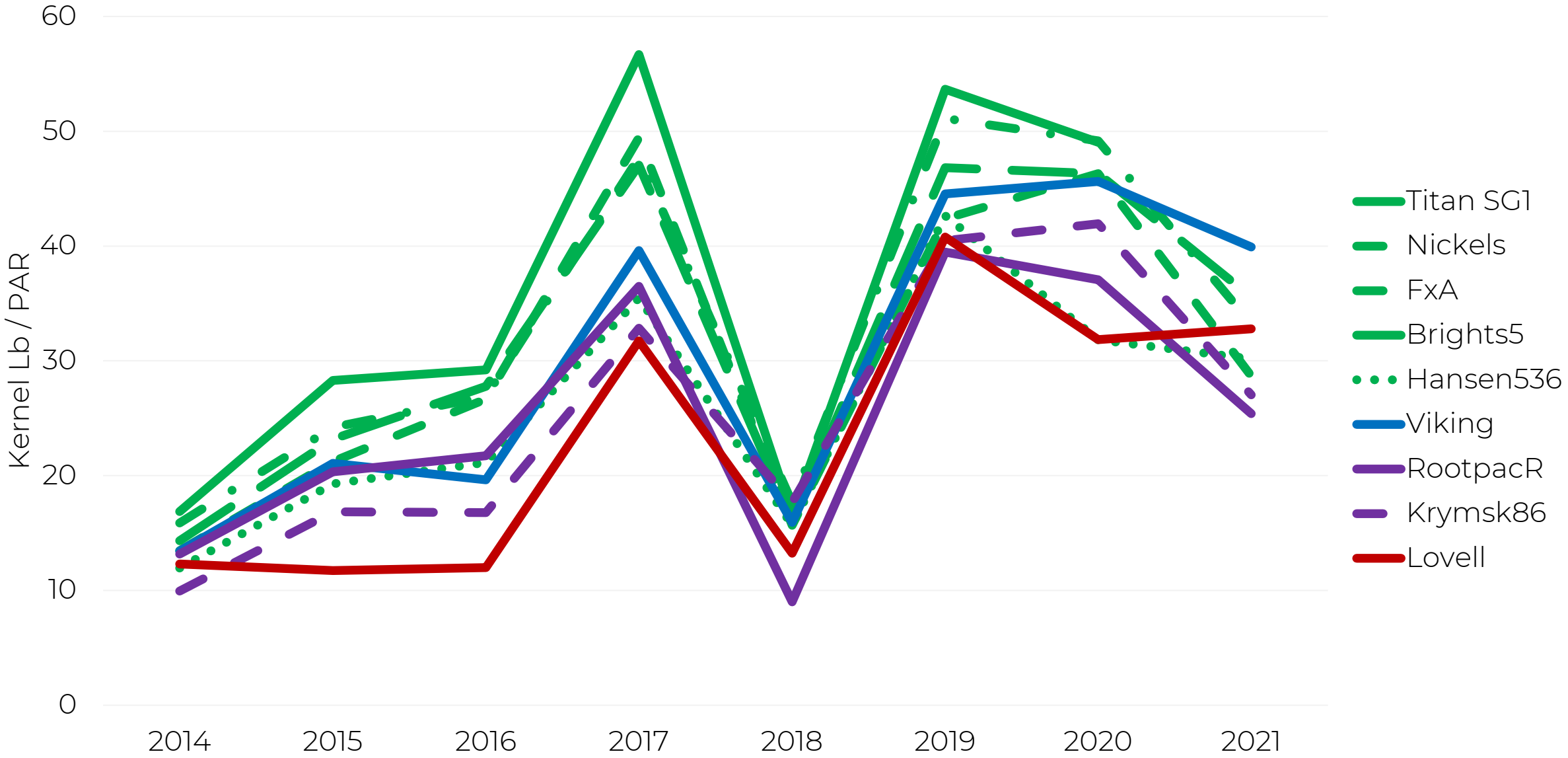
Same Boron, Different Rootstocks

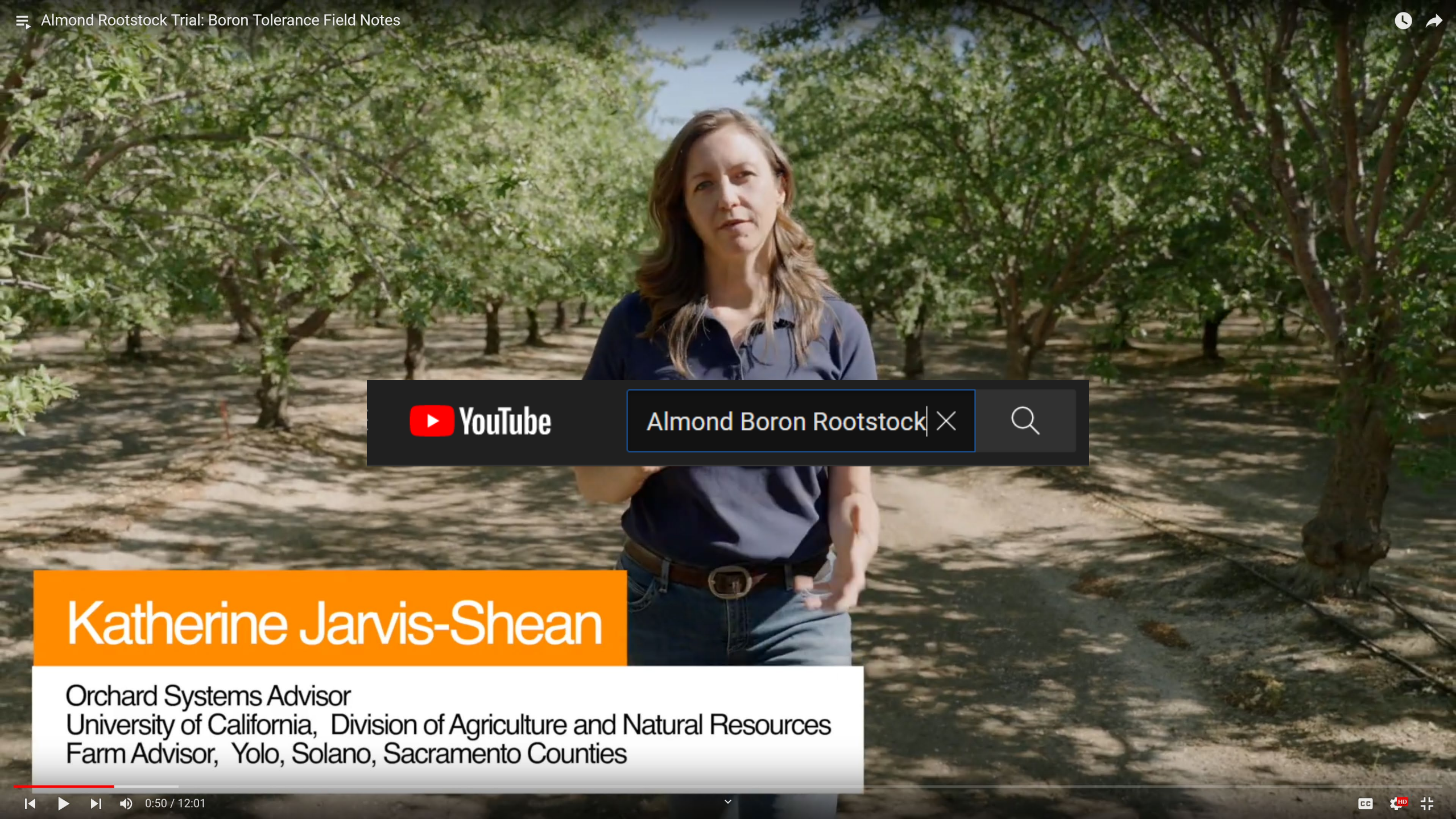
Boron

- Jarvis-Shean Yolo Trial
- 2011-2020
- Irrigated with water often high in boron



Peach-Almond Hybrid Highest Efficiency




Almond Rootstock Trial: Boron Tolerance Field Notes
YouTube
Almond Boron Rootstock
Katherine Jarvis-Shean
Orchard Systems Advisor
University of California, Division of Agriculture and Natural Resources
Farm Advisor, Yolo, Solano, Sacramento Counties
0:50 / 12:01

Nitrogen

- P x A hybrids tend to have higher N than pure peach but not very consistent.

Yolo Leaf N (% DW)		
Rootstock	2019	2020
Viking	2.2 a	2.0 a
FxA	2.1 ab	2.0 a
Brights5	2.1 ab	1.9 a
Krymsk86	2.1 ab	1.9 a
Nickels	2.1 ab	1.9 abc
Hansen536	1.9 c	1.8 bc
Lovell	2.1 b	1.7 bc
RootpacR	1.9 c	1.7 c

Westside Leaf N (% DW)	
Rootstock	2020
BB 106	2.5 a
Krymsk 86	2.5 a
F x A	2.4 ab
Atlas	2.4 abc
Cadaman	2.4 ab
HM2	2.4 abc
PAC9908-02	2.4 abc
Rootpac R	2.4 abc
GF 677	2.4 abc
Nemaguard	2.4 abc
Viking	2.4 abc
Brights 5	2.4 abc
Empyrean 1	2.3 abc
Hansen	2.3 abc
Lovell	2.3 bc
HBOK 50	2.3 c

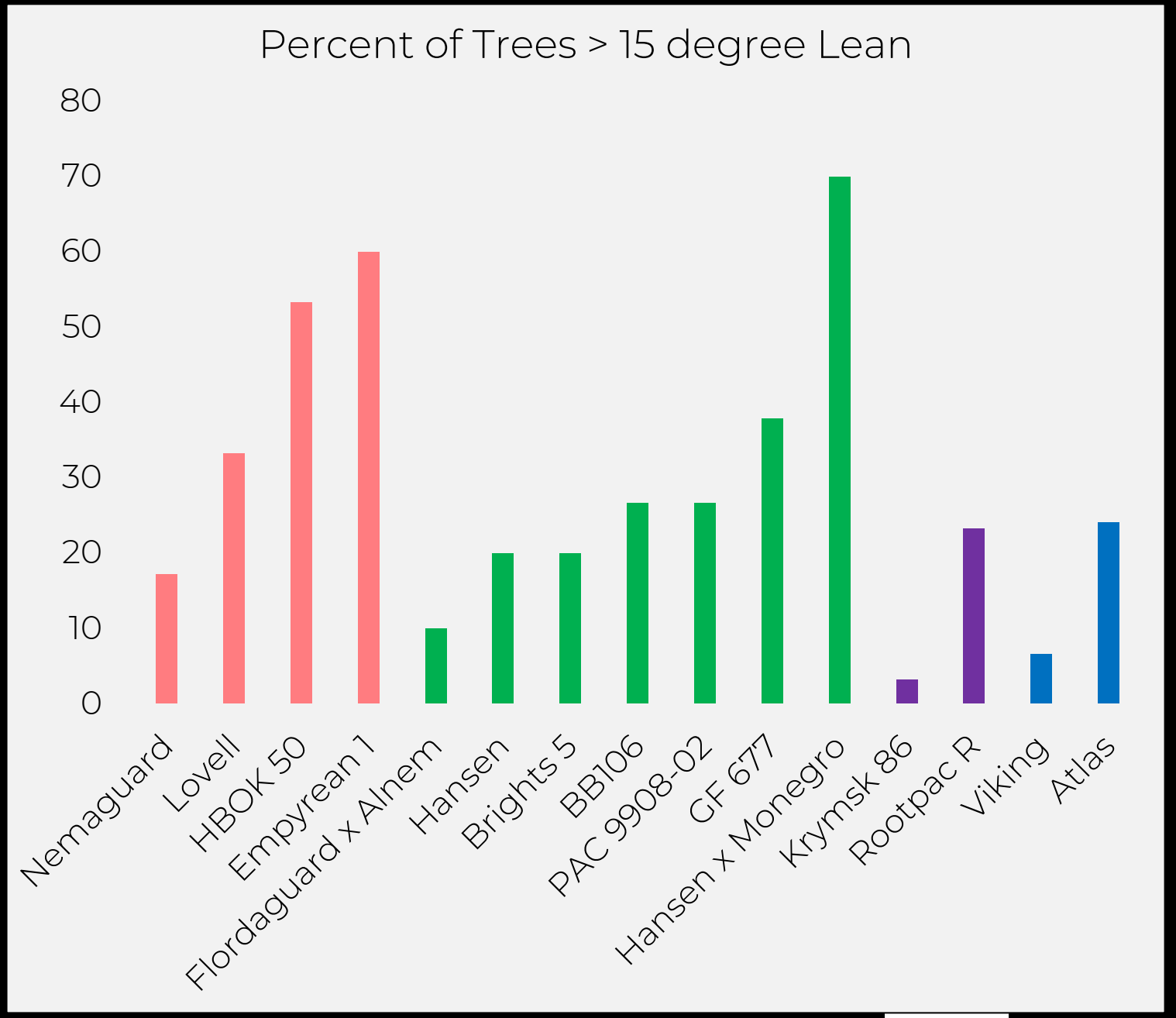
Potassium

- P x A hybrids tend to have higher K than pure peach

Yolo Leaf K (% DW)		
Rootstock	2019	2020
FxA	1.1 a	1.0 a
Nickels	1.1 ab	0.9 ab
Krymsk86	1.1 abc	0.7 ab
Viking	1.0 abc	0.8 ab
Hansen536	0.9 abcd	0.9 ab
Brights5	0.8 bcd	0.7 ab
RootpacR	0.8 cd	0.6 b
Lovell	0.7 d	0.6 b

Westside Leaf K (% DW)	
Rootstock	2020
F x A	2.48 a
Brights 5	2.46 a
Cadaman	2.44 a
BB 106	2.4 a
Hansen	2.22 ab
GF 677	2.15 ab
HM2	2.14 ab
Empyrean 1	1.95 abc
Atlas	1.94 abc
Viking	1.9 abcd
Nemaguard	1.85 abcd
HBOK 50	1.63 bcd
Rootpac R	1.57 bcd
Krymsk 86	1.39 cd
Lovell	1.38 cd
PAC9908-02	1.23 d

Anchorage



Adapted from Duncan, Stanislaus Co.

Gust Anchorage

Gust Anchorage

Kern County. Planted 1997.
March 4, 2001 – 80 mph winds for 5 hrs w/ 1.75” rain

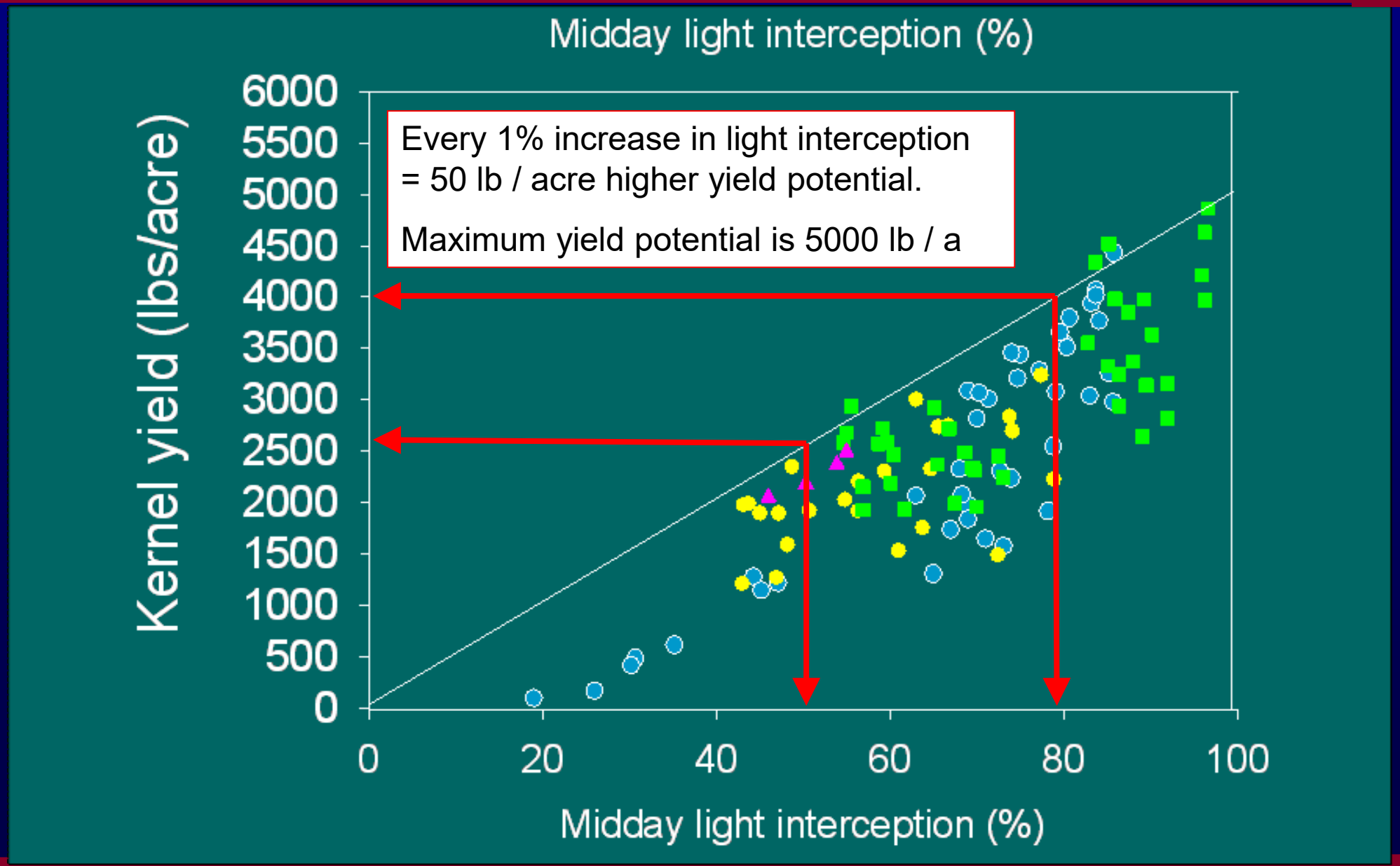
Rootstock	Parents	Blow Over
Bright’s Hybrid	PxA	13%
Hansen 536	PxA	9%
Hansen 2168	PxA	4%
Viking	Complex	4%
Atlas	Complex	30%
Nemaguard	Peach	58%

Thank You!

The Relationship Between Rootstock Vigor and Yield (and $$)

Is Bigger Vigor Better?

Work by Bruce Lampinen, UC Davis

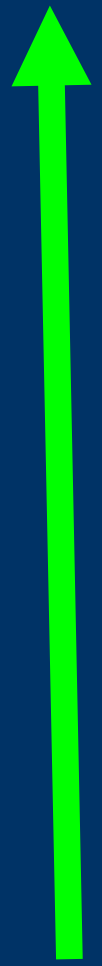


Rootstock Vigor

- Peach / Almond hybrids (Titan hybrids, Hansen, Nickels, Bright's 5, Cornerstone, FxA, etc.), Empyrean 1

- Interspecifics (Viking, Atlas)
- Peach (Nemaguard, Guardian, Lovell)

- Plum hybrids (Krymsk 86, Rootpac R, Marianna 2624, Rootpac 20, etc.)

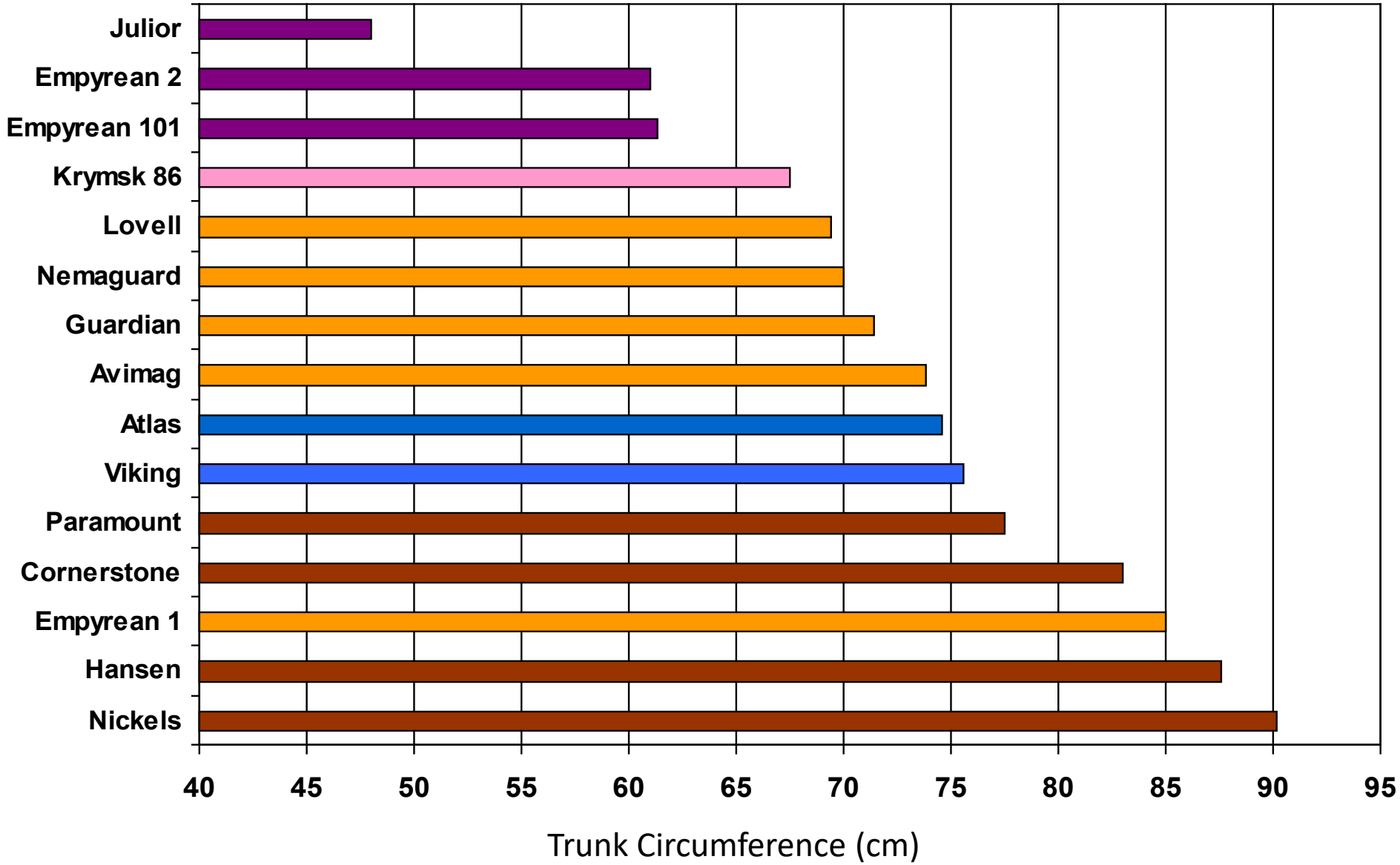


Most Vigorous

Least Vigorous

Rootstock Influence on Tree Size

Keyes, CA. Sandy Loam Soil.

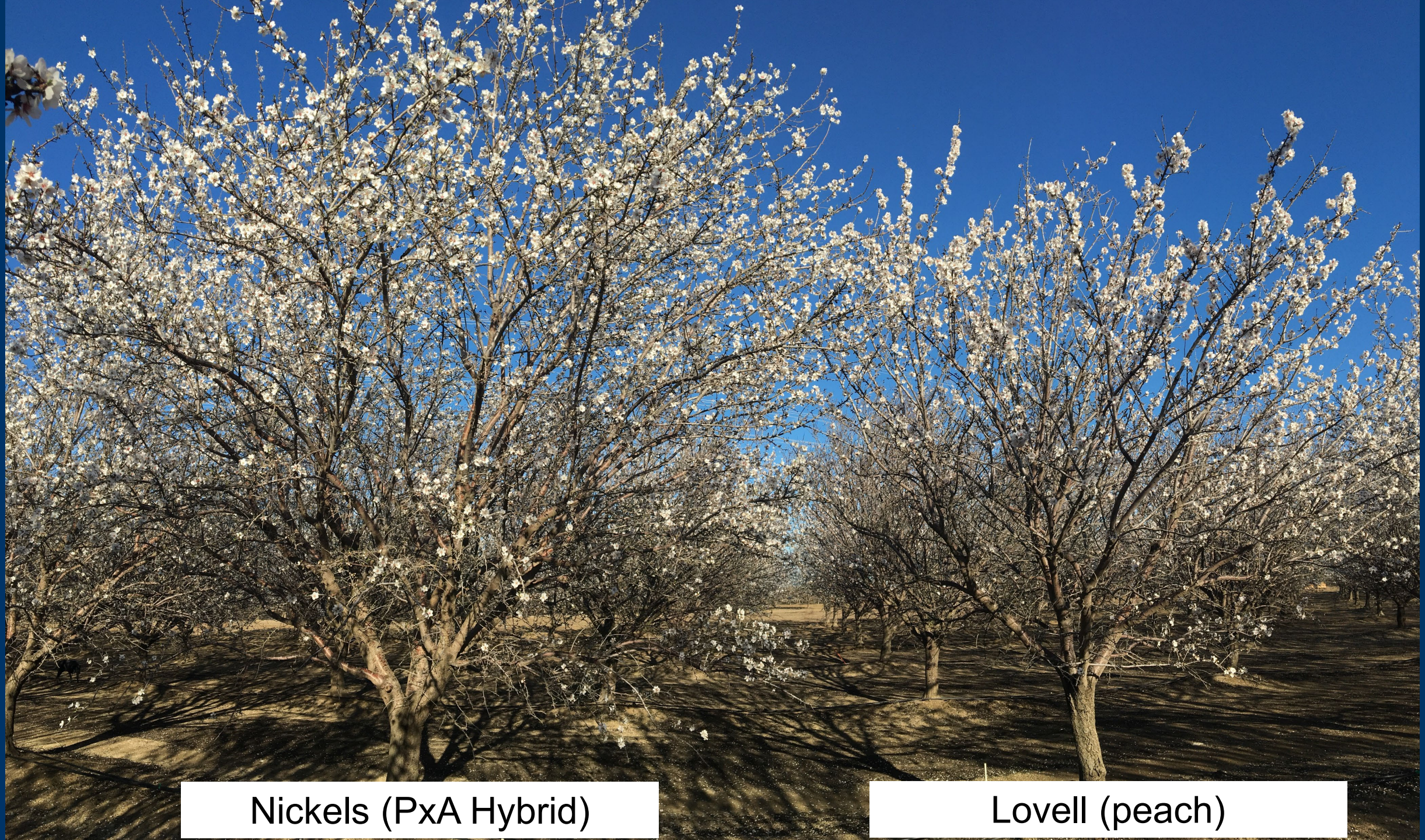


Rootstock Influences Tree Size

3rd Leaf Nonpareil
Hanford Sandy Loam

Nemaguard

Rootpac R


Nickels (PxA Hybrid)
Lovell (peach)

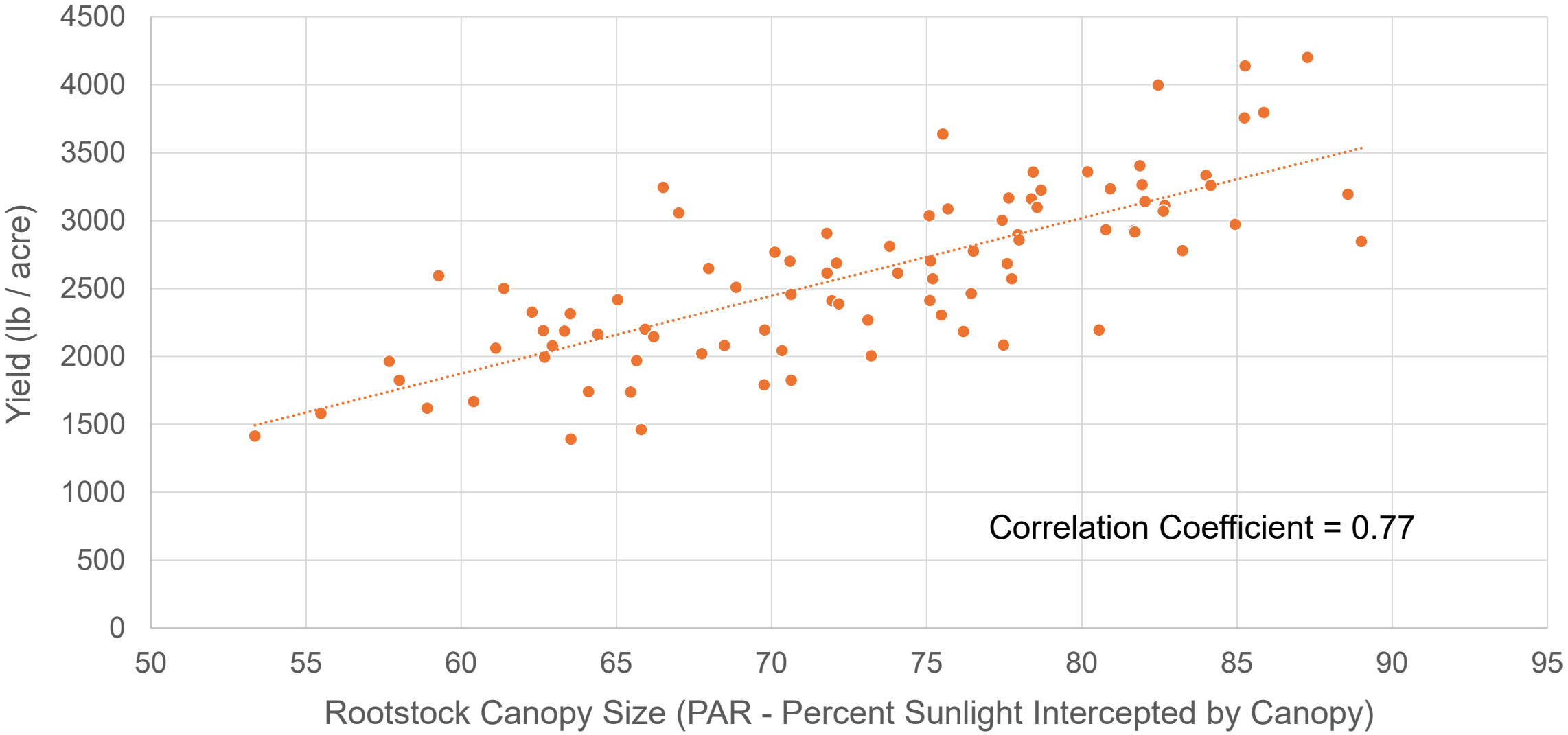
Rootstock Effect on Yield

Westside Stanislaus County Trial 2022 Yield

	2022 Yield per Acre (11th leaf)
HM2	3447 a
Flordaguard x Alnem	3356 ab
BB 106	3201 ab
Brights 5	3116 ab
Hansen	3095 ab
Paramount (GF 677)	2844 abc
Viking	2823 abc
Empyrean 1	2759 bcd
Rootpac R	2373 cde
Atlas	2223 cde
HBOK 50	2131 de
PAC9908-02	2067 e
Nemaguard	2002 e
Krymsk 86	1925 e
Lovell	1883 e

Rootstock Size is Strongly Related to Yield

West Side Stanislaus Rootstock Trial.
2022 Yield vs. Canopy Size



Rootstock Effect on Yield

Westside Stanislaus County 2022 Yields

	2022 Yield per Acre (11th leaf)	Cum Yield (4th – 7th), 9th & 11th leaf
BB 106	3201 ab	19,495
Flordaguard x Alnem	3356 ab	18,802
Brights 5	3116 ab	18,539
HM2	3447 a	18,255
Hansen	3095 ab	18,111
Empyrean 1	2759 bcd	17,316
Rootpac R	2373 cde	15,786
Paramount (GF 677)	2844 abc	15,507
PAC9908-02	2067 e	15,453
Atlas	2223 cde	15,355
Viking	2823 abc	15,318
HBOK 50	2131 de	13,658
Nemaguard	2002 e	13,626
Krymsk 86	1925 e	13,265
Lovell	1883 e	11,603

Rootstock Effect on Yield

Westside Stanislaus County 2022 Yields

	2022 Yield per Acre (11th leaf)	Cum Yield (4th – 7th), 9th & 11th leaf	Difference in Gross Income over Nemaguard*
BB 106	3201 ab	19,495	$11,738
Flordaguard x Alnem	3356 ab	18,802	$10,352
Brights 5	3116 ab	18,539	$9,826
HM2	3447 a	18,255	$9,258
Hansen	3095 ab	18,111	$8,970
Empyrean 1	2759 bcd	17,316	$7,380
Rootpac R	2373 cde	15,786	$4,320
Paramount (GF 677)	2844 abc	15,507	$3,762
PAC9908-02	2067 e	15,453	$3,654
Atlas	2223 cde	15,355	$3,458
Viking	2823 abc	15,318	$3,384
HBOK 50	2131 de	13,658	$64
Nemaguard	2002 e	13,626	--
Krymsk 86	1925 e	13,265	-$722
Lovell	1883 e	11,603	-$4,046

*Gross income calculated at $2.00 / lb

Rootstock Effect on Yield Efficiency

West side Stanislaus County 2022 Yields

	2022 Yield per Acre (11th leaf)	2022 Yield Efficiency (lb / % PAR)
BB 106	3201 ab	38.8 b
Flordaguard x Alnem	3356 ab	40.7 ab
Brights 5	3116 ab	39.1 b
HM2	3447 a	44.8 a
Hansen	3095 ab	38.0 bc
Empyrean 1	2759 bcd	36.9 bcd
Rootpac R	2373 cde	34.0 cde
Paramount (GF 677)	2844 abc	37.3 bc
PAC9908-02	2067 e	28.4 f
Atlas	2223 cde	32.4 def
Viking	2823 abc	40.0 b
HBOK 50	2131 de	32.0 ef
Nemaguard	2002 e	28.8 f
Krymsk 86	1925 e	30.5 ef
Lovell	1883 e	31.9 ef

Rootstock Effect on Yield Efficiency

West side Stanislaus County 2022 Yields

Peach x almond hybrids not just larger, but more yield efficient in this trial

	2022 Yield per Acre (11th leaf)	2022 Yield Efficiency (lb / % PAR)
BB 106	3201 ab	38.8 b
Flordaguard x Alnem	3356 ab	40.7 ab
Brights 5	3116 ab	39.1 b
HM2	3447 a	44.8 a
Hansen	3095 ab	38.0 bc
Empyrean 1	2759 bcd	36.9 bcd
Rootpac R	2373 cde	34.0 cde
Paramount (GF 677)	2844 abc	37.3 bc
PAC9908-02	2067 e	28.4 f
Atlas	2223 cde	32.4 def
Viking	2823 abc	40.0 b
HBOK 50	2131 de	32.0 ef
Nemaguard	2002 e	28.8 f
Krymsk 86	1925 e	30.5 ef
Lovell	1883 e	31.9 ef

Yolo County Rootstock Trial – Katherine Jarvis-Shean

Rootstock	Origin	2020 Avg. Yield (kernel lbs/acre)*		Light Intercep't (% PAR)		Size Efficiency (Lbs/PAR)	Trunk Circum (inches 18" above soil)	
Titan SG1	Peach-Alm	3,790		77		49	31	
Nickels	Peach-Alm	3,788	a	77	a	49	32	ab
FxA	Peach-Alm	3,693	ab	80	a	46	33	a
Brights 5	Peach-Alm	3,305	ab	71	ab	46	29	d
Viking	Pch-Al-Myro-Apr	2,911	bc	64	bc	46	29	cd
Hansen 536	Peach-Alm	2,307	cd	72	ab	32	31	bc
Krymsk 86	Myro Plum-Peach	2,278	cde	54	cd	42	27	de
Rootpac-R	Myro Plum-Alm	1,961	de	53	cd	37	29	cd
Lovell	Peach	1,475	e	46	d	32	26	e

Colusa County Rootstock Trial – John Edstrom

Rootstock	Nonpareil yield (kernel lbs/ac)				Midday PAR Interception (%)				Yield per unit PAR intercepted			
	2009		2010		2009		2010		2009		2010	
Brights	3671	a	2912	bcd	63.4	b	63.8	bc	59.3	a	48.3	abc
Nickels	3721	a	3451	a	65.5	b	66.8	b	56.6	ab	51.9	a
Hansen 536	3955	a	3142	ab	73.2	a	74	a	54.1	abcd	42.5	cd
Atlas	2938	b	2889	bcd	59.6	b	56.8	bc	49.6	bcde	51.4	ab
Viking	2909	b	2680	cd	61.5	b	61.1	bc	47.6	cde	43.8	cd
Nemaguard	3959	a	2616	cd	63.3	b	64.2	bc	47.0	de	40.7	cd
Lovell	2672	b	2564	d	61.5	b	61.2	bc	43.6	e	41.8	cd

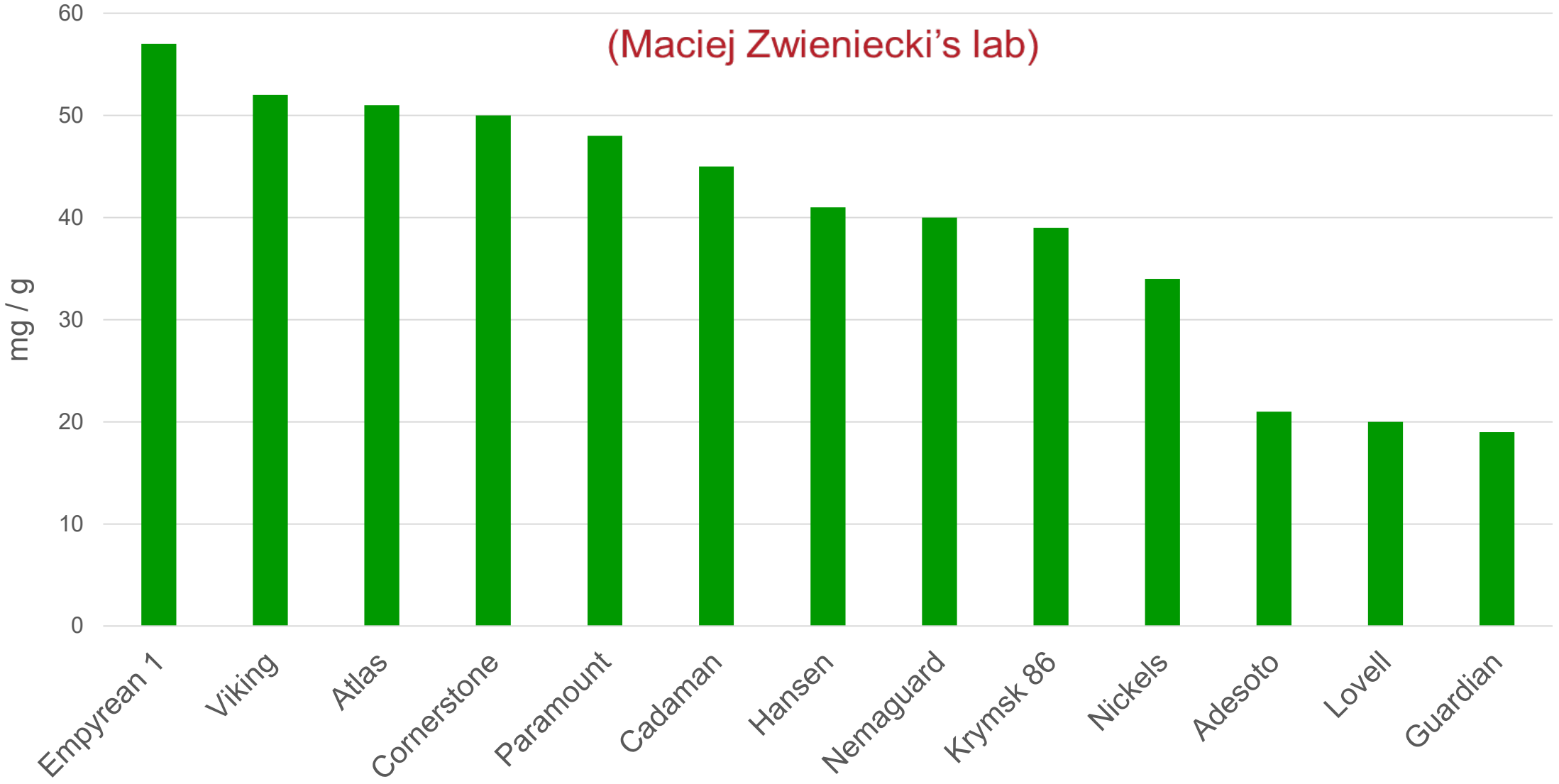
Rootstock Effect on Kernel Size

Higher vigor rootstocks also have larger kernels

	Kernel Size 2022 (g / kernel)
Flordaguard x Alnem	1.31 a
BB 106	1.23 ab
Paramount (GF 677)	1.23 ab
Brights 5	1.21 ab
HM2	1.17 bc
Hansen	1.16 bc
Empyrean 1	1.11 bcd
Atlas	1.06 cde
Viking	1.06 cde
PAC9908-02	1.03 de
Krymsk 86	1.01 def
Nemaguard	0.99 def
HBOK 50	0.98 def
Rootpac R	0.95 ef
Lovell	0.90 f

Carbohydrate Levels in Bark of Almond Shoots Prior to Bloom 2019 (not replicated)
Ceres, CA

(Maciej Zwieniecki's lab)



Why might higher vigor trees be higher yielding?

- Vigorous trees fill space more quickly (without more inputs)
- More growth / more spur renewal (without more inputs)
- Vigorous trees generally have larger kernels (without more inputs)
- Vigorous rootstocks may have more stored carbohydrates in shoots at bloom (without more inputs)

What does this mean for use of high-density systems with dwarfing rootstocks?

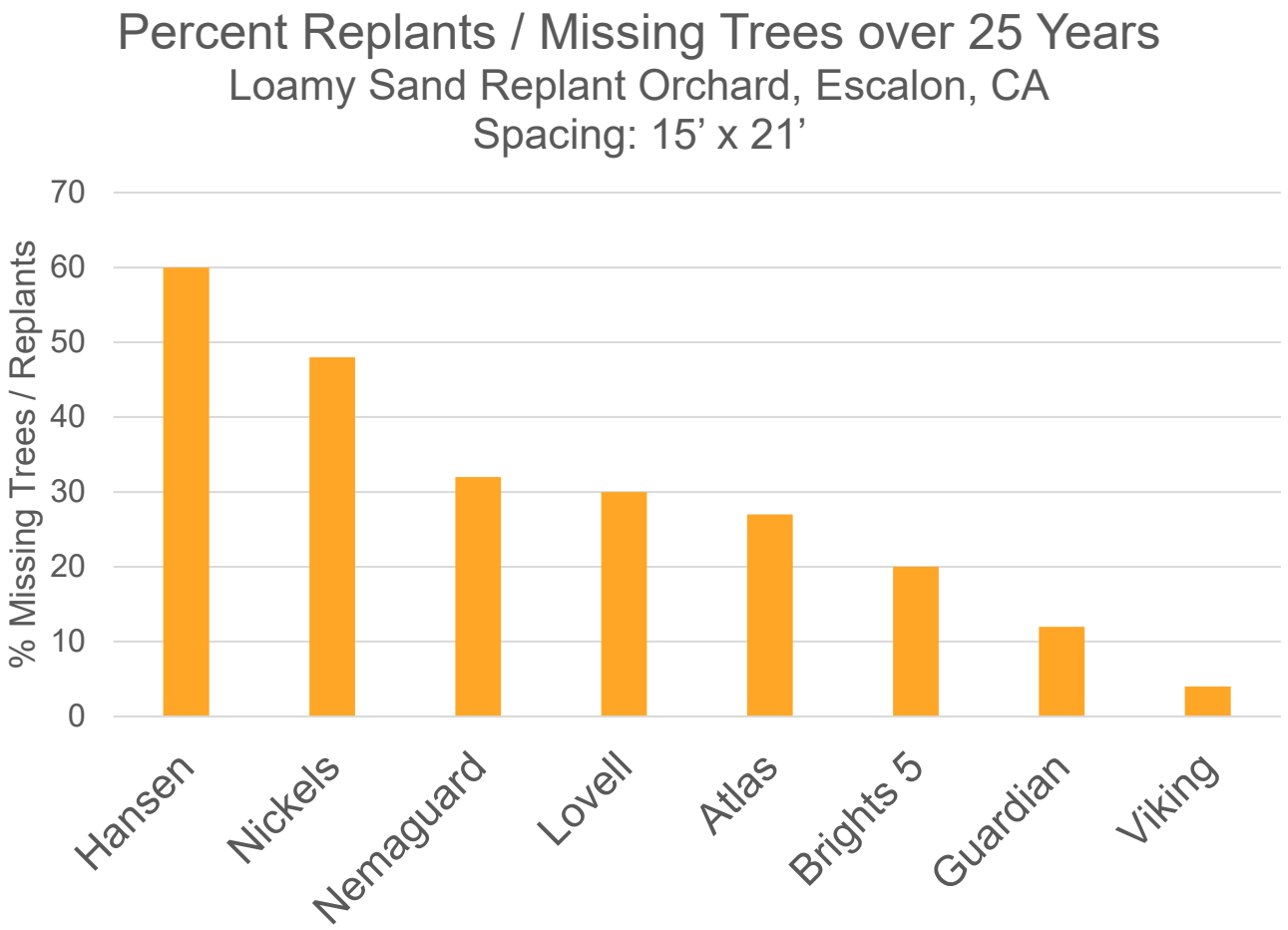
- Can you fully compensate by planting lower vigor rootstocks more densely?

High Density Rootstock Trial, 8’ x 18’

2nd leaf Monterey on Rootpac 20

2nd leaf Monterey on Brights 5

Maximizing Profits – Orchard Longevity – 1997 Rootstock Trial



Most trees missing from early bacterial canker or late-life blow over due to wood decay

Crown Gall Rating of Remaining Trees

• Hansen	2.7
• Nickels	2.6
• Guardian	1.8
• Lovell	1.7
• Brights 5	1.0
• Nemaguard	0.9
• Atlas	0.6
• Viking	0.3

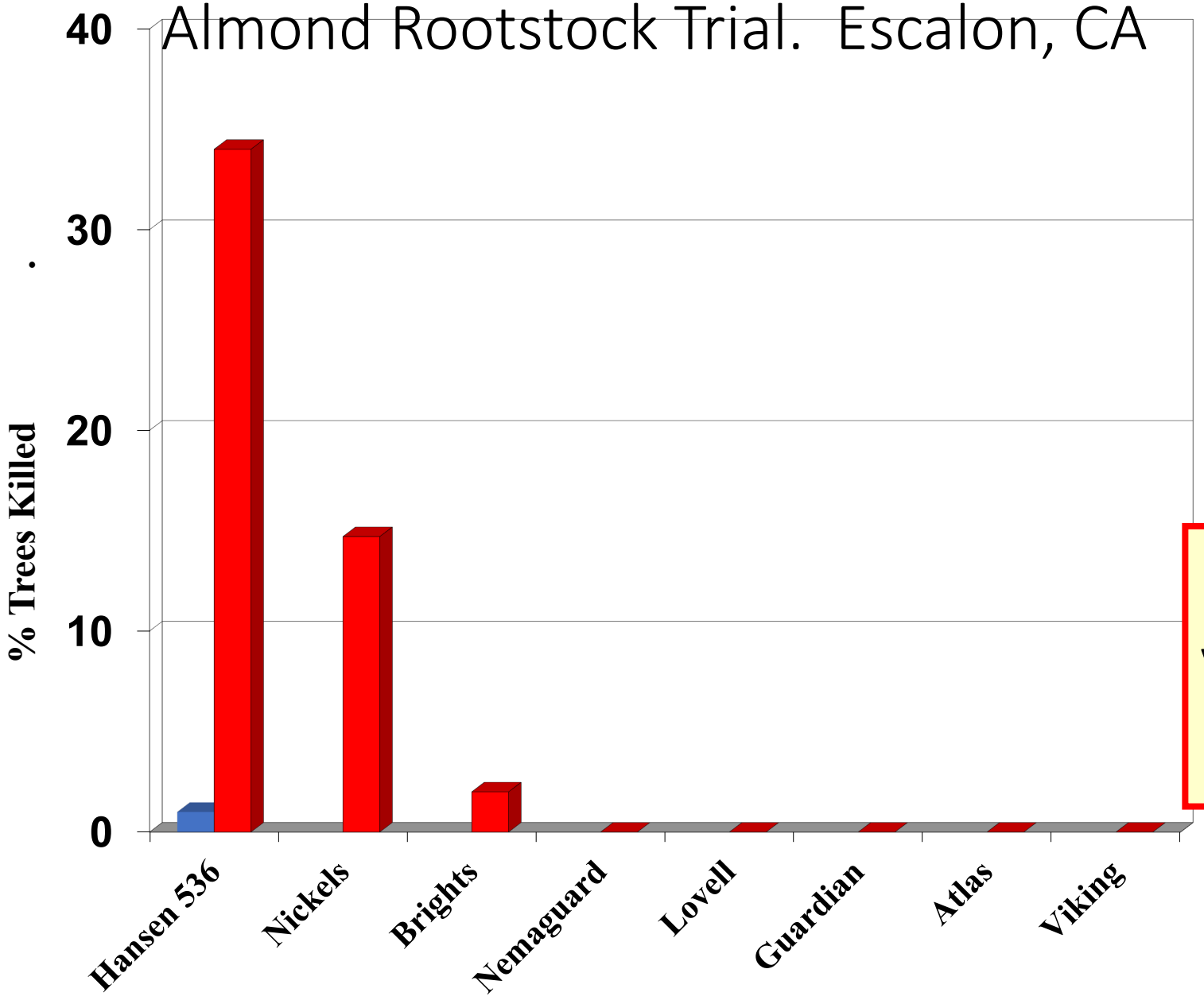
0 = no galls

1= mild: one small gall

2= moderate: galls up ½ way around crown

3= severe: more than half of crown affected, tree performance affected

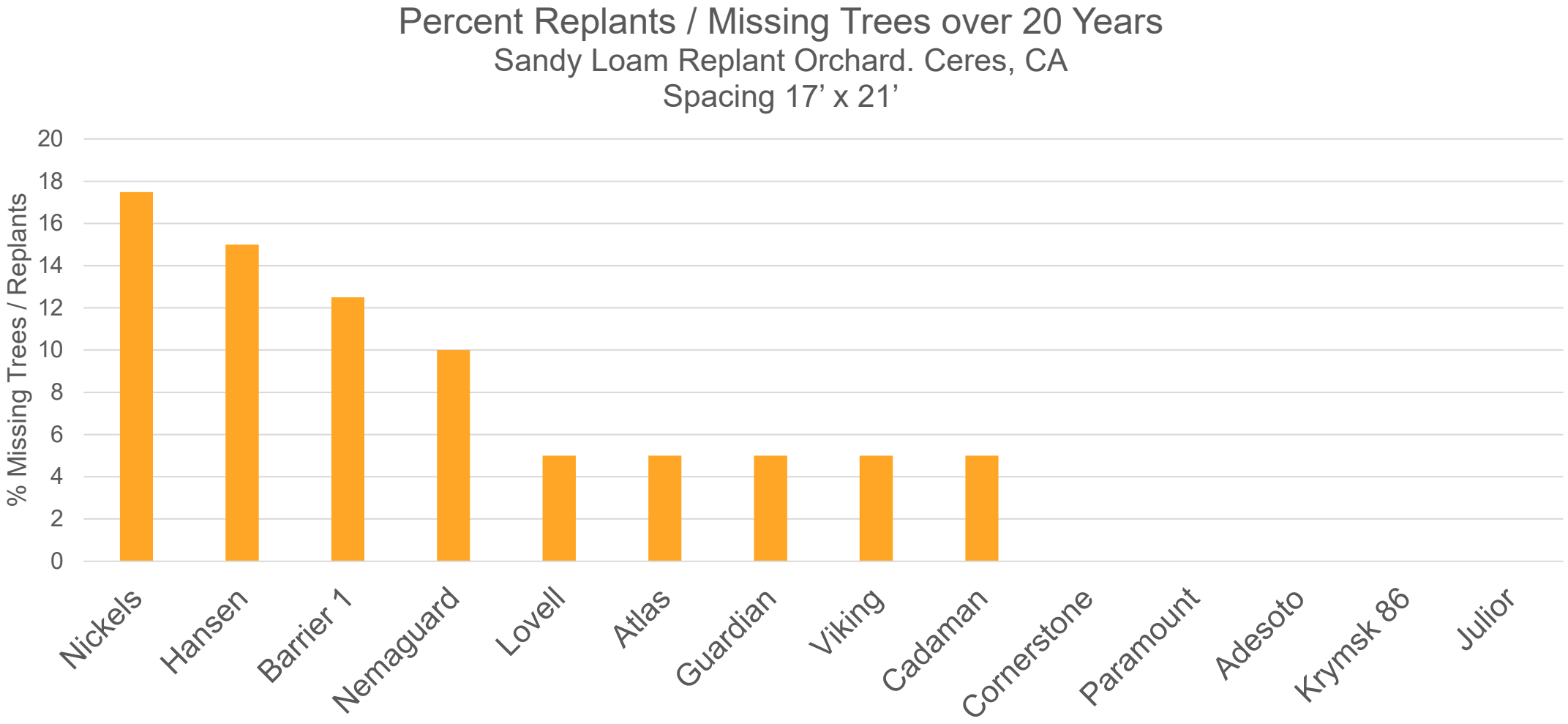
Rootstocks Killed by Bacterial Canker
Almond Rootstock Trial. Escalon, CA



- Peach / almond hybrid rootstocks are very susceptible to bacterial canker
- Viking, Lovell & Guardian are tolerant

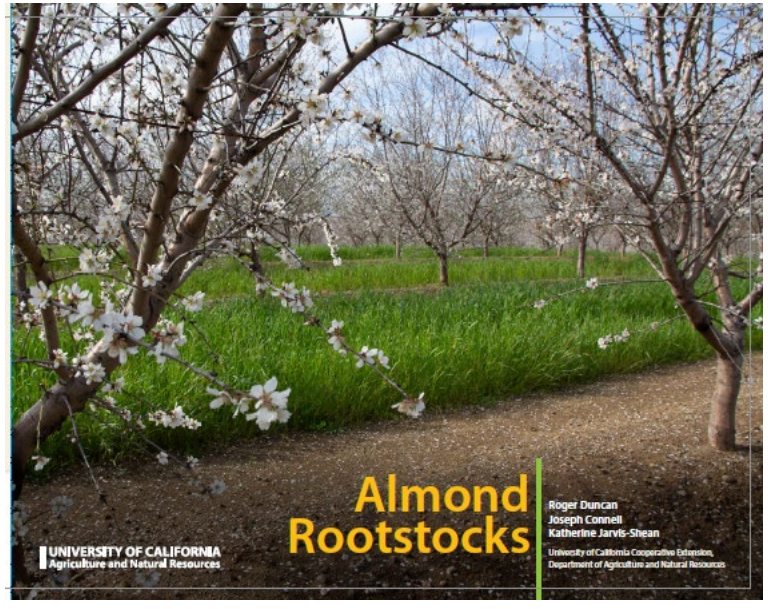
Hansen with crown gall and Ceratocystis Canker

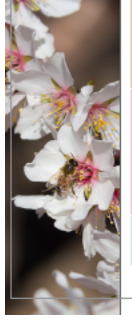
Maximizing Profits – Orchard Longevity – 2003 Rootstock Trial



Most trees missing from scaffold failure or late-life blow over due to wood decay

New Tri-fold Rootstock Chart





				Horticultural Characteristics				Abiotic Conditions					Diseases							Nematodes		
Parentage	Rootstock	Genetic Background[1]	Comments	Compatibility	Anchorage	Vigor[2]	Suckering	Excessive Sodium	Excessive Chloride	Lime-induced Chlorosis	Excessive Boron	In-season Waterlogging[3]	Oak Root Fungus	Crown Gall	*Phytophthora*	Verticillium Wilt	Replant Disease	Bacterial Canker	Rootknot[4]	Ring[5]	Root Lesion[6]
Peach	Guardian®	*P. persica*	Similar to Nemaguard but with good resistance to ring nematode and bacterial canker.	Good	Fair	Moderately high	Low	Susceptible	Susceptible	Susceptible	Susceptible	Sensitive	Susceptible	Susceptible	Moderately susceptible	Susceptible	Unknown	Tolerant	Resistant	Tolerant	Susceptible
	Lovell®	*P. persica*	Historical standard in Sacramento Valley heavier soils due to perceived better asphyxia tolerance than Nemaguard. Susceptible to rootknot nematode.	Good	Fair	Moderate	Low	Susceptible	Highly susceptible	Susceptible	Highly susceptible	Sensitive	Susceptible	Susceptible	Moderately susceptible	Highly susceptible	Highly susceptible	Tolerant	Susceptible	Tolerant	Susceptible
	Nemaguard®	*P. persica*	Historical standard rootstock for the San Joaquin Valley in well-drained soil. Being replaced by newer, better-suited rootstocks. Prone to zinc deficiency.	Good	Moderately high	Low	Highly susceptible	Susceptible	Susceptible	Susceptible	Susceptible	Sensitive	Susceptible	Unknown	Moderately susceptible	Susceptible	Highly susceptible	Susceptible	Resistant	Susceptible	Susceptible
Peach Hybrids	Cadaman®	*P. persica* x *P. davidiana*	Similar to Nemaguard but better tolerance of alkaline and saline conditions.	Good (limited experience)	Good	Moderately high	Low	Moderately tolerant	Moderately tolerant	Moderately tolerant	Highly susceptible	Sensitive	Susceptible	Unknown	Moderately susceptible	Susceptible	Unknown	Moderately tolerant	Resistant	Susceptible	Highly susceptible
	Empyrean 1® (Barrier 1®)	*P. persica* x *P. davidiana*	High vigor and salt tolerance similar to peach x almond hybrids but less susceptible to ring nematode. Fair anchorage may limit use in windy areas.	Good (limited experience)	Fair	Very high	Low	Tolerant	Tolerant	Moderately tolerant	Susceptible	Sensitive	Susceptible	Unknown	Moderately susceptible	Susceptible	Low susceptibility	Assumed tolerant[7]	Resistant	Tolerant	Highly susceptible
Peach x Almond Hybrids	Brights 5®	*P. dulcis* x *P. persica*	Similar to Hansen but with more moderate vigor.	Good	Good	High	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Sensitive	Susceptible	Moderately susceptible	Highly susceptible	Susceptible	Low susceptibility	Highly susceptible	Resistant	Highly susceptible	Susceptible
	Cornerstone®	*P. dulcis* x *P. persica*	Similar to Hansen but with more moderate vigor.	Good (limited experience)	Good	Very high	Low	Tolerant	Tolerant	Moderately tolerant	Assumed Moderately tolerant	Sensitive	Susceptible	Highly susceptible	Highly susceptible	Susceptible	Unknown	Assumed susceptible	Resistant	Highly susceptible	Susceptible
	Flordaguard x Alnem (FxA®)	*P. dulcis* x *P. persica*	Similar to Hansen. New release by USDA-ARS. Limited experience.	Good (limited experience)	Excellent	Very high	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Unknown	Unknown	Highly susceptible	Unknown	Highly susceptible	Unknown	Unknown	Unknown	Unknown	Unknown
	Hansen 536®	*P. dulcis* x *P. persica*	Standard peach x almond hybrid rootstock developed by the University of California. High vigor, excellent anchorage, high salt and alkalinity tolerance. Highly susceptible to ring nematode and bacterial canker.	Good	Excellent	Very high	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Sensitive	Highly susceptible	Highly susceptible	Highly susceptible	Highly susceptible	Low susceptibility	Highly susceptible	Resistant	Highly susceptible	Moderately tolerant
	Nickels®	*P. dulcis* x *P. persica*	Similar to Hansen but better adapted to nursery propagation and storage practices. More tolerant of wet spring soils due to higher chilling requirement.	Good	Very good	Very high	Low	Moderately tolerant	Moderately tolerant	Tolerant	Moderately tolerant	Sensitive	Susceptible	Highly susceptible	Highly susceptible	Susceptible	Unknown	Highly susceptible	Resistant	Highly susceptible	Susceptible
	Titan Hybrids (Titan 1®, SG 1®, etc.)	*P. dulcis* x *P. persica*	More vigorous than Hansen with possibly better wet-soil tolerance.	Good	Good	Very high	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Sensitive	Susceptible	Unknown	Moderately susceptible	Susceptible	Unknown	Highly susceptible	Resistant	Unknown	Unknown
Plum Hybrids	Krymsk 86® (plum x peach)	*P. cerasifera* x *P. persica*	Excellent anchorage and general tolerance to root diseases. Lower vigor in sandy soil. Susceptible to sodium, chloride, boron, and all nematodes. Incompatible with Independence.	Good with Nonpareil. Incompatible with Independence.[8] Marginal with Monterey and Shasta	Excellent	Moderate	Low / Moderate	Susceptible	Highly susceptible	Susceptible	Susceptible	Tolerant[9]	Moderately Resistant	Susceptible	Resistant	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible
	Marianna 40® (plum x plum)	*P. cerasifera* x *P. munsoniana*	Better vigor and anchorage and less suckering than Marianna 2624. Assumed resistance to oak root fungus and *Phytophthora* but experience is limited.	Assumed similar to M 2624	Very good	Moderate	Low	Unknown	Unknown	Unknown	Assumed susceptible	Tolerant[9]	Resistant	Unknown	Assumed resistant	Unknown	Unknown	Assumed susceptible	Resistant	Susceptible	Susceptible
	Marianna 2624® (plum x plum)	*P. munsoniana* x *P. cerasifera*	Standard in soils infested with oak root fungus and *Phytophthora*. Incompatible with Nonpareil and Independence. Root suckering and low vigor are common.	Incompatible with Nonpareil and Independence. Marginal with Monterey	Good	Moderately low	High (variable)	Tolerant	Tolerant	Susceptible	Susceptible	Tolerant[9]	Resistant	Moderately tolerant	Resistant	Unknown	Highly susceptible	Highly susceptible	Resistant	Susceptible	Susceptible
	Rootpac 20® (plum x sand cherry)	*P. besseyi* x *P. cerasifera*	Dwarfing rootstock (about 65% of Nemaguard) used in Super High-Density plantings in Spain. Limited experience in California.	Unknown	Very low	High	Unknown	Unknown	Unknown	Unknown	Assumed susceptible	Unknown	Unknown	Susceptible	Resistant	Unknown	Unknown	Assumed susceptible	Unknown	Unknown	Unknown
	Rootpac R® (plum x almond)	*P. cerasifera* x *P. dulcis*	Best suited for alkaline, heavy soils high in chloride. Not well suited for sandy soils (low vigor) or where excess sodium and boron are a problem. Performance has been variable in UC trials.	Good with Nonpareil (limited experience)	Good	Moderate to low	Moderate	Susceptible	Tolerant	Tolerant	Susceptible	Tolerant[9]	Unknown	Unknown	Resistant	Susceptible	Highly susceptible	Assumed susceptible	Resistant	Highly susceptible	Susceptible
Complex Hybrids (peach, almond, plum, apricot)	Atlas®	*P. persica* x [*P. dulcis* x (*P. cerasifera* x *P. mume*)]	Similar to Nemaguard but may have higher yield efficiency. Intolerant to cold storage or dehydration when planted bare root.	Good	Fair	Moderately high	Low	Susceptible	Susceptible	Moderately tolerant	Highly susceptible	Sensitive	Susceptible	Moderately tolerant	Highly susceptible	Tolerant	Unknown	Susceptible	Resistant	Susceptible	Highly susceptible
	Viking®	*P. persica* x [*P. dulcis* x (*P. cerasifera* x *P. mume*)]	Slightly more vigorous than Nemaguard but good tolerance to ring nematode, bacterial canker, salt, and alkaline conditions. Excellent anchorage.	Good	Excellent	Moderately high	Low	Moderately tolerant	Moderately tolerant	Moderately tolerant	Moderately tolerant	Sensitive	Susceptible	Moderately tolerant	Highly susceptible	Susceptible	Unknown	Tolerant	Resistant	Tolerant	Susceptible

[1] As per Rubio-Cabetas, et al., 2017.

[2] Vigor of rootstocks with plum parentage is often significantly lower in sandy soil.

[3] Wet soil in season can worsen incompatibility symptoms.

[4] Rootknot nematode resistance infers *Meloidogyne incognita*, *M. arenaria*, and *M. javanica*, not the peach rootknot nematode *M. floridensis*.

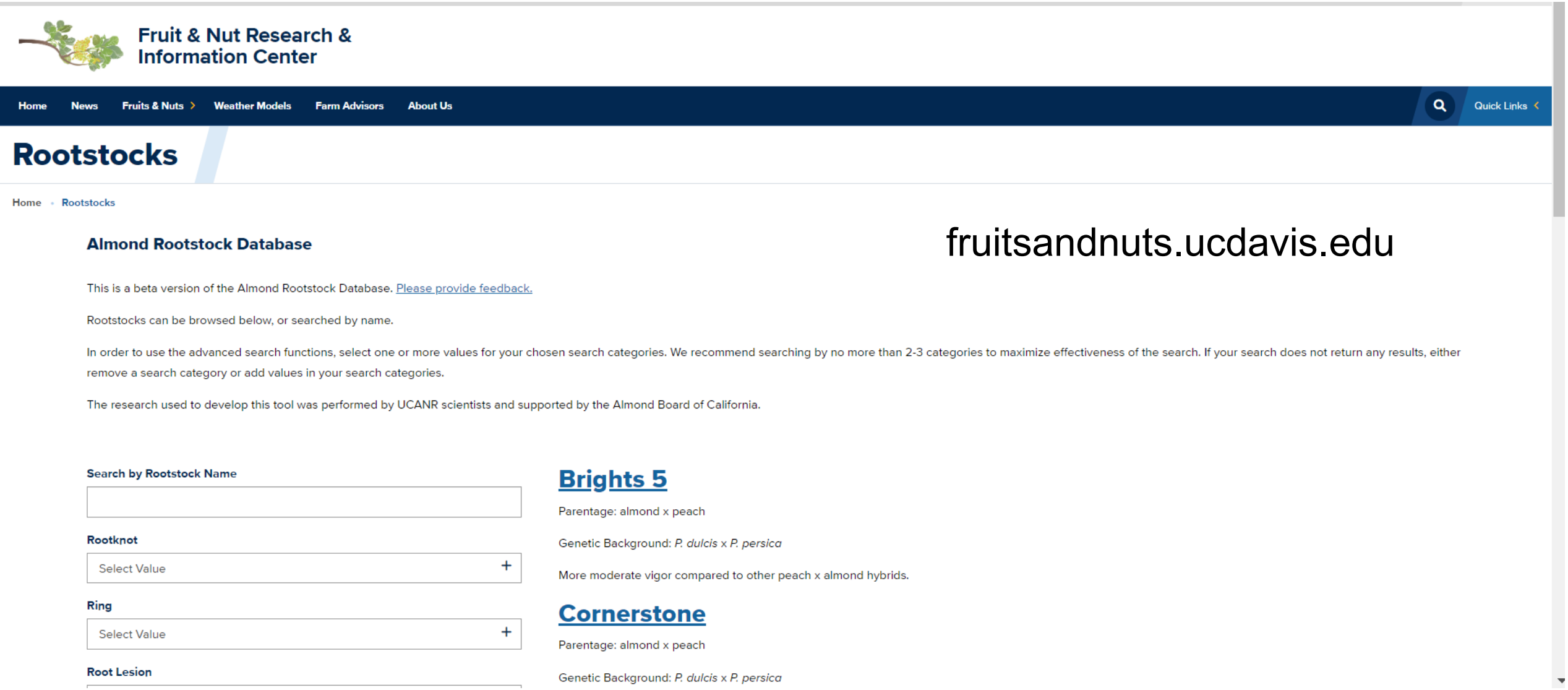
[5] Ring — *Mesocriconema* (=*Criconemella*) *xenoplax*.

[6] Root lesion — *Pratylenchus vulnus*.

[7] Assumed susceptibility or resistance is based on other rootstocks with similar parentage, but insufficient data exists for confirmation.

[8] Sporadic incompatibility symptoms have been observed with Independence on Krymsk 86, while some orchards have performed acceptably.

Online Rootstock Database – UC Fruit & Nut Center



Conclusions

- **Vigorous rootstocks have consistently been the highest yielding, and usually the most yield efficient in UC trials**
- **More vigorous rootstocks have larger kernels**
- **Increased yields & larger kernels = higher profits with little to no added expense**
- ***IF*, you have no significant site challenges, consider a more vigorous rootstock (and don't plant too far apart)**

THE ALMOND CONFERENCE

50 YEARS

Use of Rootstocks to Mitigate Soilborne Diseases

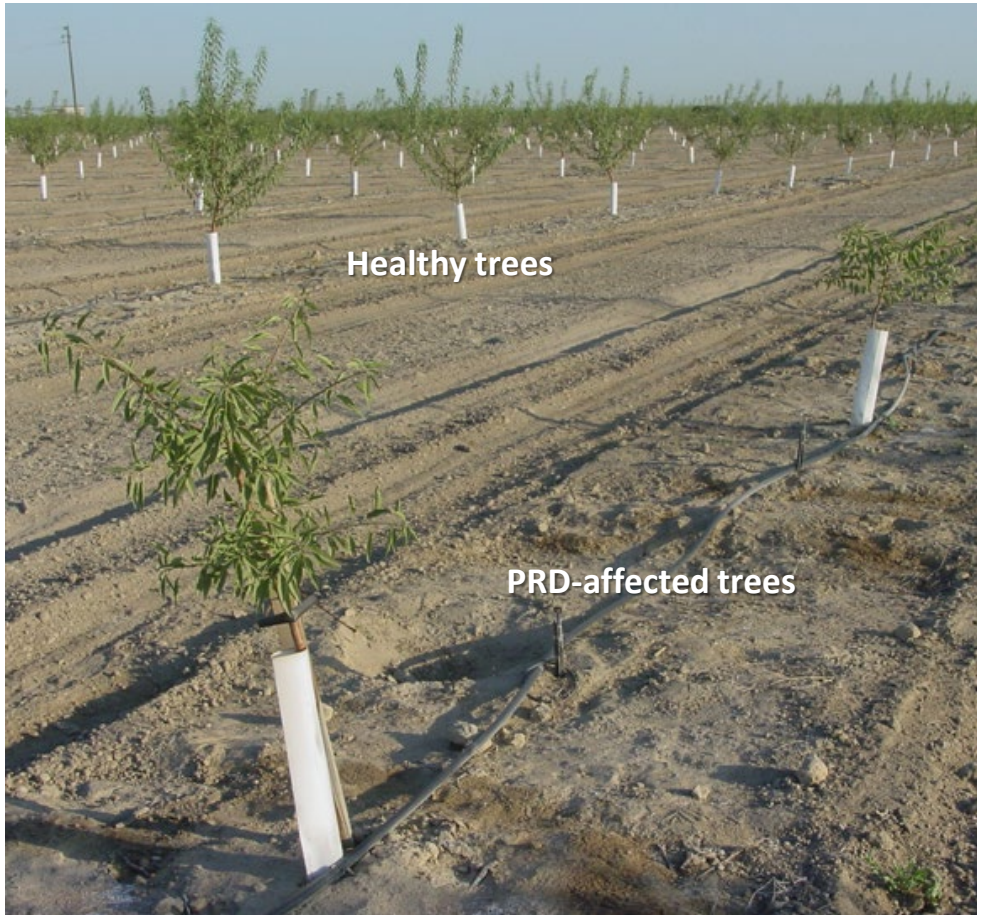
8 December 2022 / N.J. Ott for G.T. Browne

california almonds®
Almond Board of California

Soilborne diseases covered here:

1. Phytophthora crown & root rot

2. Armillaria root rot



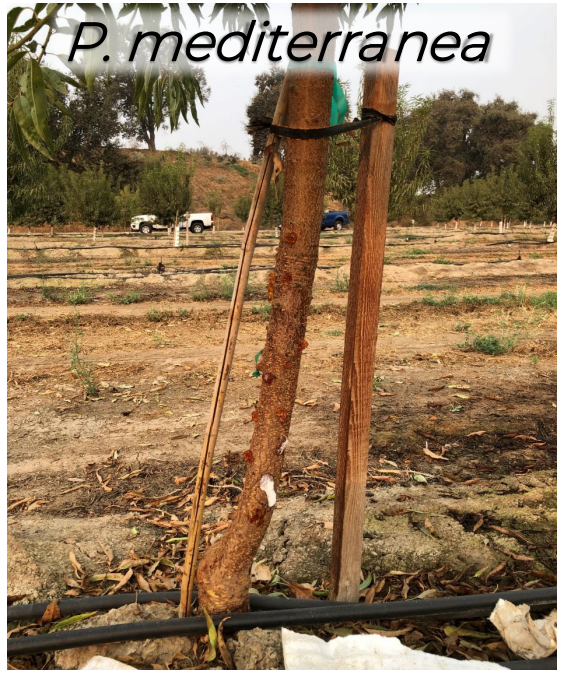
Healthy tree

PRD-affected tree

3. Prunus replant disease (PRD)

1. Rootstocks and *Phytophthora*

- Multiple, diverse causal species
- Vast majority of species infect through roots, crown
- Rootstock a key for management of crown and root rot



“Give your rootstock a chance”, reduce risk of *Phytophthora* infection by:

- Putting graft union above soil line
- Avoiding soil water saturation at crown

Proper placement of dual drip lines

- The biological basis of zoospore infections by *Phytophthora*
- Goal: non-water-saturated conditions at root crown while supplying needed water to roots
- Move lines away from root crowns ASAP, to extent possible
- Shovel- or soil-auger-based checking of moisture helpful

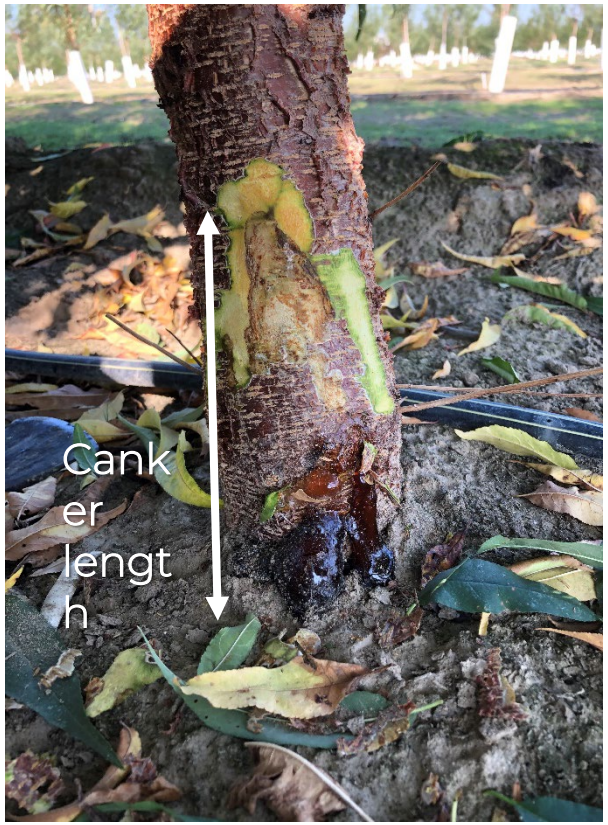
Genetic resistance of rootstocks to *Phytophthora*, orchard evaluations, KARE, 2020-present

Testing genetic resistance to Phytophthora at KARE, 2020-present

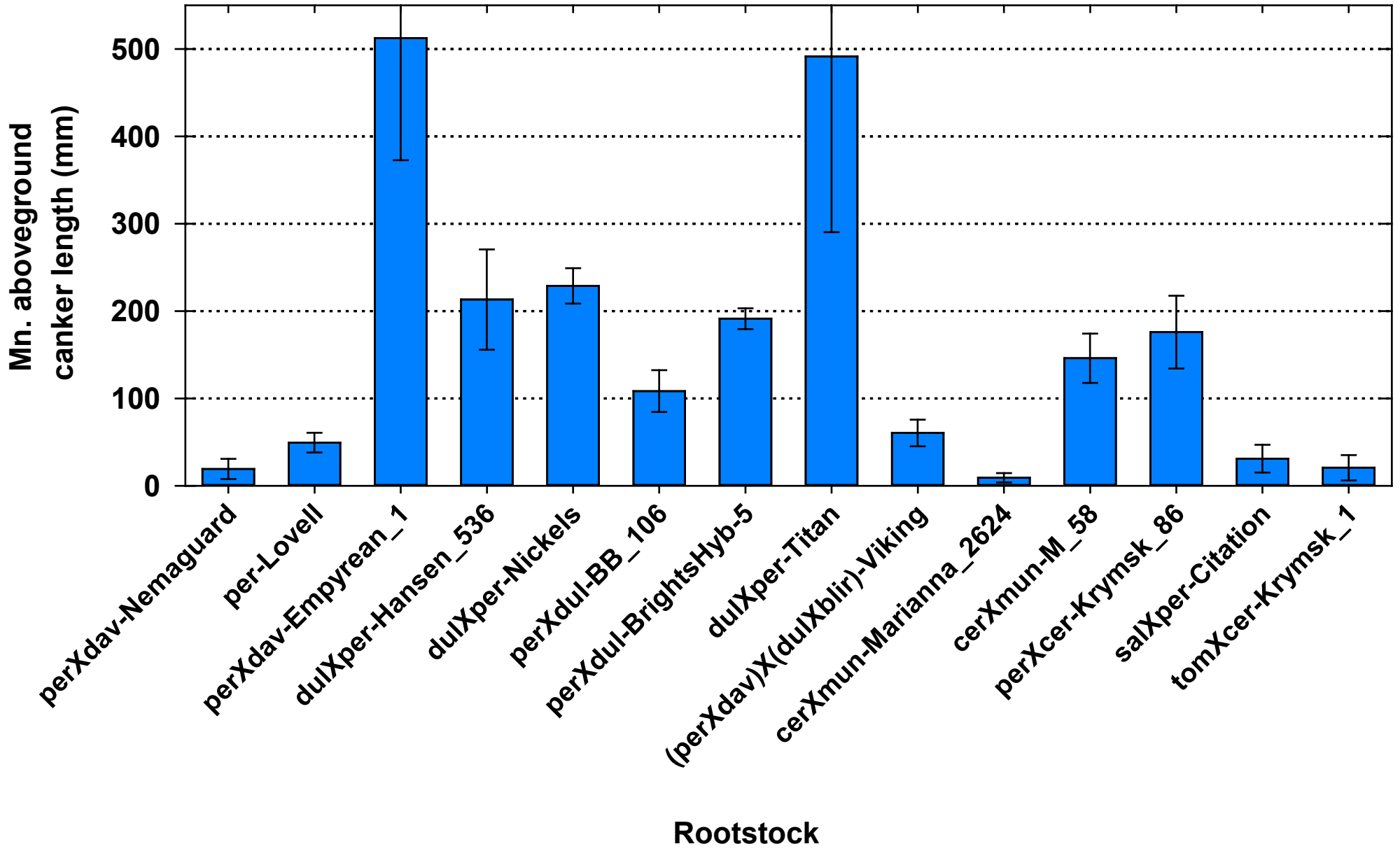
- **Trees establish for 4 to 6 mo, then soil inoculated with *Phytophthora* and control**
- **Split plot design, ≥12 *P*-inoculated trees and 4 control trees per rootstock**
- **Trees drip irrigated normally except for monthly 24-h "flooding" periods, spring-fall**
- **Pear baiting to monitor inoculum activity**
- **Initial resistance assessment based on aboveground canker incidence, length**
- **Final resistance assessment based on above and belowground crown rot incidence, length**
- **Isolations monitor species of *Phytophthora***

From control plots

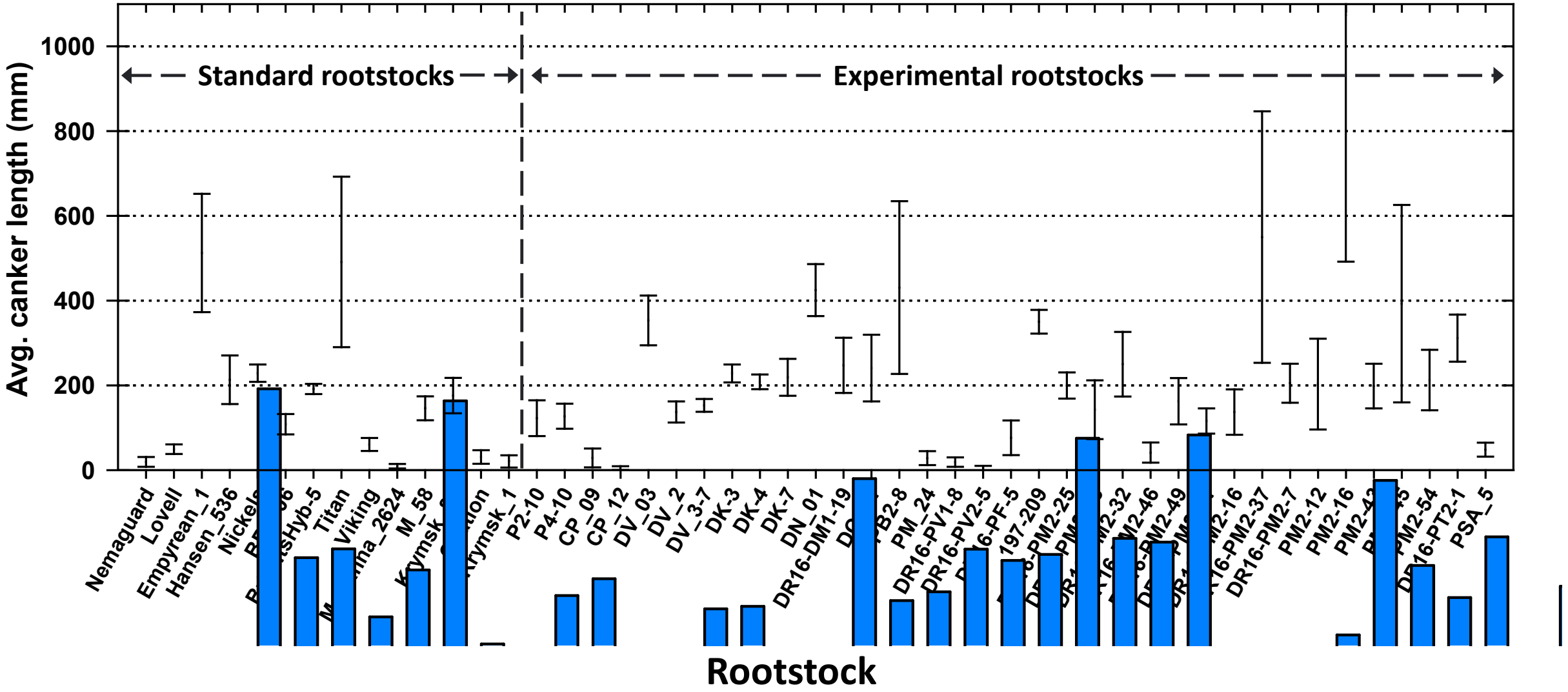
From Phytophthora plots



2022 results, from trial planted in 2020, standard rootstocks



2022 results, trial planted in 2020, standard & experimental rootstocks



2. Rootstocks and *Armillaria*

- **'Marianna 2624' is the only widely tested almond rootstock known for high tolerance / resistance to Armillaria**

- **'MP-29', is an experimental interspecific hybrid developed by USDA-ARS at Byron, GA (Elible Sloe plum hybrid x SL0014 peach), selected in the SE US for its resistance to *Armillaria*. It is being tested in CA for its graft compatibility with almond (R. Duncan) and response to local isolates of *Armillaria* (K. Baumgartner)**

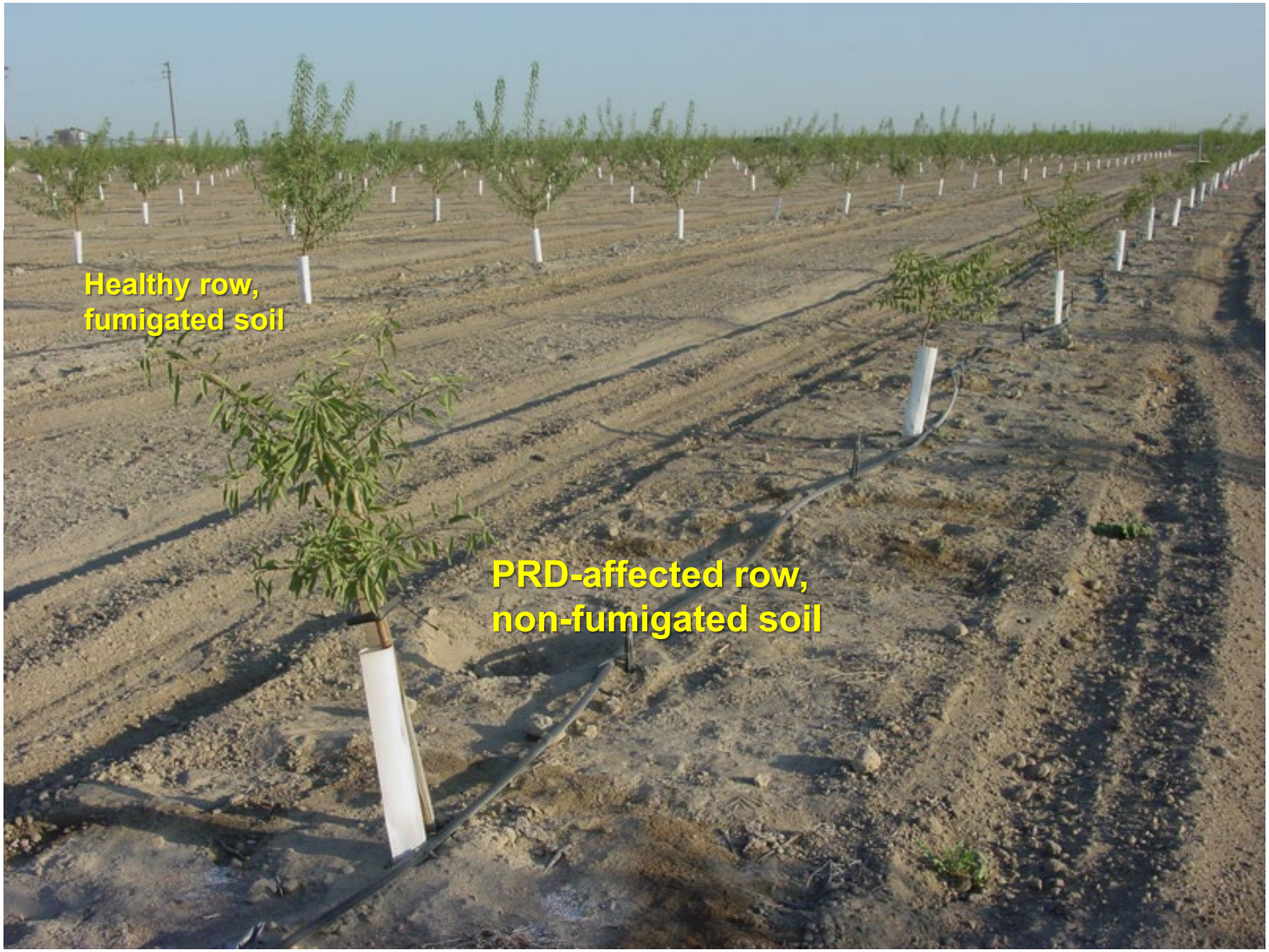
Armillaria-caused tree collapse (Almond doctor photo)

Crown rot- Armillaria (UC-IPM photo)

Root rot- Armillaria (Browne)

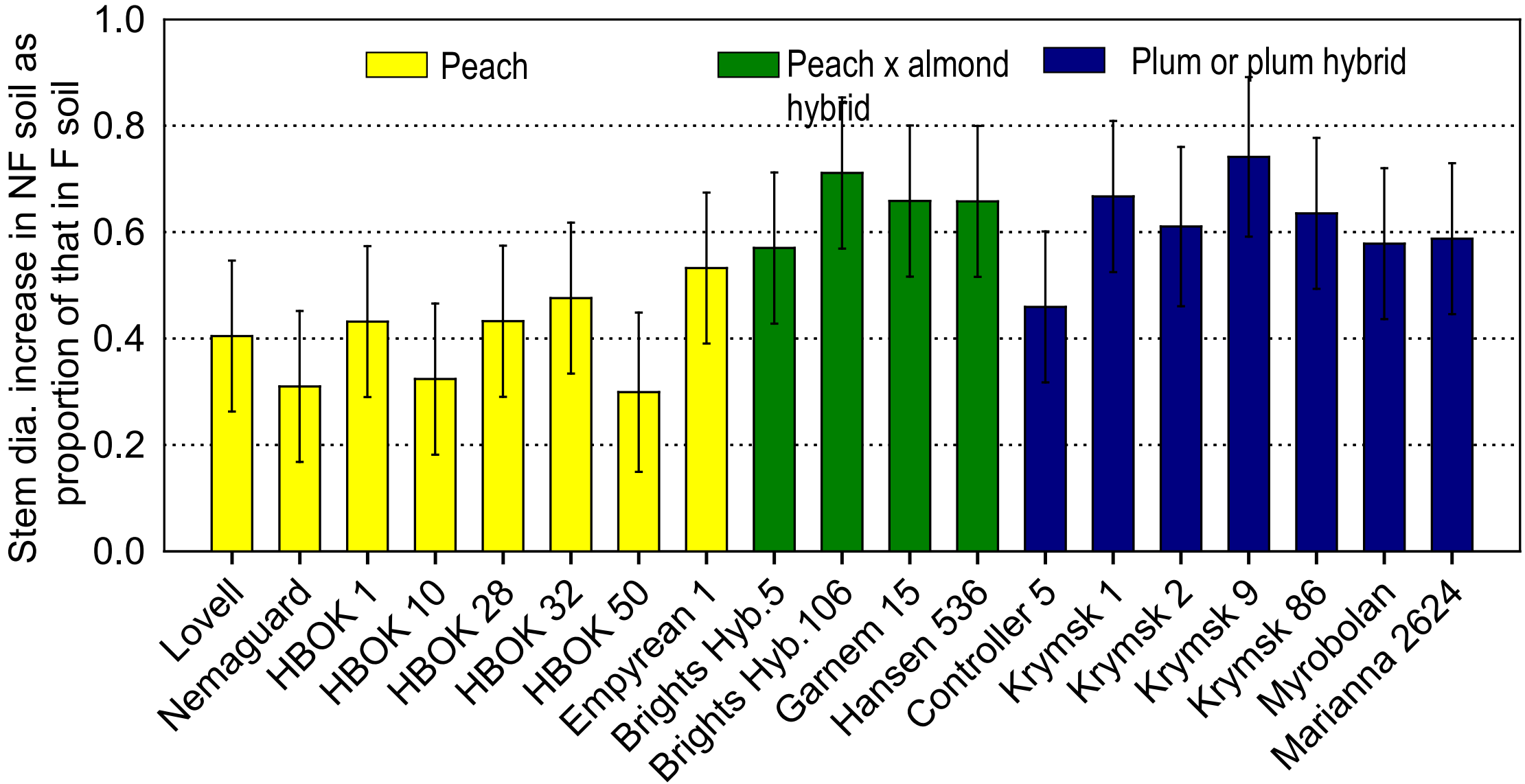
3. Rootstocks & Prunus replant disease (PRD)

- Microbe-induced growth suppression in *Prunus* planted after *Prunus*
- "PRD" is distinct from nematode parasitism
- Impacted by many factors, rootstock is focus here



Testing sensitivity of different rootstocks to Prunus replant disease, Parlier, CA, 2011-13

Sensitivity of different rootstocks to Prunus replant disease, Parlier, CA, 2011-13



Summary

- Rootstocks are valuable tools for management of *Phytophthora*, *Armillaria*, and PRD.
- Give your rootstock a chance with *Phytophthora* by planting bud union above soil line, avoiding unnecessary soil water saturation at root crown.
- Available and experimental rootstocks vary widely in susceptibility to *Phytophthora,* evaluations of new selections are underway.
- Select rootstock appropriate for all site and scion characteristics; be aware of high susceptibility to *Phytophthora* in peach-almond hybrid rootstocks.
- Marianna 2624 rootstock offers field-tested tolerance to *Armillaria*, but not compatible with 'Nonpareil'; testing of alternative rootstocks with resistance to *Armillaria* underway.
- Peach-almond hybrids generally offer greater PRD tolerance than peach rootstocks, may reduce need for fumigation for PRD management in some soils.

50 YEARS of The Almond Conference

WHAT DID YOU THINK?

Scan the QR Code below and answer 4 short questions to help us in planning future presentations.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YEARS