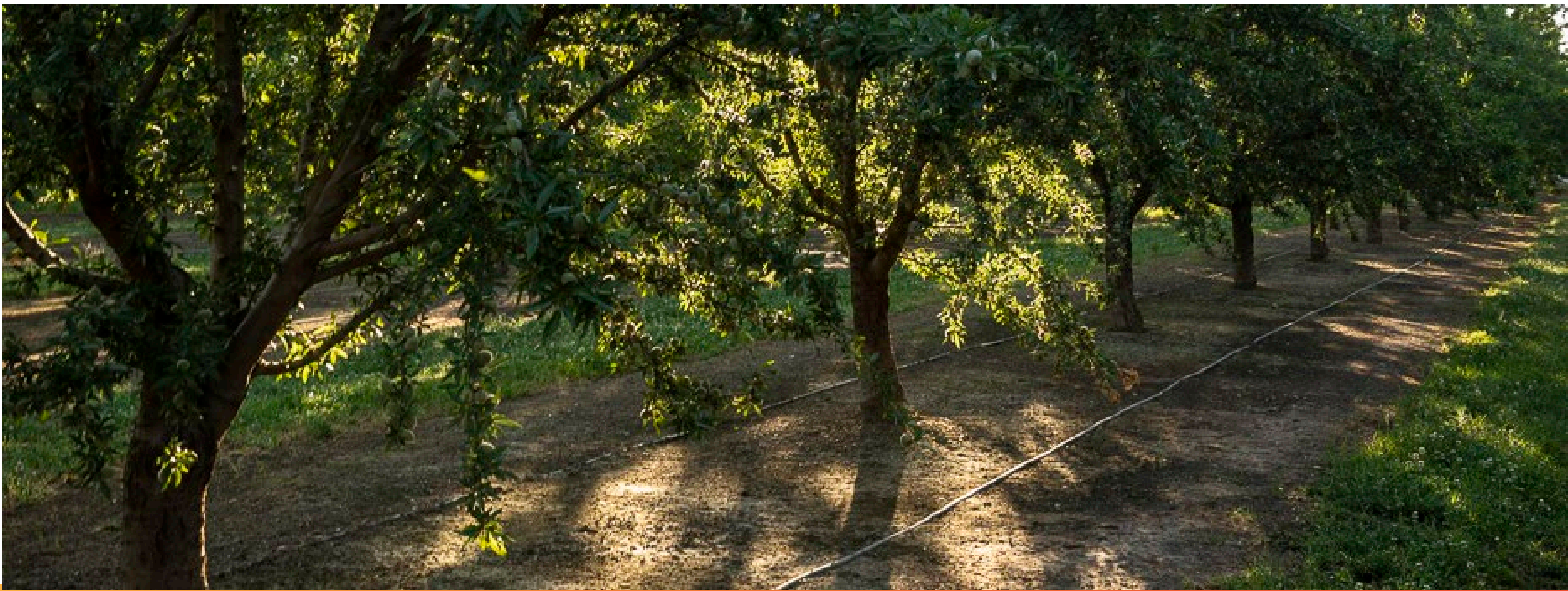

2018 | THE ALMOND CONFERENCE

SPEED TALKS: ROOTSTOCKS AND VARIETIES

ROOM 312-313 | DECEMBER 6, 2018

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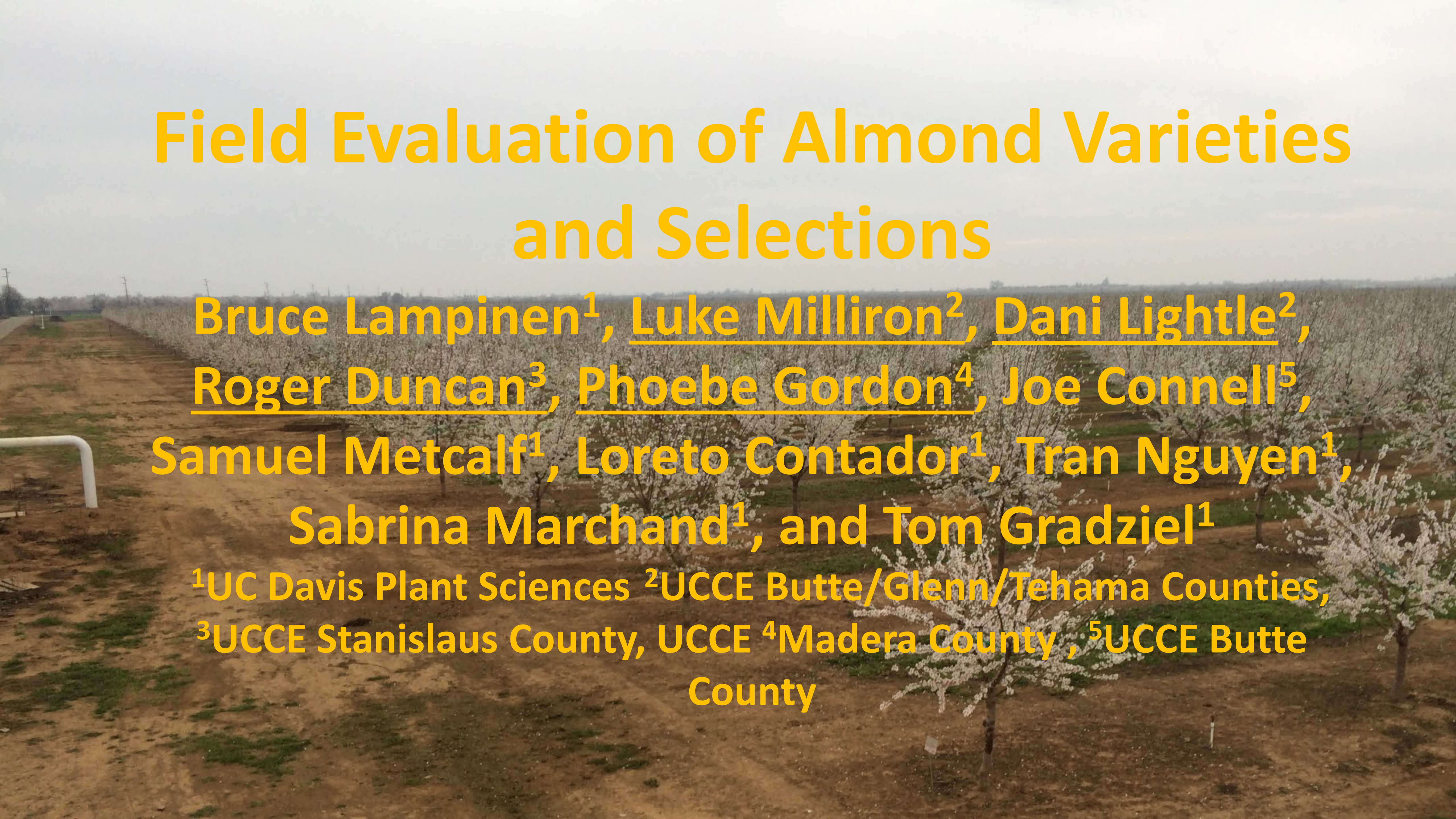
Almond Board of California

growing ADVANTAGE®
The Almond Conference

AGENDA

- **Sebastian Saa**, Almond Board of California, moderator
- **Almond Board Funded Researchers**
  - Bruce Lampinen, UC Davis/ANR
  - Roger Duncan, UCCE Stanislaus
  - Devinder Sandhu (Jorge Ferreira), USDA-ARS US Salinity Lab
  - Georgia Drakakaki, UC Davis
  - Malli Aradhya & Daniel Kluepfel, USDA-ARS, UC Davis
  - Jonathan Fresnedo, Ohio State University
  - Mysore R. Sudarshana, USDA-ARS, UC Davis (Kurtis Dluge)



Field Evaluation of Almond Varieties and Selections

Bruce Lampinen[1], Luke Milliron[2], Dani Lightle[2], Roger Duncan[3], Phoebe Gordon[4], Joe Connell[5], Samuel Metcalf[1], Loreto Contador[1], Tran Nguyen[1], Sabrina Marchand[1], and Tom Gradziel[1]

[1]UC Davis Plant Sciences [2]UCCE Butte/Glenn/Tehama Counties, [3]UCCE Stanislaus County, UCCE [4]Madera County , [5]UCCE Butte County

The next generation almond variety trials were planted in the winter of 2014 in Butte County (Chico State University), Stanislaus County (Salida School District Site), and Madera County (Chowchilla grower site).

Objective- evaluate new varieties and selections compared to standard varieties in three different almond production areas in the Central Valley.

Site	Rootstock	Spacing	#trees/acre
Butte	Krymsk 86	18’ x 22’	110
Stanislaus	Nemaguard	16’ x 21’	130
Madera	Hansen 536	12’ x 21’	173

Table 2. Varieties and selections planted at the next generation regional almond variety trials. Items 1-30 are planted at all 3 sites while additional material planted at individual sites is listed at the end.

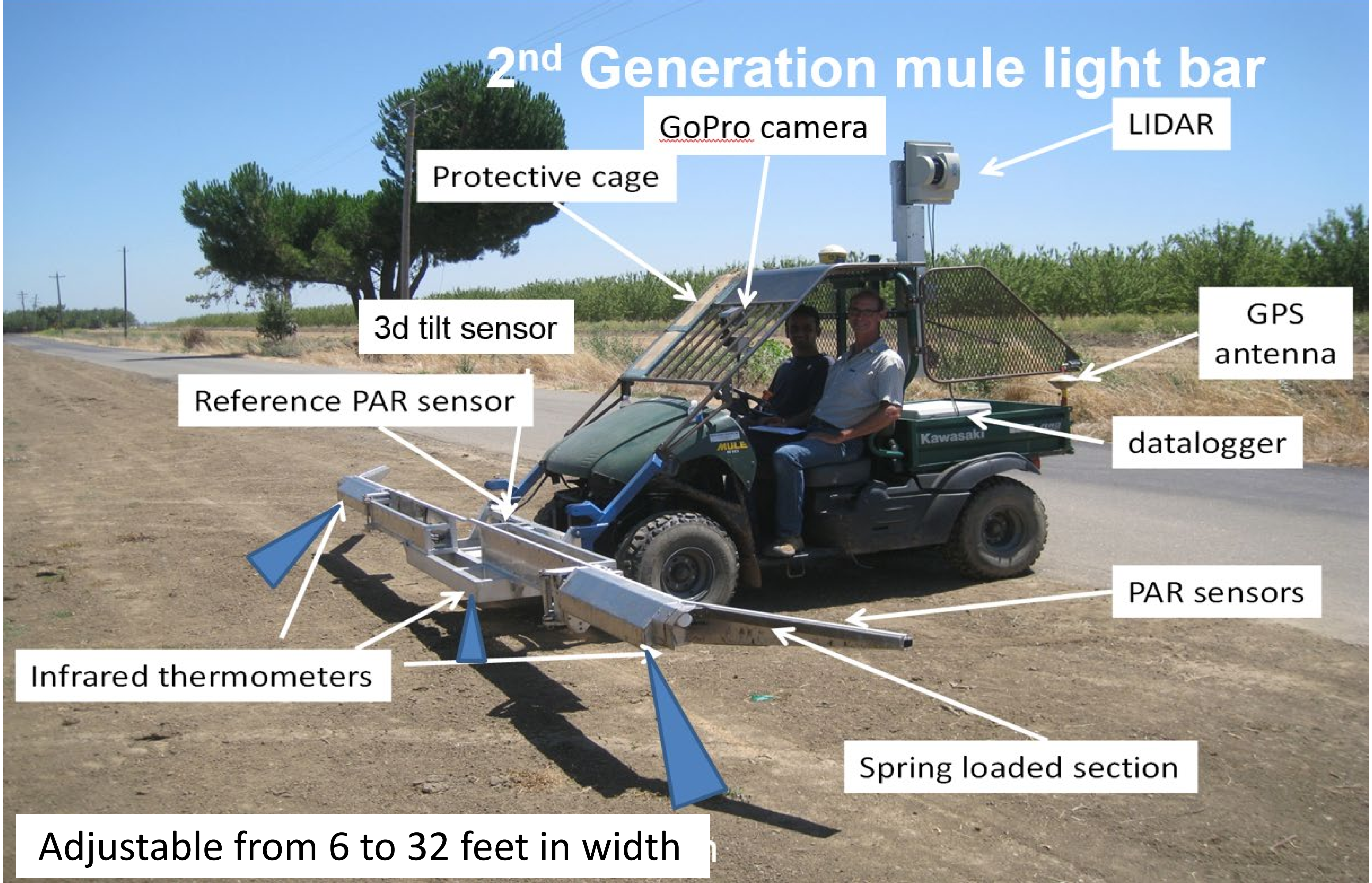
	Variety	Source
1	Eddie	Bright's
2	Capitola	Burchell
3	Supareil	Burchell
4	self-fruitful P16.013	Burchell
5	Self-fruitful P13.019	Burchell
6	Booth	Burchell
7	Sterling	Burchell
8	Bennett	Duarte
9	Nonpareil	Fowler
10	Durango	Fowler
11	Jenette	Fowler
12	Aldrich	Fowler
13	Marcona	Spain
14	Winters	UCD
15	Sweetheart	UCD
16	Kester (2-19e)*	UCD
17	UCD3-40	UCD
18	UCD18-20	UCD
19	UCD1-16	UCD
20	UCD8-160	UCD
21	UCD8-27	UCD
22	UCD1-271	UCD
23	UCD1-232	UCD
24	UCD7-159	UCD
25	UCD8-201	UCD
26	Y121-42-99	USDA
27	Y117-86-03	USDA
28	Y116-161-99**	USDA
29	Y117-91-03	USDA
30	Folsom	Wilson
31	Wood Colony on Krymsk 86 (Butte only)	
31	Lone Star on Hansen 536 (Chowchilla only	

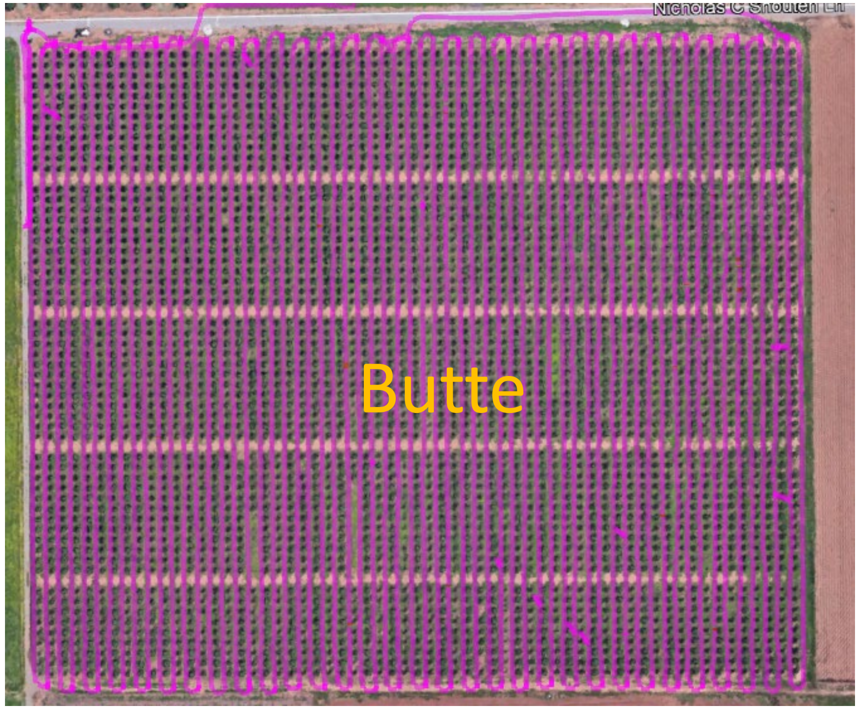
*Kester (2-19e) was planted at all three sites on the usual rootstock f
In addition at the Butte and Stanislaus sites it was also planted in t
replicated trial on Hansen 536 rootstock
** Y116-161-99 planted only in two reps outside of main trial at Butte

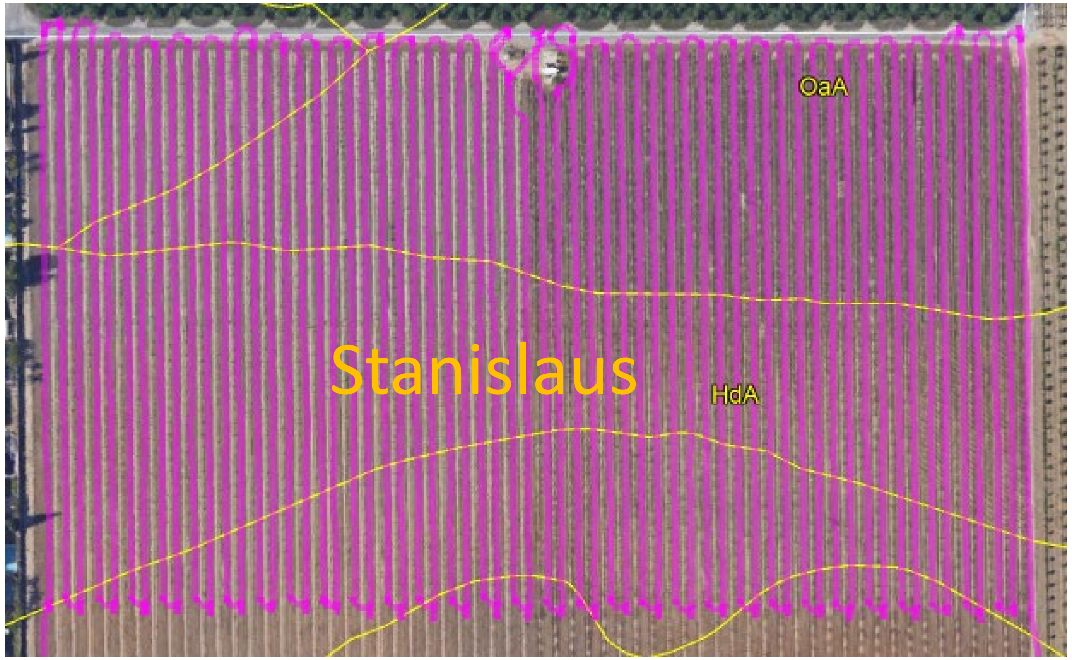
There are 4 replications of each variety and selection at each site

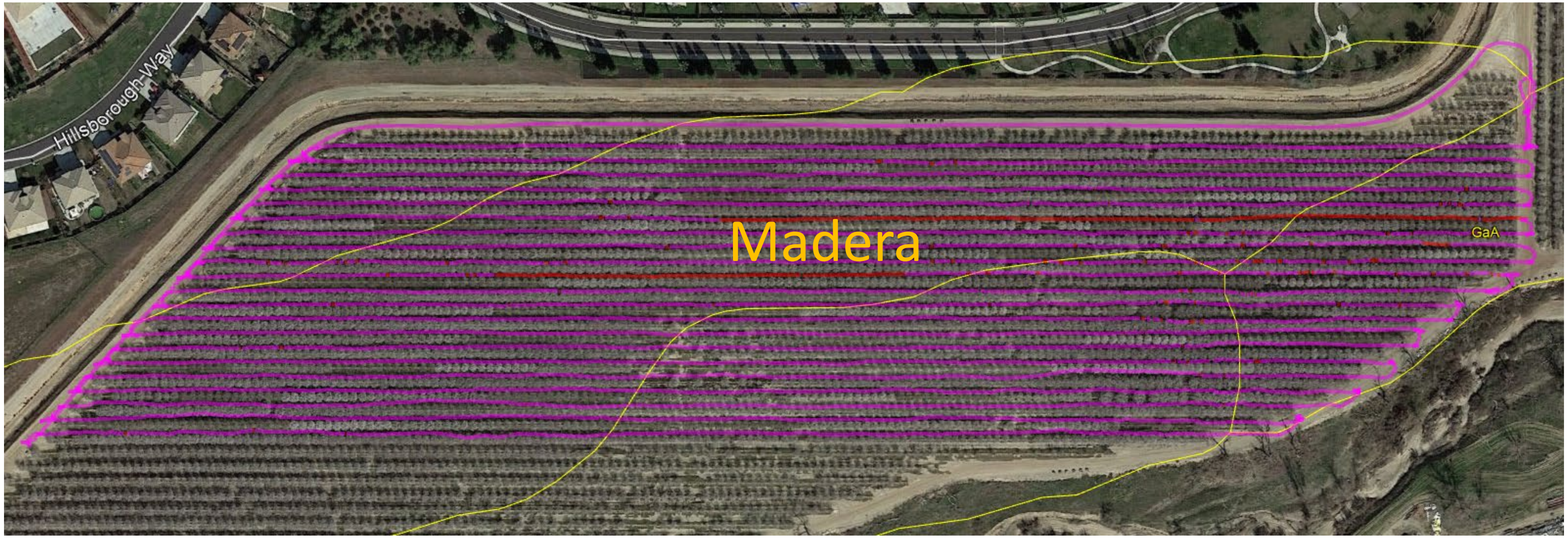
Data collected

- Bloom timing
- Hullsplit timing
- Midday canopy PAR interception
- Yield
- Nut quality
- Harvestability
- Disease incidence
- Tree loss


2nd Generation mule light bar
GoPro camera
LIDAR
Protective cage
3d tilt sensor
GPS antenna
Reference PAR sensor
datalogger
Kawasaki
MULE
PAR sensors
Infrared thermometers
Spring loaded section
Adjustable from 6 to 32 feet in width


Butte

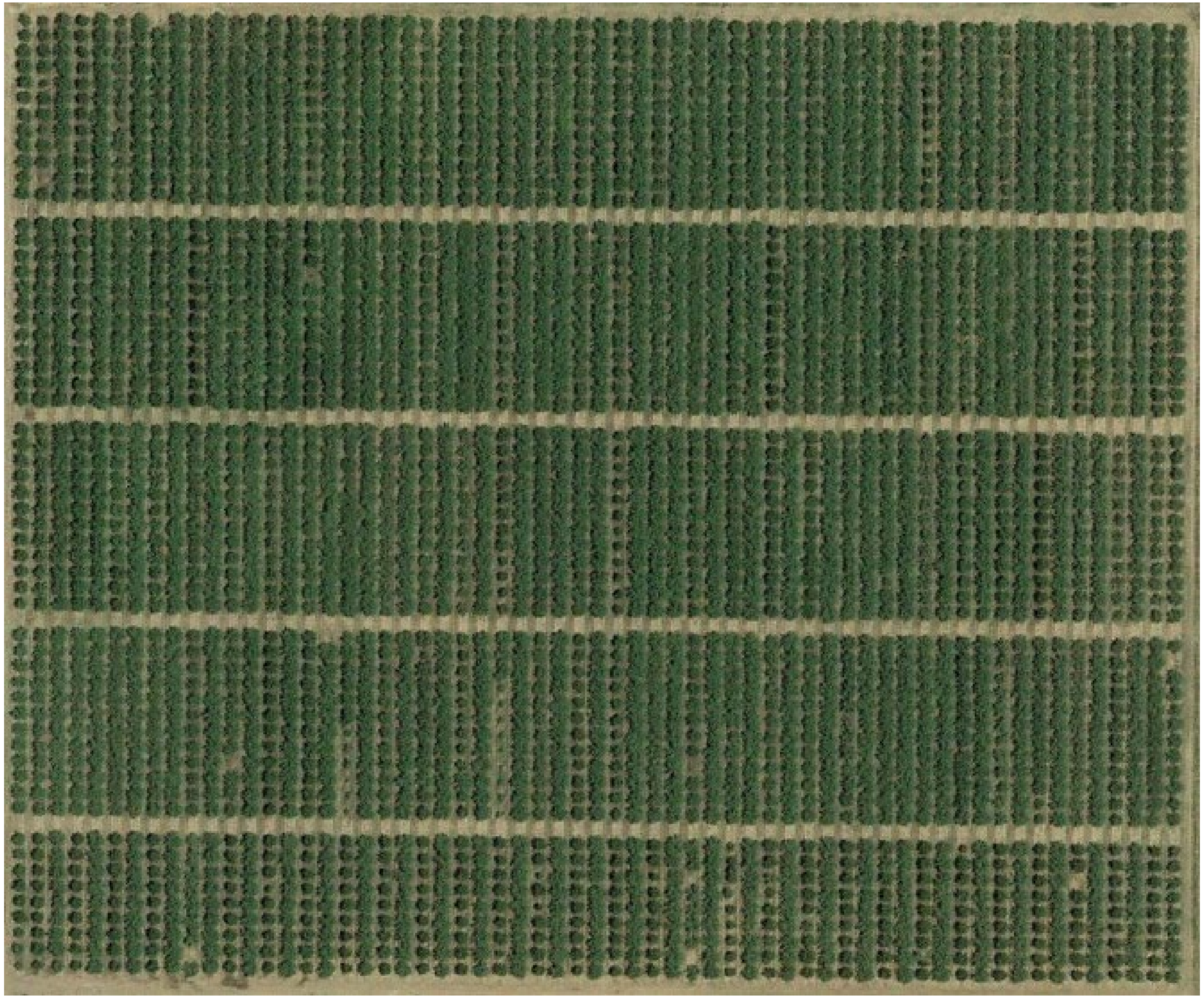

OaA
Stanislaus
HdA


Hillsborough Way
Madera
GaA

2018

Site	Midday PAR interception (%)
Butte	36-78
Stanislaus	15-75
Madera	37-96

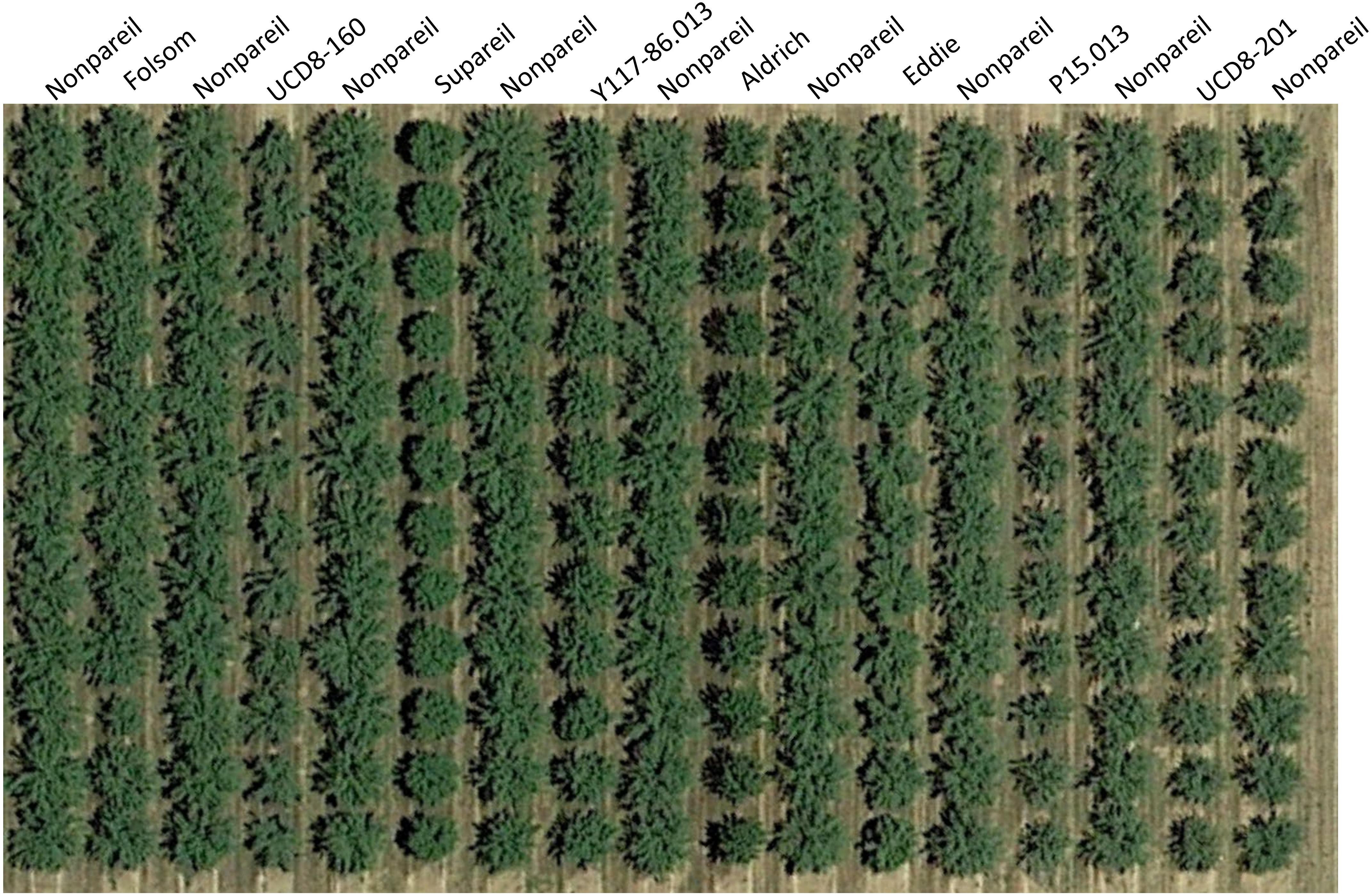
Challenges- Butte



2016
- Extensive rust damage

2017
- Bacterial blast
- Extensive hull rot
- Gopher damage

2018
- Significant frost damage during bloom
- Significant hull rot
- Minor bacterial blast
- Almond leaf scorch
  (UCD1-271 and P13.019)
- Band canker
- Spider mite infestation
- Low bee activity
- Low frame density of hives


Nonpareil
Folsom
Nonpareil
UCD8-160
Nonpareil
Supareil
Nonpareil
Y117-86.013
Nonpareil
Aldrich
Nonpareil
Eddie
Nonpareil
P15.013
Nonpareil
UCD8-201
Nonpareil

Challenges- Stanislaus

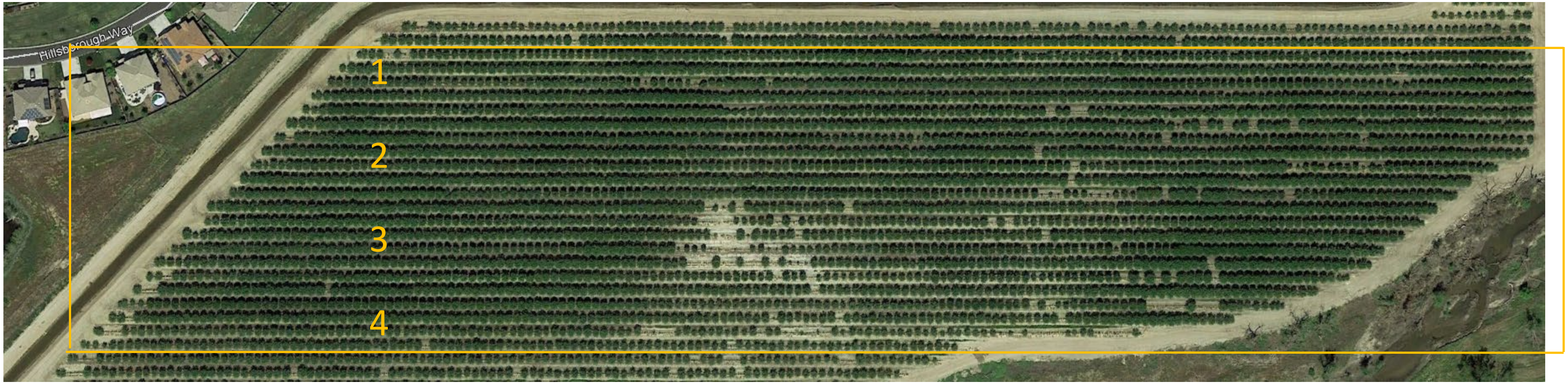
2015
- Extensive verticillium wilt

2016
- Glyphosonate drift during bloom
- Band canker

2017
- Band canker (~100 Nonpareil trees lost)
- Also some on Y121-42-99, Sterling and
- Kester/Hansen 536

2018
- Significant hull rot
  - Y121-42-99, Sterling, Y116-161-99, Kester/Hansen, Nonpareil
- Scab
- Band canker

Challenges- Madera



2016-2017

Shaker damage (a few Nonpareil and Wood colony)

Shot-hole like symptoms

Cankers (all Y-121-42-99 in one block, some Jenette)

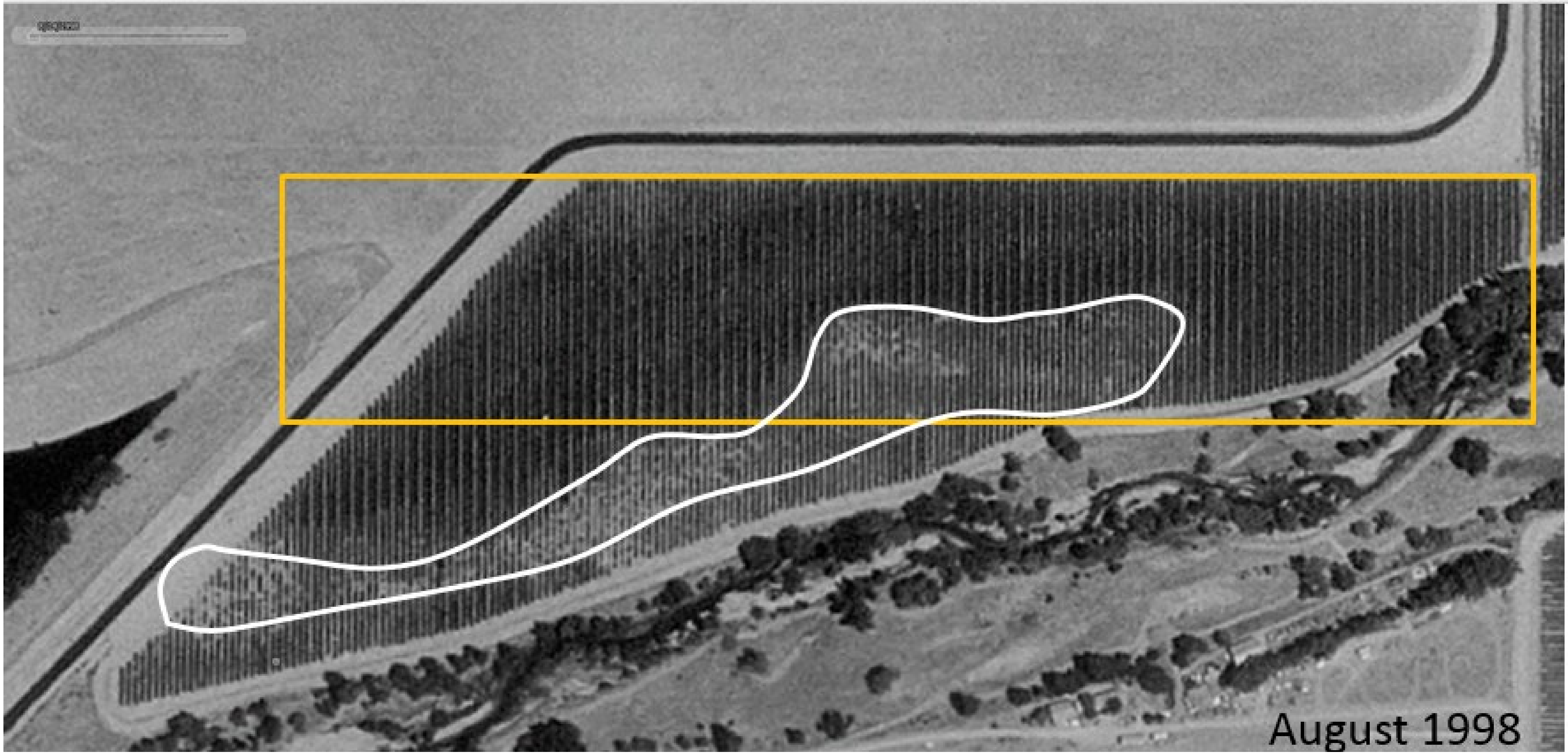
Dead trees due to infiltration issues in blocks 3 and 4)

2018

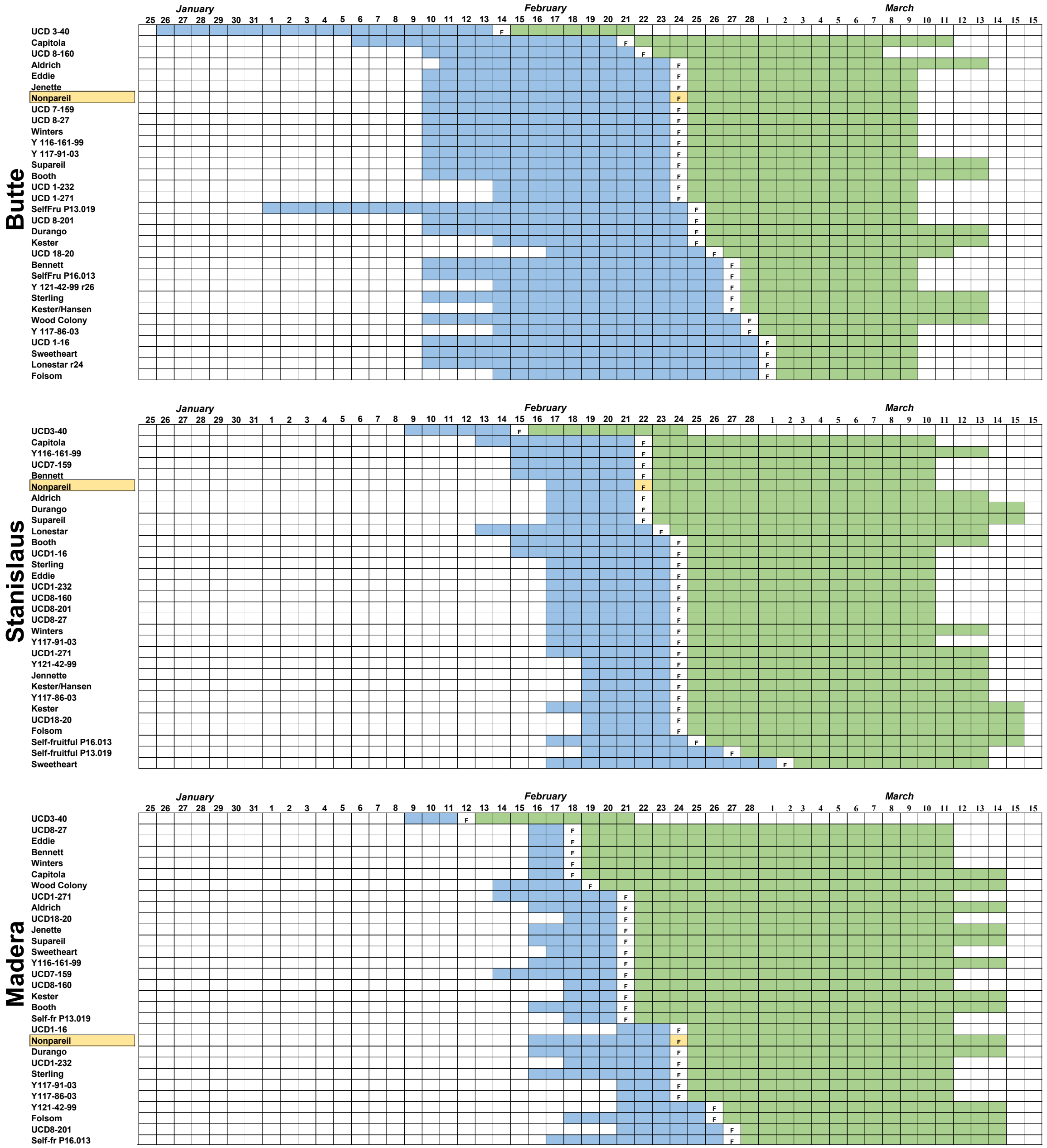
Significant frost damage on 3 dates during bloom

Significant hull rot

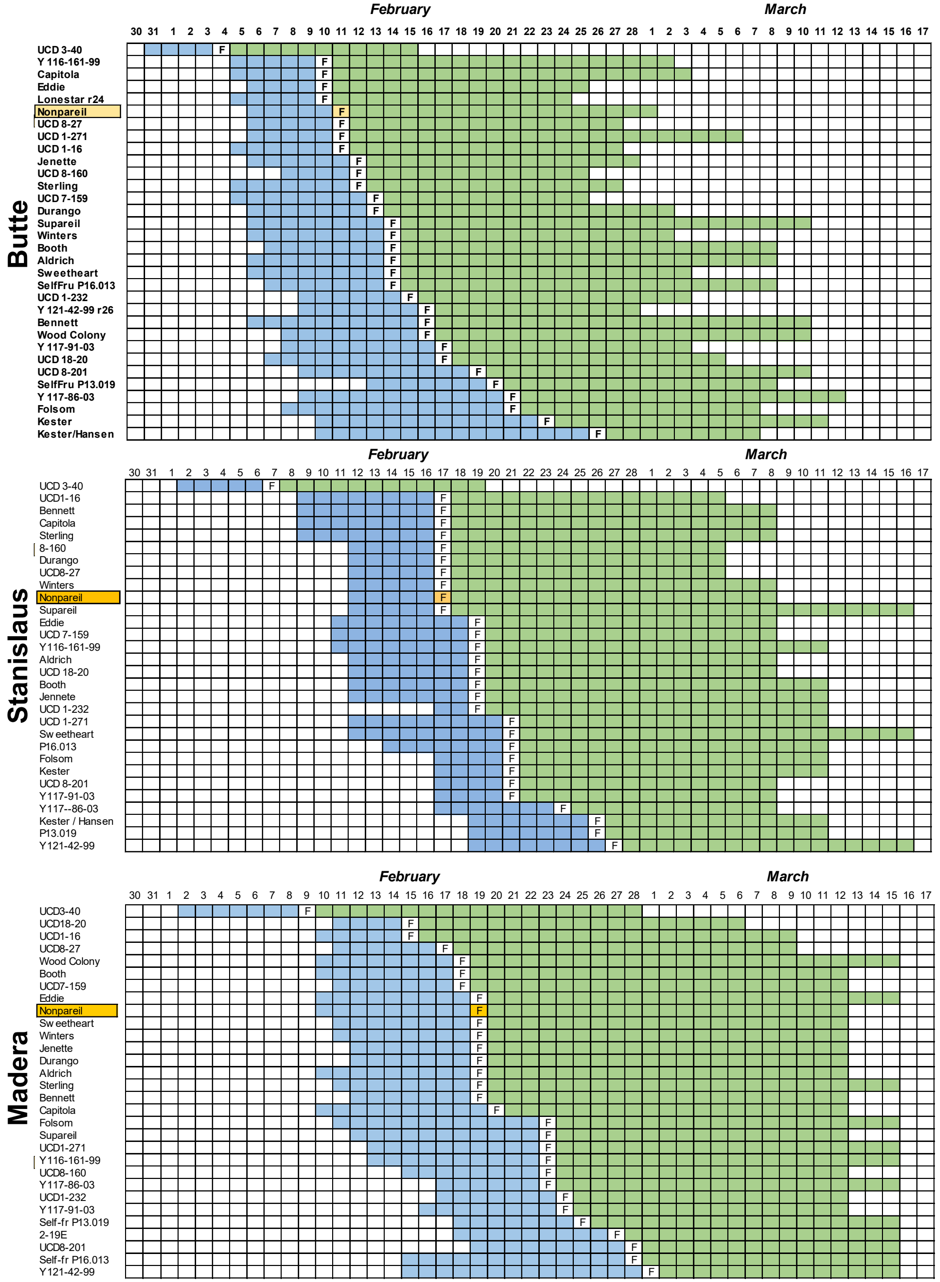
Problem with many varieties accidentally shaken earlier than desired


August 1998

2017 Bloom

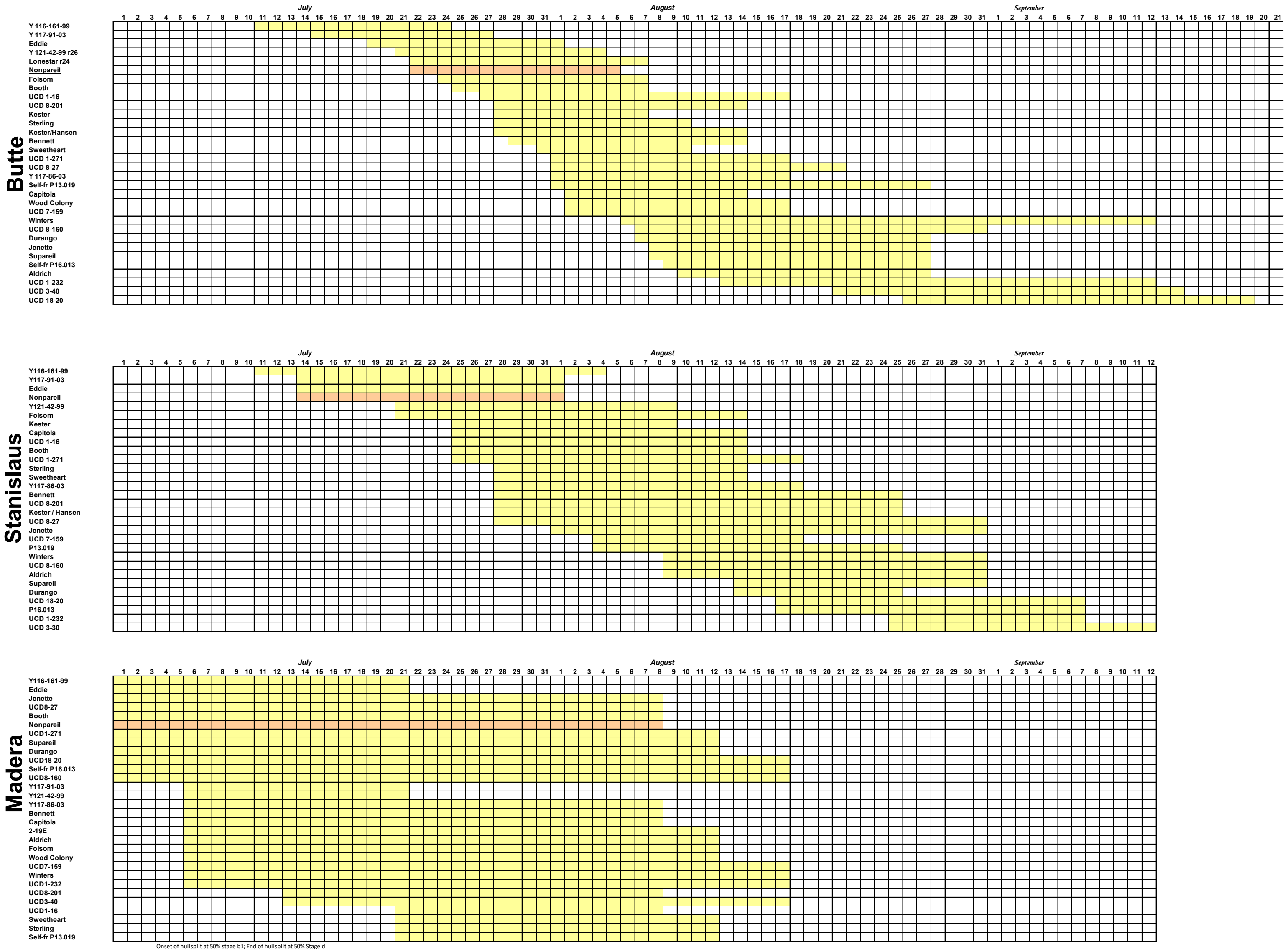


2018 Bloom



Onset of bloom   F Full bloom   Petal fall

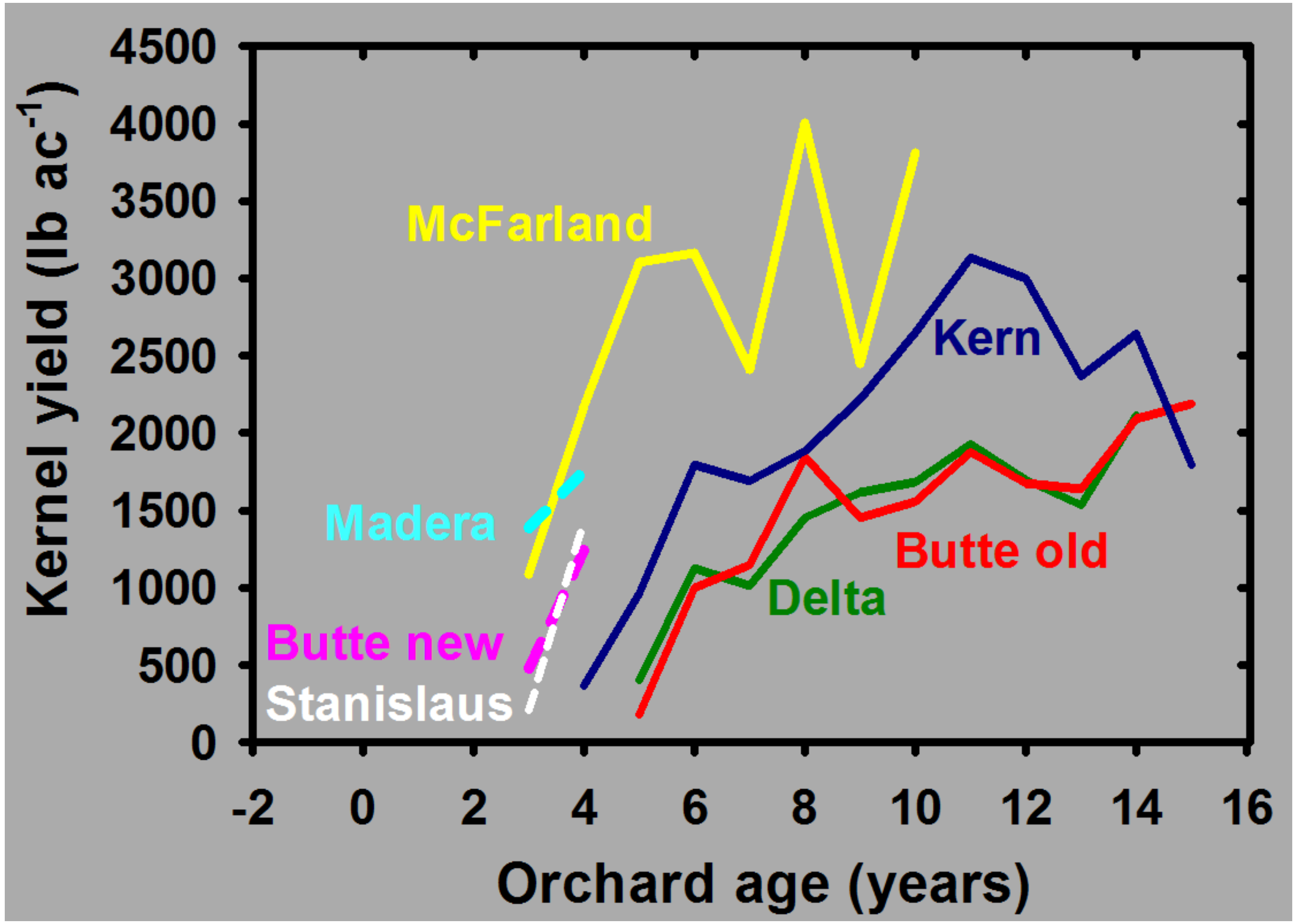
2017 Hullsplit



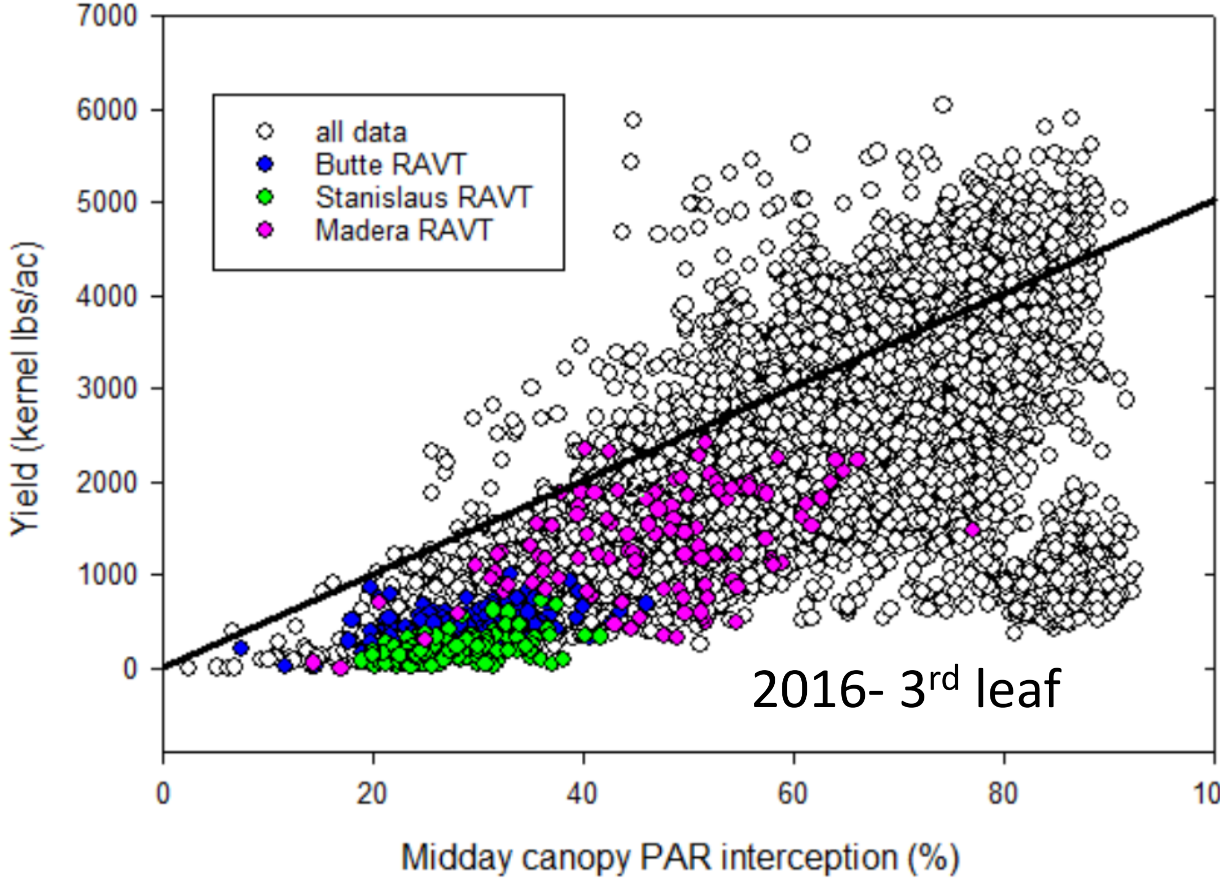
2017 defects

	Varieties with defect	Butte	(%)	Stanislaus	(%)	Madera	(%)
Doubles	**6% or more double kernels**	UCD 18-20	41	UCD 18-20	22	UCD 8-201	36
		Self-fru P16.013	37	UCD 8-201	18	Booth	22
		Booth	30	Booth	16	UCD 18-20	20
		UCD 8-201	26	Y121-42-99	16	UCD 8-27	18
		Wood Colony	24	Self-fru P16.01	15	Self-fru P16.01	13
		UCD 8-27	21	UCD 8-27	15	UCD 1-16	8
		UCD 8-160	20	Self-fru P16.01	14	Durango	7
		UCD 1-232	19	UCD 1-16	11	UCD 1-232	7
		Self-fru p13.019	19	Jenette	8		
		UCD 1-16	18	Durango	7		
		Jenette	14	Y117-91-03	6		
		Durango	13				
		Aldrich	9				
		Winters	9				
		Folsom	8				
		Kester	7				
		Bennett	7				
Twins	**6% or more twin kernels (two kernels within the same pellicle)**	UCD 8-27	18	UCD 3-40	14	UCD 3-40	28
		UCD 3-40	12	UCD 8-27	11	Jenette	9
		Sweetheart	10	Jenette	9	UCD 8-27	8
		Nonpareil	9	UCD 8-201	8	UCD 8-201	7
		UCD 1-232	7	UCD 8-160	7	2-19E	7
		UCD 8-160	7	Self-fru P16.01	7	UCD 7-159	6
		Booth	6				
		Jenette	6				
		UCD 8-201	6				
NOW	**6% or more navel orange worm damage**	UCD 8-27	6	UCD 8-27	8	UCD 1-271	14
						UCD 8-27	11
						UCD 8-201	8
						Supareil	7
						Bennett	7
						UCD 3-40	7
Blanks	**6% or more blank kernels**	Self-fru P16.013	16	(none)		(none)	
		Booth	14				
		Y121-42-99	12				
		UCD 18-20	9				
		Jenette	6				
Severe shrivel	**6% or more severe shrivel**	Folsom	21	Jenette	10	Folsom	10
		Y117-86-03	17	UCD 8-201	8	Jenette	9
		Eddie	16	Y117-86-03	6	UCD 8-201	8
		Self-fru P16.013	14			Self-fru P13.01	7

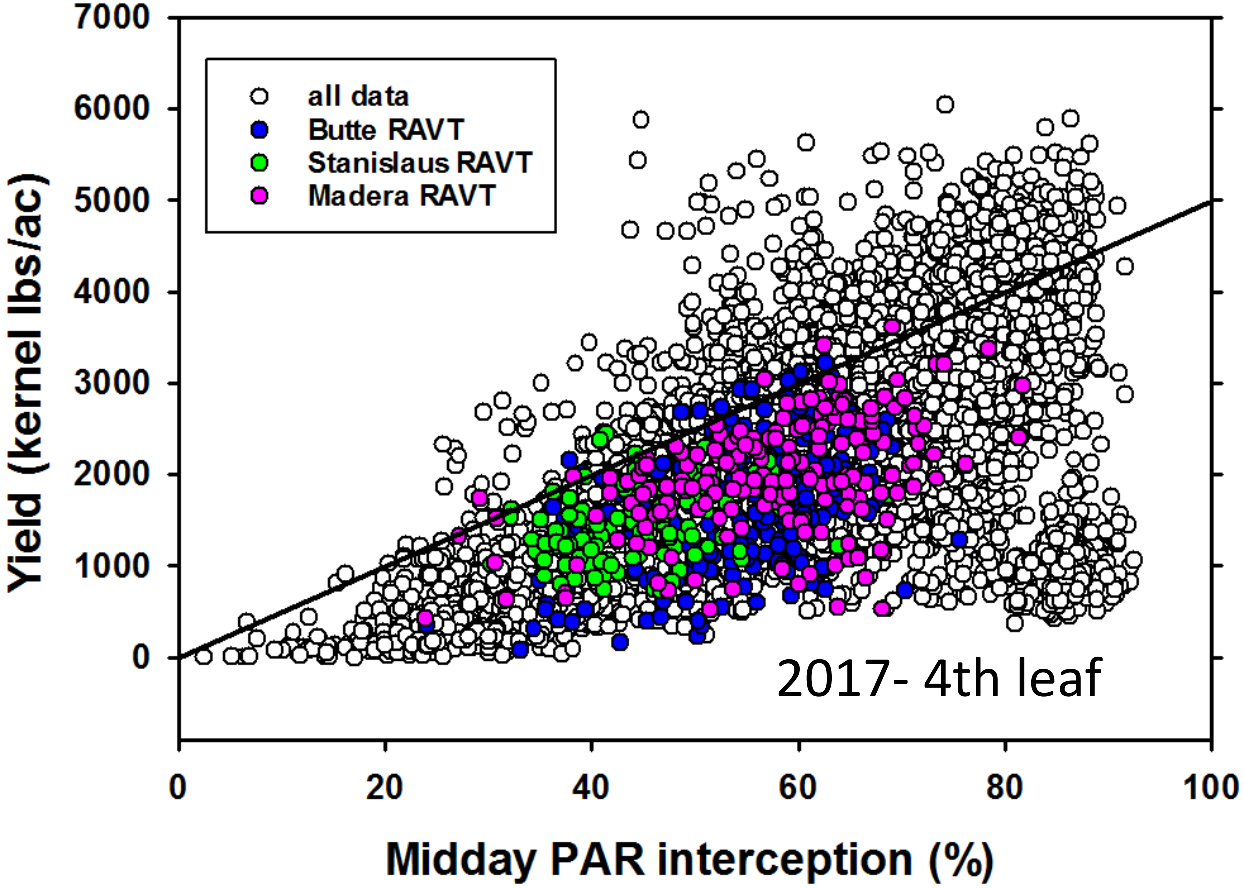
Site	Trees per acre	2016 (kernel lb/ac)	2017 (kernel lb/ac)
Butte	110	159-796	405-2145
Stanislaus	130	40-460	907-2058
Madera	173	410-1999	708-2604



PAR interception versus yield



2016- 3rd leaf



2017- 4th leaf

Cumulative 2016-2017 yields

Butte

# reps	Variety or selection	Yield (kernel lbs/ac)	
4	Booth	2778	a
4	UCD18-20	2650	a b
4	UCD1-232	2581	a b c
108	**Nonpareil**	**2579**	**a b c**
4	Winters	2509	a b c d
4	UCD8-160	2379	a b c d e
4	Folsom	2106	a b c d e f
4	Y117-91-03	1981	b c d e f g
4	Capitola	1955	b c d e f g
4	UCD8-201	1922	c d e f g h
4	Self-fruitful P13.019	1881	c d e f g h
4	Wood Colony	1801	d e f g h i
4	Jenette	1795	d e f g h i
4	Kester (2-19e)	1763	e f g h i
4	Kester (2-19e) /Hansen	1669	e f g h i
4	Durango	1662	e f g h i
4	UCD8-27	1612	f g h i
4	Eddie	1537	f g h i j

Stanislaus

# reps	Variety or selection	Yield (kernel lbs/ac)	
4	UCD8-160	2282	a
4	Self-fruitful P13.019	2243	a b
4	UCD18-20	2233	a b
3	Kester (2-19e)	2127	a b c
4	Y117-91-03	2096	a b c d
4	Aldrich	1837	a b c d e
3	Kester (2-19e) /Hansen	1809	a b c d e
4	Bennett	1808	a b c d e
4	Y121-42-99	1785	a b c d e
4	Y116-161-99	1763	a b c d e
4	Y117-86-03	1749	a b c d e f
4	Winters	1739	a b c d e f
4	UCD8-201	1692	a b c d e f g
4	Booth	1678	b c d e f g h
3	Durango	1633	c d e f g h i
4	UCD1-232	1629	c d e f g h i
4	Eddie	1595	c d e f g h i
4	**Nonpareil**	**1587**	**c d e f g h i**

Madera

# reps	Variety or selection	Yield (kernel lbs/ac)	
3	Y-116-161-99	4782	a
4	Booth	4103	a b
4	Capitola	3971	a b c
4	UCD-18-20	3905	a b c d
4	Self-fr-P16-013	3842	a b c d
4	Y-117-86-03	3801	a b c d
4	Bennett	3747	a b c d e
83	**Nonpareil**	**3641**	**b c d e f**
4	Kester	3623	b c d e f
4	Y-117-91-03	3469	b c d e f g
4	Winters	3435	b c d e f g
4	Eddie	3429	b c d e f g
4	Jenette	3427	b c d e f g
1	Y-121-42-99	3290	b c d e f g h
4	Durango	3242	b c d e f g h i
4	Aldrich	3137	b c d e f g h i
4	UCD-1-16	3116	b c d e f g h i
4	Self-fr-P13-019	3023	b c d e f g h i

Data to be collected in 2019

- Bloom timing
- Hullsplit timing
- Midday canopy PAR interception
- Yield
- Nut quality
- Harvestability
- Disease incidence
- Tree loss
- Tree structure rating

Thanks to the Almond Board of
California for supporting this work

Questions?

For more information see Poster #69

Thank you!

Exploring Alternative Rootstocks in Butte County

Joseph Connell, UCCE Advisor Emeritus & Luke Milliron, Farm Advisor, Butte Co., German Campos, Deseret Farms of California-Durham, and Fowler Nursery

Objective

- To compare field performance of 'Nonpareil' on six rootstocks
- Orchard planted March 2010, 24'x16' on Farwell Loam Soil

✓ 'Lovell'
✓ 'Krymsk 86'
✓ 'Atlas'
✓ 'Empyrean 1'
✓ 'Nickels'
✓ 'Rootpac-R'

Hullsplit observations

- Nuts on ‘Rootpac-R’ rooted trees matured rapidly reaching 100% hullsplit first followed by ‘Lovell’.
- ‘Krymsk 86’ is intermediate and slow to mature.
- The most vigorous rootstocks, ‘Empyrean 1’, and ‘Nickels’ take longest to complete hullsplit.

Dates in 2018 when 'Nonpareil' reached 1% and 100% Hullsplit.

Rootstock	Hullsplit Percentage Date at 1%*	Hullsplit Percentage Date at 100%	# Days Total for Hullsplit
'Lovell'	7/25	8/5	12
'Krymsk 86'	7/27	8/12	17
'Atlas'	7/26	8/8	14
'Empyrean 1'	7/27	8/15	20
'Nickels'	7/27	8/16	21
'Rootpac-R'	7/24	8/3	11

* Dates based on a 3 replicate average with interpolation between observations.

Block was commercially shaken on 8/20/2018 with pickup on 8/31/2018.

Pre-Harvest ‘Nonpareil’ SWP measured August 24, 2018 in Durham, CA

Rootstock	Mean SWP in bars*
'Lovell'	- 22.4 a
'Krymsk 86'	- 17.1 b
'Atlas'	- 17.5 b
'Empyrean 1'	- 20.1 ab
'Nickels'	- 18.1 ab
'Rootpac-R'	- 22.1 a

Pre-harvest Stem Water Potential

- Trees on ‘Krymsk 86’ and ‘Atlas’, had the least stress.
- The largest, most vigorous trees, ‘Empyrean 1’ and ‘Nickels’ were intermediate in stress.
- ‘Rootpac-R’ rooted trees are smaller, weaker, and among the most stressed as are trees on ‘Lovell’.

Nutrient analysis of ‘Nonpareil’ leaf tissue collected in Durham, California July 8, 2018.

Rootstock	N (%)	K (%)	B (ppm)	Ca (%)	Mg (%)	Zn* (ppm)	Mn (ppm)	Cl (%)	Na (ppm)
'Lovell'	2.60 bc	2.03 bc	35.6 b	3.56 c	1.41 a	51.9	20.7 b	0.09 a	293.0
'Krymsk 86'	2.79 a	2.34 a	38.8 a	3.61 c	1.10 c	53.0	21.5 b	0.07 b	192.8
'Atlas'	2.65 b	2.46 a	41.1 a	3.62 c	1.21 b	58.7	21.4 b	0.04 d	316.4
'Empyrean 1'	2.47 d	1.92 c	40.1 a	4.08 b	1.49 a	65.4	27.3 a	0.03 e	250.6
'Nickels'	2.47 d	2.26 ab	39.7 a	4.68 a	1.20 b	63.9	20.9 b	0.03 e	260.0
'Rootpac-R'	2.58 c	2.47 a	35.6 b	3.73 c	1.09 c	54.9 ns	30.8 a	0.05 c	219.8 ns

Values followed by the same letters are not significantly different from one another at P< 0.05 as measured by Fisher's least significant difference (LSD).

* Zinc levels are high likely due to leaf surface contamination.

Rootstock effects on Leaf nutrient levels

- ‘Krymsk 86’ rooted trees had the highest level of leaf nitrogen
- ‘Nickels’ rooted trees are highest in calcium and among the lowest in N and Na
- Trees on ‘Lovell’ are intermediate in nitrogen and potassium but the highest in chloride
- Come study our poster for the full story!

Field Evaluation of Rootstocks for the Westside of the San Joaquin Valley

- Roger Duncan, UC Cooperative Extension, Stanislaus County
- Brent Holtz, UC Cooperative Extension, San Joaquin County

- In cooperation with Lee Del Don, Westley CA

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- Zacharias clay loam soil
- Soil and irrigation water alkaline, moderately high in Cl and/or boron, depending on year / water source
- Following decades of row crops (tomatoes & melons)

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List of Rootstocks. Planted Dec. 2012

Lovell	*P. persica*
Nemaguard	*P. persica*
Empyrean 1 (a.k.a. Barrier 1)	*P. persica x P. davidiana*
Avimag (a.k.a. Cadaman)	*P. persica x P. davidiana*
HBOK 50	*Harrow blood x Okinawa peach*
Hansen	*P. dulcis x P. persica*
Brights 5	*P. dulcis x P. persica*
BB 106	*P. dulcis x P. persica*
Paramount (a.k.a. GF 677)	*P. dulcis x P. persica*
Flordaguard x Alnem a.k.a. Y119-109-98.	*P. persica x* Israeli bitter almond
PAC9908-02	*(P. dulcis x P. persica) x P. persica*
Hansen x Monegro (HM2)	*(P. dulcis x P. persica) x (P. dulcis x P. persica)*
Viking	*P. Persica x (P. dulcis)x [(P. cerasifera x P. armeniaca)]*
Atlas	*P. Persica x (P. dulcis)x [(P. cerasifera x P. armeniaca)]*
Krymsk 86	*P. cerasifera x P. persica*
Rootpac R	*P. cerasifera x P. dulcis*

Rootstock Effect on Chloride Accumulation in Leaf Tissue

Cl critical level = 0.3%

	% Cl
Krymsk 86	0.89 a*
Lovell	0.72 b
Nemaguard	0.57 c
PAC9908-02	0.45 d
Atlas	0.42 de
Cadaman	0.38 def
Empyrean 1	0.33 ef
HBOK 50	0.31 ef
Viking	0.30 f
F x A	0.19 g
BB 106	0.19 g
Brights 5	0.18 g
GF 677	0.18 g
Rootpac R	0.17 g
HM2	0.16 g
Hansen	0.15 g

*P ≤ 0.05

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Rootstock Effect on Boron Accumulation in Hull Tissue

B critical level = 300 ppm

	B (ppm)
Lovell	180 a*
Cadaman	170 ab
Atlas	158 ab
HBOK 50	158 ab
Nemaguard	153 bc
Krymsk 86	152 bc
Empyrean 1	133 cd
Rootpac R	132 cd
Hansen	126 de
GF 677	120 de
HM2	116 de
Viking	109 e
PAC9908-02	108 e
Brights 5	106 e
F x A	104 e
BB 106	102 e

*$P \leq 0.05$

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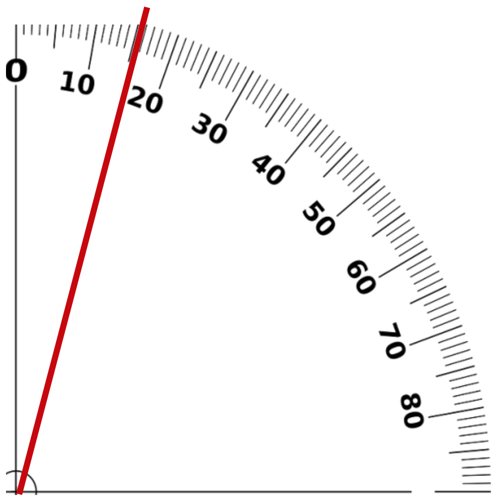
Anchorage



	Average Trunk Lean (degrees)	% of Trees > 15^0 Lean
Krymsk 86	6.4 a	3.3
Hansen	7.4 a	20.0
Flordaguard x Alnem	8.1 a	10.0
Rootpac R	9.8 a	23.3
Viking	10.2 a	6.7
BB106	10.8 ab	26.7
Nemaguard	11.0 ab	17.2
GF 677	11.0 ab	37.9
PAC 9908-02	11.1 ab	26.7
Lovell	11.9 abc	33.3
Brights 5	12.1 abc	20.0
Atlas	12.1 abc	24.1
HBOK 50	16.3 bcd	53.3
Empyrean 1	17.0 cd	60.0
Hansen x Monegro	21.1 d	70.0

*$P \leq 0.05$

Rootstock Effect on Tree Size, Yield & Yield Efficiency

	Trunk Circumference	2018 Yield	Cum Yield (4^{th} – 7^{th})	Yield Efficiency
Flordaguard x Alnem	66.0 a	3965 a	12,276	35.5
BB 106	62.1 b	3875 ab	12,203	39.9
Brights 5	54.6 de	3701 abc	11,564	48.8
Empyrean 1	63.2 b	3487 abcd	11,461	36.2
HM2	63.4 b	3572 abc	11,361	35.6
Hansen	62.8 b	3665 abc	11,355	36.3
PAC9908-02	63.3 b	3362 bcd	10,916	34.3
Rootpac R	62.0 b	3476 abcd	10,587	34.7
Atlas	54.5 de	3457 abcd	10,506	44.5
Viking	54.3 de	3085 cd	9,704	41.5
Paramount (GF 677)	55.4 cd	3194 cde	9,579	39.3
HBOK 50	57.5 c	3060 de	9,201	35.1
Krymsk 86	51.4 f	3004 de	8,866	42.2
Nemaguard	55.3 cd	2802 e	8,833	36.3

Seventh Year Evaluation of 13 Almond Rootstocks in a Sandy Location With Nematodes

David Doll, UCCE Merced

Arnold Farms, Atwater, CA

Cameron Zuber, UCCE Merced

University of California
Agriculture and Natural Resources

Merced County Rootstock Trial

Background:

- Planted in January 2011,
- Spacing 22’ x 18’
- 13 rootstocks tested on ‘Nonpareil.’
- 7 rootstocks tested on varieties ‘Monterrey,’ and ‘Fritz.’

Challenges:

- Sandy soil near Atwater, CA,
- low cation exchange capacity,
- Irrigated with groundwater with high nitrates and moderate sodium

‘Nonpareil,’ ‘Monterey,’ and ‘Fritz’	‘Nonpareil’ only
Atlas	BB106
BH5	Cadaman*
Empyrean-1	Cornerstone*
Hansen 536	Floridaguard x Alnem
Nemaguard	Krymsk-86
Viking	

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Merced County Rootstock Trial

Rootknot Nematode (*Meloidogyne* sp.)

- Causes severe stunting and loss of productivity;
- Krymsk-86 is susceptible and should not be planted in Rootknot infested soils;
- FxA, could be due to weed populations;

	Root knot nematodes per 500 grams of soil						
Rootstock	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Atlas	0	0	0	0	0	0	0
BB106	0	0	0	0	0	0	0
BH5	0	0	0	0	0	0	0
Cadaman	0	0	0	0	0	0	0
Cornerstone	0	0	0	0	0	0	0
Empyrean-1	0	0	0	0	0	0	0
Floridaguard x Alnem	0	0	0	0	0	0	15
Hansen 536	0	0	0	0	0	0	0
Krymsk-86	0	0	1	131	88	13	312
Nemaguard	0	0	0	0	0	0	0
RootpacR	0	0	0	0	0	0	0
TemproPac	0	0	0	0	0	0	0
Viking	0	0	0	0	0	0	0

Merced County Rootstock Trial

Root Lesion Nematode (*Pratylenchus vulnus)*

- Causes stunting of almond trees, especially when in the presence of Ring
- Most rootstocks are susceptible in the trial
- Numbers are low due to extraction method.

	Lesion nematodes per 500 grams of soil						
Rootstock	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Atlas	0	0	0	0	0	0	16
BB106	0	0	0	0	0	12	0
BH5	0	0	0	38	6	46	0
Cadaman	0	0	0	0	0	0	0
Cornerstone	0	311	31	0	2	13	51
Empyrean-1	0	0	0	0	0	0	29
Floridaguard x Alnem	0	0	0	0	0	0	0
Hansen 536	0	0	0	0	131	34	0
Krymsk-86	0	0	33	547	160	0	47
Nemaguard	0	0	0	0	0	0	0
RootpacR	0	0	0	9	33	2	25
TemproPac	0	0	0	34	26	0	0
Viking	0	0	0	0	41	55	26

Merced County Rootstock Trial

Ring Nematode (*Mesocriconema xenoplax)*

- Predisposing factor of bacterial canker
- Peach almond hybrids are highly susceptible;
- All rootstocks in the trial are susceptible

	Ring nematodes per 500 grams of soil[1]						
Rootstock	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Atlas	0	0	0	0	75	418	290
BB106	0	0	0	46	1	122	978
BH5	0	0	0	123	282	934	824
Cadaman	0	0	0	1	624	510	702
Cornerstone	0	0	0	0	150	610	861
Empyrean-1	0	0	0	0	229	91	630
Floridaguard x Alnem	0	0	0	12	656	774	2506
Hansen 536	0	0	1	1832	1066	470	1367
Krymsk-86	0	0	8	247	319	730	926
Nemaguard	0	0	0	0	8	230	265
RootpacR	0	0	0	0	530	1586	909
TemproPac	0	0	0	0	86	188	811
Viking	0	0	0	0	6	11	923

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Merced County Rootstock Trial

- Percent of nuts with split hulls from mid-July though beginning of August


Initial hull split


Initial drying stage


Complete dry stage

- Almonds considered split include above stages

Rootstock	Percent of nuts with split hulls (%)			
	7/13/2018	7/17/2018	7/21/2018	8/3/2018
Atlas	0	5	23	93
BB106	0	0	0	68
BH5	0	2	22	70
Cadaman	0	2	5	70
Cornerstone	0	7	30	87
Empyrean-1	0	0	3	78
Floridaguard x Alnem	0	17	10	62
Hansen 536	0	0	3	60
Krymsk-86	0	23	63	100
Nemaguard	2	12	17	75
RootpacR	12	35	72	100
TemproPac	0	5	12	55
Viking	0	3	20	80

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Merced County Rootstock Trial

<u>Rootstock effects on anchorage</u>.

- Rootstocks crossed with cherry plum (*P. cerasifera*) appear to be more upright (RootPacR, Krymsk-86 and Viking).

Rootstock	Average Trunk Angle (°)
RootPacR	82.7
Krymsk-86	82.1
Viking	81.0
Empyrean-1	79.7
Hansen 536	78.9
BH5	78.8
Floridaguard x Alnem	78.7
Nemaguard	78.1
Atlas	76.7
Cornerstone	76.7
TemproPac	75.9
BB106	75.7
Cadaman	75.7

Rootstock Trial at CSU Fresno

Gurreet Brar
California State University, Fresno

University of California
Agriculture and Natural Resources

CSU Fresno Rootstock Trial

- Planted March 2017, 21’ X 14’
- Plot has 3 different soil types
- Experiment blocked by 3 EC zones
- Hanford Sandy Loam
- Tajunga Loamy Sand
- Hanford Fine Sandy Loam
  - 7 rootstocks/2 scion cultivars
    - ✓ Lovell

- ✓ Empyrean 1
- ✓ Rootpac-R
- ✓ Rootpac-20
- ✓ Guardian

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CSU Fresno Rootstock Trial

- Compare performance of conventional peach rootstocks with peach almond hybrid and dwarfing rootstocks
- Other than growth and yield performance evaluation, water use efficiency and photosynthetic parameters for these rootstocks are also being studied

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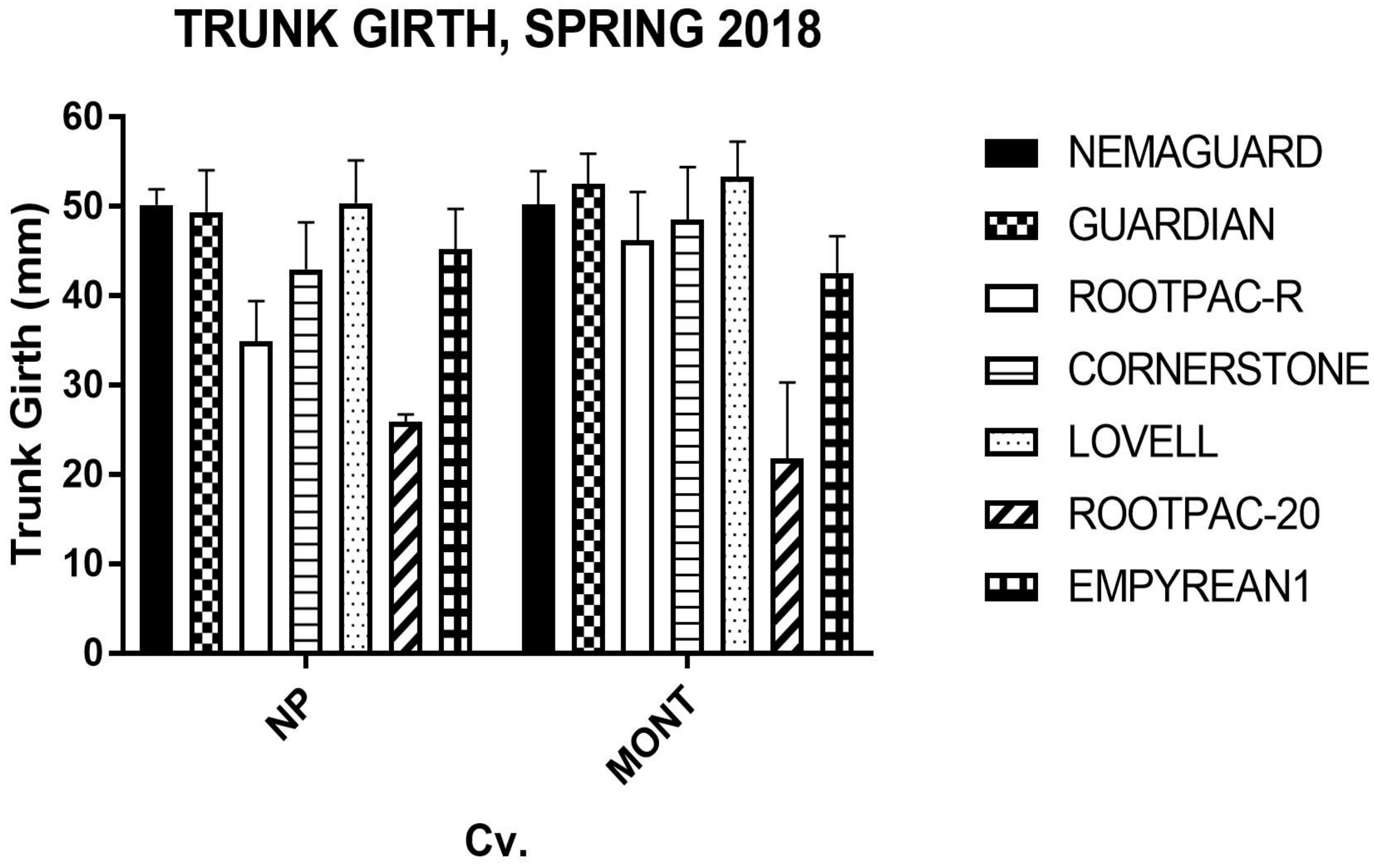
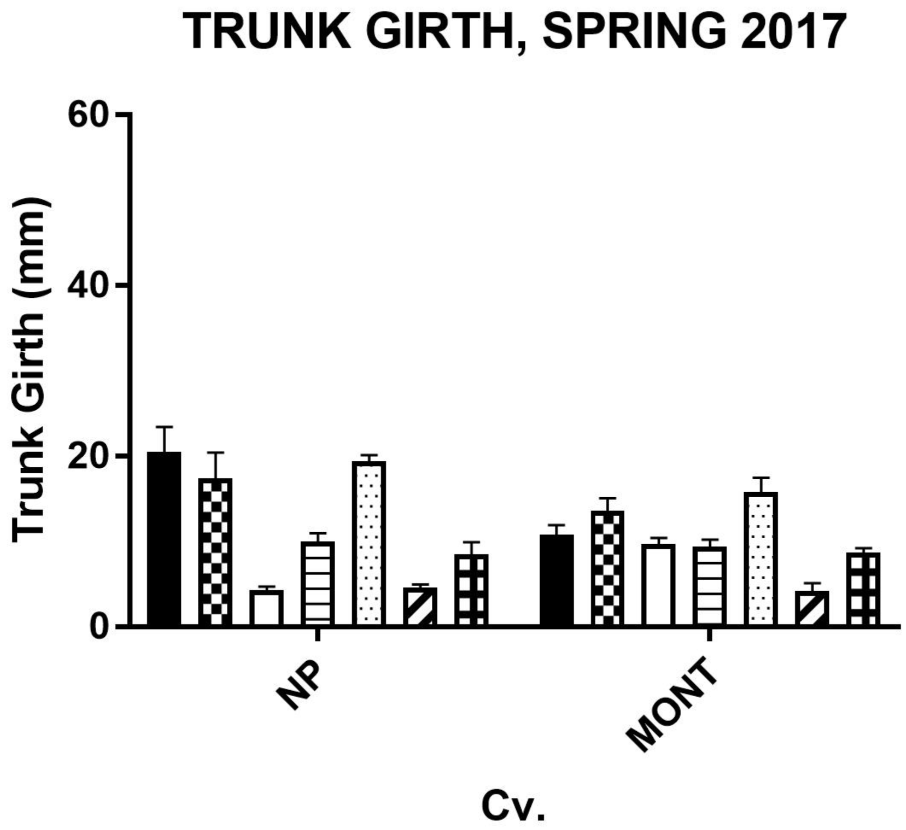
CSU Fresno Rootstock Trial





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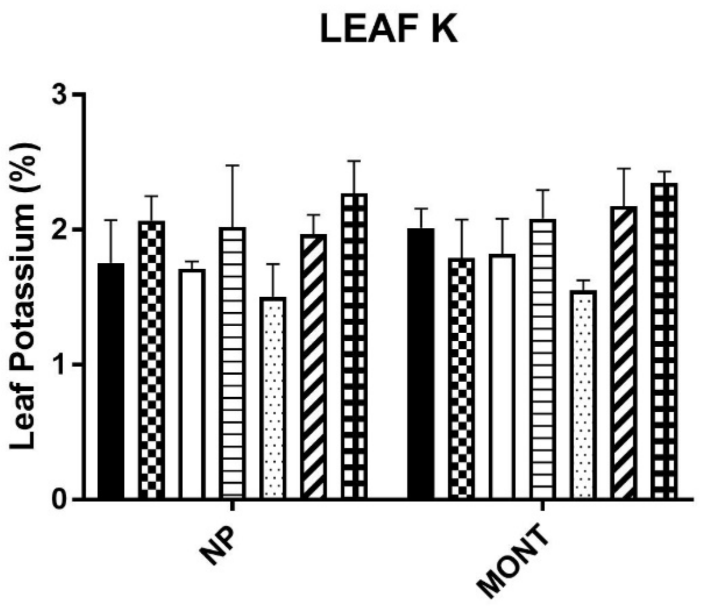
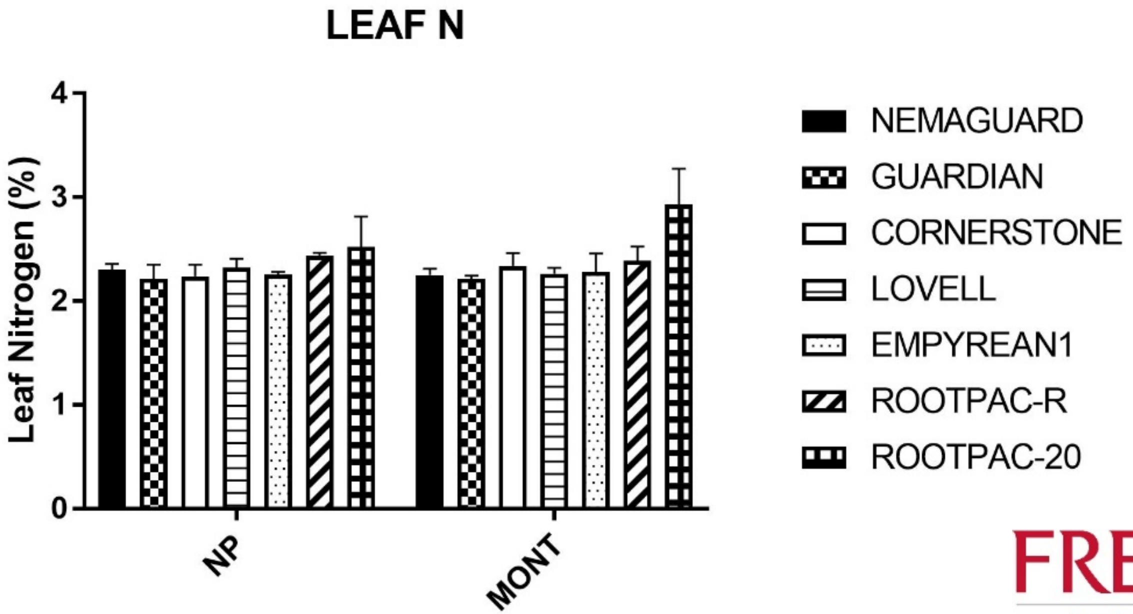
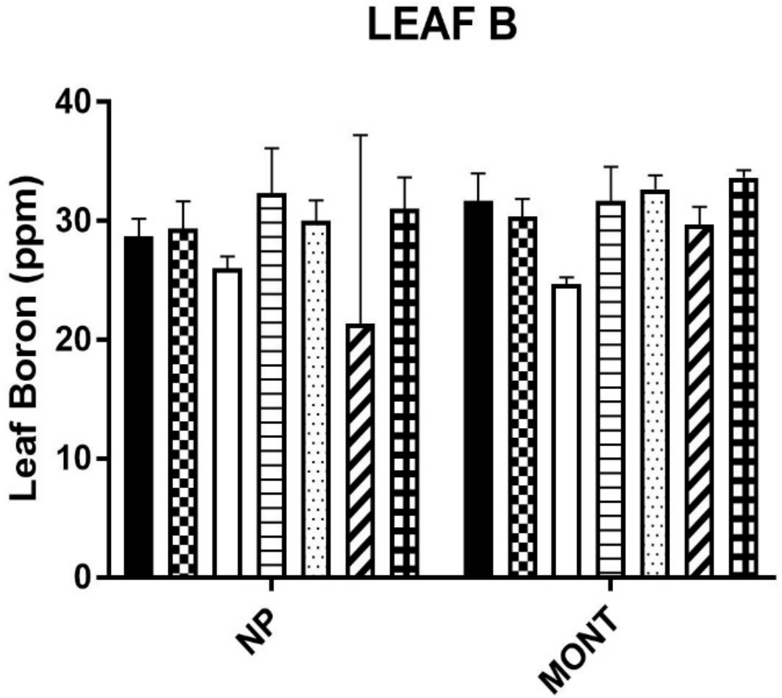
CSU Fresno Rootstock Trial

- Lovell accumulated most B in leaves of NP while Rootpac-20 had highest leaf B levels in Monterey
- Rootpac-R and Rootpac-20 had highest leaf N and K levels in both scion cultivars







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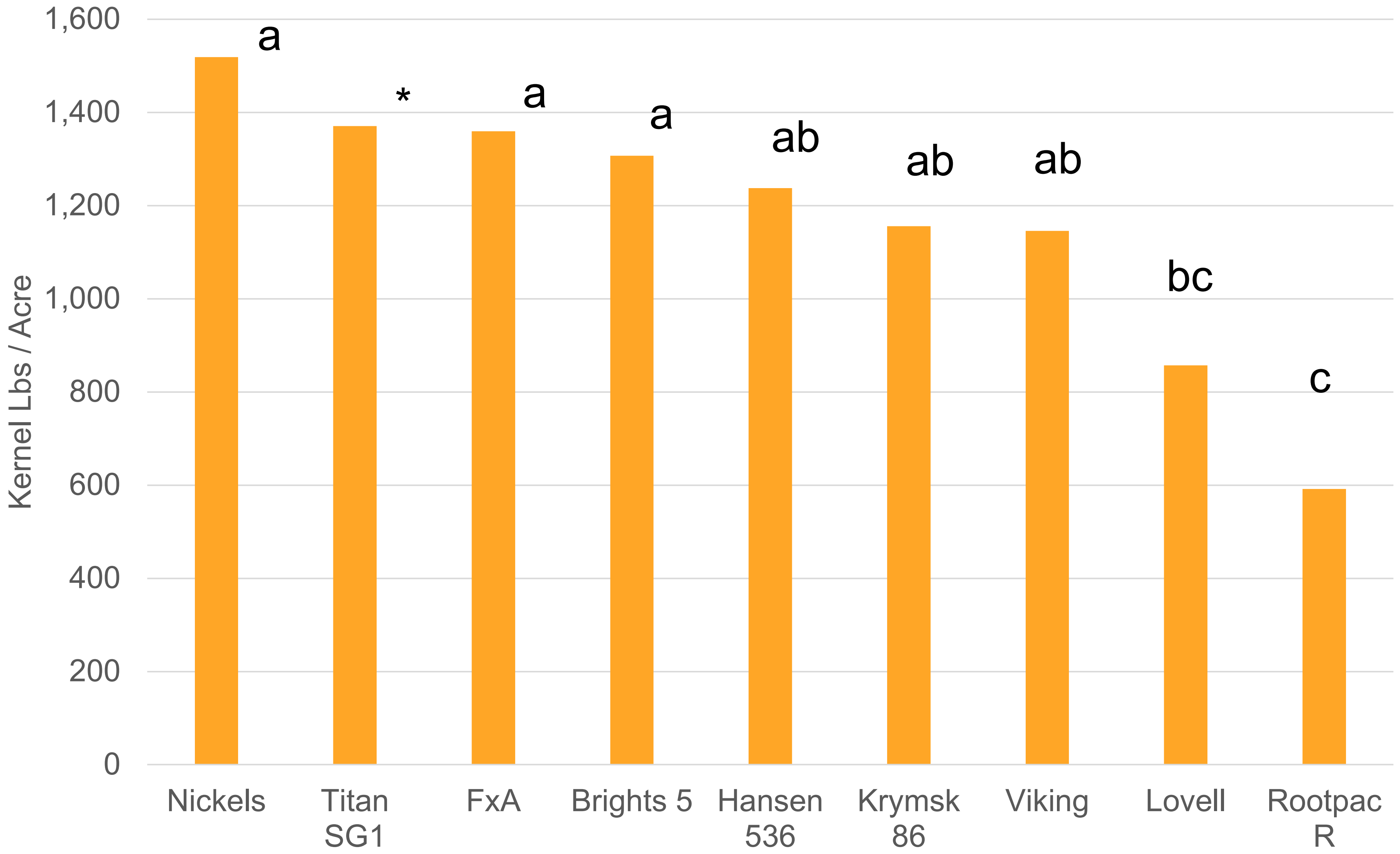
Effects of Rootstocks on Marginal, High Boron Soil

Katherine Jarvis-Shean, *UCCE Sac-Solano-Yolo;*

Lampinen Lab*, UC Davis;*

Carolyn DeBuse, *USDA*

Boron Rootstock Trial – Rootpac R & Lovell tend for lower yields



Marvin silty clay loam
Water: <1 - 3.1 mg/l B
Soil: 1.3-2.2 mg/l B

cv. Nonpareil
Nursery grafted
Planted: Feb, 2011
(Titan Apr 2011 not rep'd)
Spacing: 22' x 18'

Different letters indicate statistical diff. values when compared in same year.

Boron Rootstock Trial – Low Yields likely due in part to frost damage across the board

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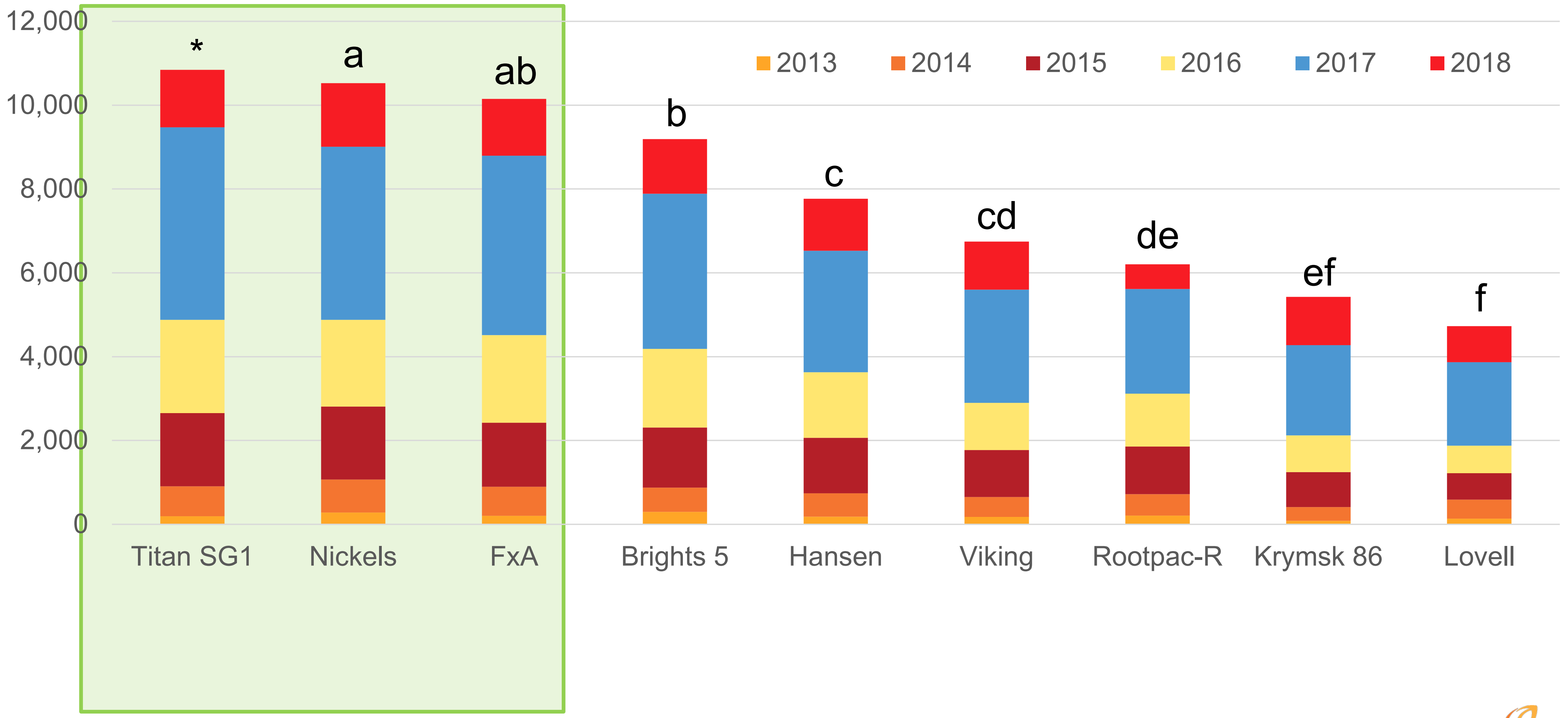
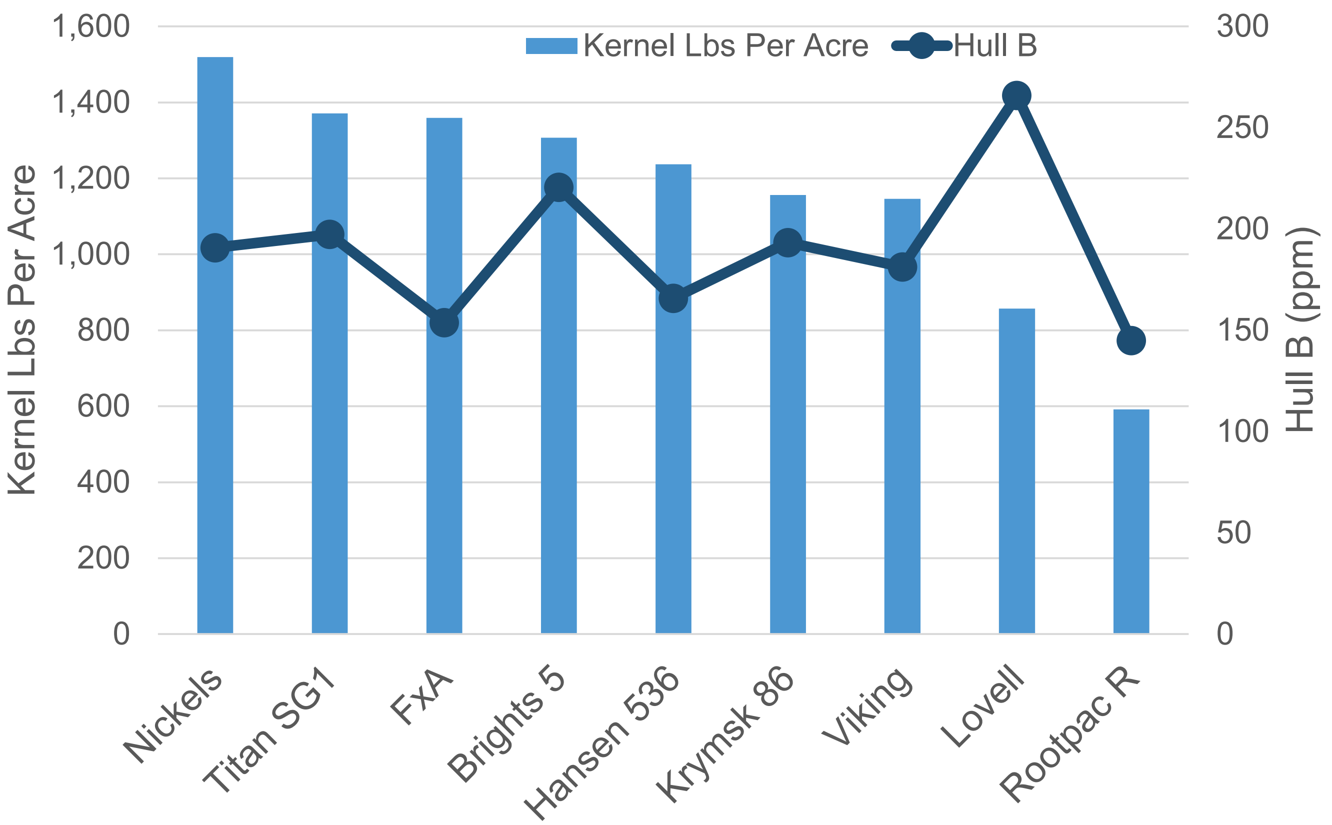
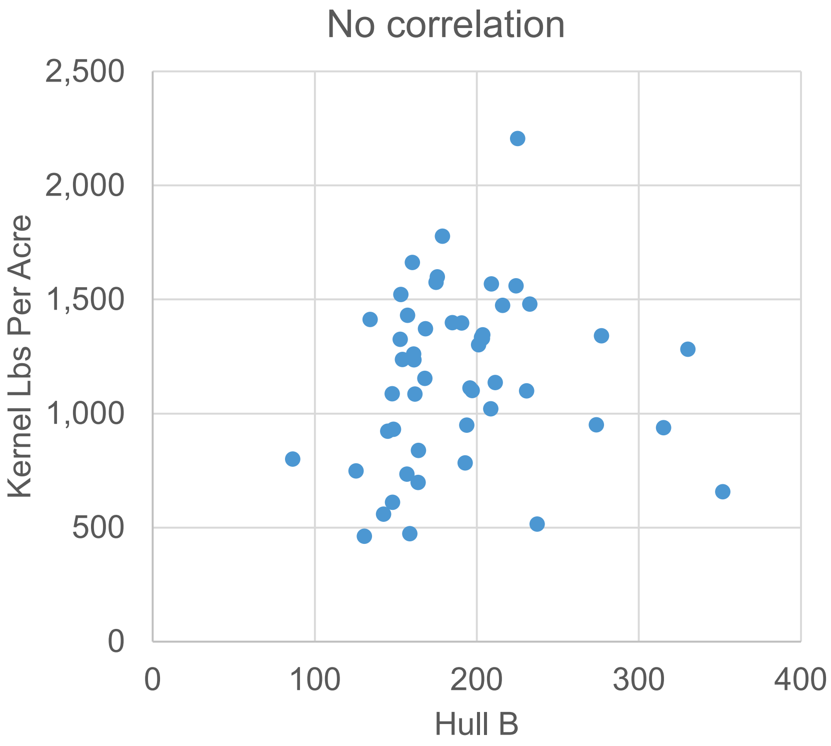
Boron Rootstock Trial – Titan, Nickels & FxA cumulatively highest yield



Boron Rootstock Trial – In 2018, No correlation between Hull B & Yield.





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Thank you for your Attention

See you at the posters 3:00 – 5:00

Roger Duncan
209-525-6800

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University of California
Agriculture and Natural Resources

Linking Performance of Almond Rootstocks to Underlying Physiological and Genetic Determinants of Salinity Tolerance

Devinder Sandhu, Research Geneticist
Amita Kaundal, Assistant Project Scientist
Jorge Ferreira, Plant Physiologist
Donald L. Suarez, Soil Scientist

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USDA US Salinity Laboratory
Riverside, CA

Experimental set up:

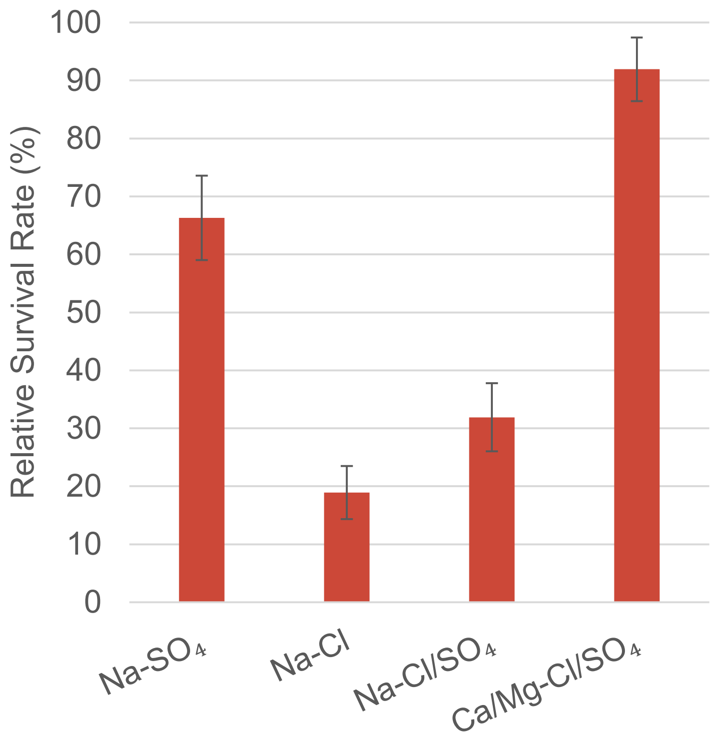
- Experiment was set up in a randomized complete block design
- Non-grafted plants of 16 different rootstocks
- 3 replications x 3 plants per replication (one plant per pot)
- 5 treatments of water (irrigation water composition) with total 720 trees.
- 15 blocks, each containing combinations of genotypes and replications were created.

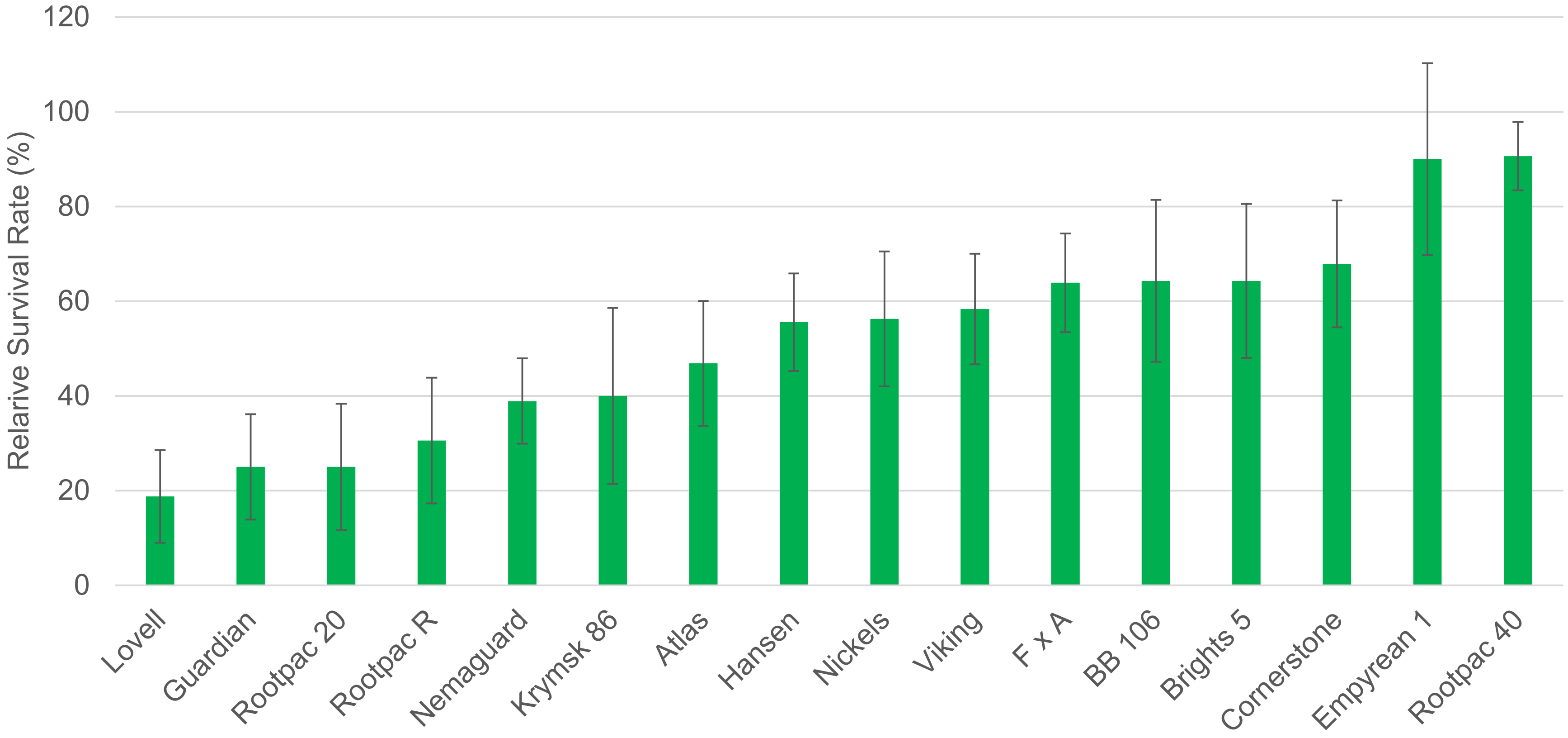
Salt treatments:

- ***Treatment 1 (Control):*** Non saline control {Na^+ 1.65 meq L^{-1}, K^+ 6.5 meq L^{-1}, PO_4^{3-} 1.5 meq L^{-1}, Mg^{2+} 1.3 meq L^{-1}, SO_4^{2-} 1.5 meq L^{-1}, Cl^- 1.5 meq L^{-1}, NO_3^- 5 meq L^{-1} and micronutrients}
- ***Treatment 2 (Na-SO₄):*** mixed cations (Ca^{2+} = 1.25Mg^{2+} = .25 Na^+) with predominantly sulfate (Cl^- = 0.2 $SO^{2-}{}_4$) {Na^+ 18 meq L^{-1}, Ca^{2+} 4.5 meq L^{-1}, K^+ 6.5 meq L^{-1}, PO_4^{3-} 1.5 meq L^{-1}, Mg^{2+} 3.6 meq L^{-1}, SO_4^{2-} 22 meq L^{-1}, Cl^- 4.4 meq L^{-1}, NO_3^- 5 meq L^{-1} and micronutrients}
- ***Treatment 3 (Na-Cl):*** mixed cations (Ca^{2+} = 1.25Mg^{2+} = .25 Na^+) with predominantly chloride ($SO^{2-}{}_4$ = 0.2 Cl^-) {Na^+ 15.5 meq L^{-1}, Ca^{2+} 3.8 meq L^{-1}, K^+ 6.5 meq L^{-1}, PO_4^{3-} 1.5 meq L^{-1}, Mg^{2+} 3.1 meq L^{-1}, SO_4^{2-} 3.8 meq L^{-1}, Cl^- 19 meq L^{-1}, NO_3^- 5 meq L^{-1} and micronutrients}
- ***Treatment 4 (Na-Cl-SO₄):*** mixed anions SO_4-Cl ($SO^{2-}{}_4$=Cl^-), predominantly Sodium (Ca^{2+} = 1.25Mg^{2+} = .25 Na^+) {Na^+ 17 meq L^{-1}, Ca^{2+} 4.25 meq L^{-1}, K^+ 6.5 meq L^{-1}, PO_4^{3-} 1.5 meq L^{-1}, Mg^{2+} 3.4 meq L^{-1}, SO_4^{2-} 12.32 meq L^{-1}, Cl^- 12.32 meq L^{-1}, NO_3^- 5 meq L^{-1} and micronutrients}
- ***Treatment 5 (Ca-Mg-Cl-SO₄):*** mixed anions $SO^{2-}{}_4$-Cl^- ($SO^{2-}{}_4$=Cl^-), predominantly Ca^{2+} and Mg^{2+}. (Ca^{2+} = 1.25 Mg^{2+} = 5 Na^+) {Na^+ 2.75 meq L^{-1}, Ca^{2+} 13.5 meq L^{-1}, K^+ 6.5 meq L^{-1}, PO_4^{3-} 1.5 meq L^{-1}, Mg^{2+} 10.8 meq L^{-1}, SO_4^{2-} 13.5 meq L^{-1}, Cl^- 13.5 meq L^{-1}, NO_3^- 5 meq L^{-1} and micronutrients}

Treatments 2-5 all had EC = 3.0 dS/m.

Survival rate under salinity treatment

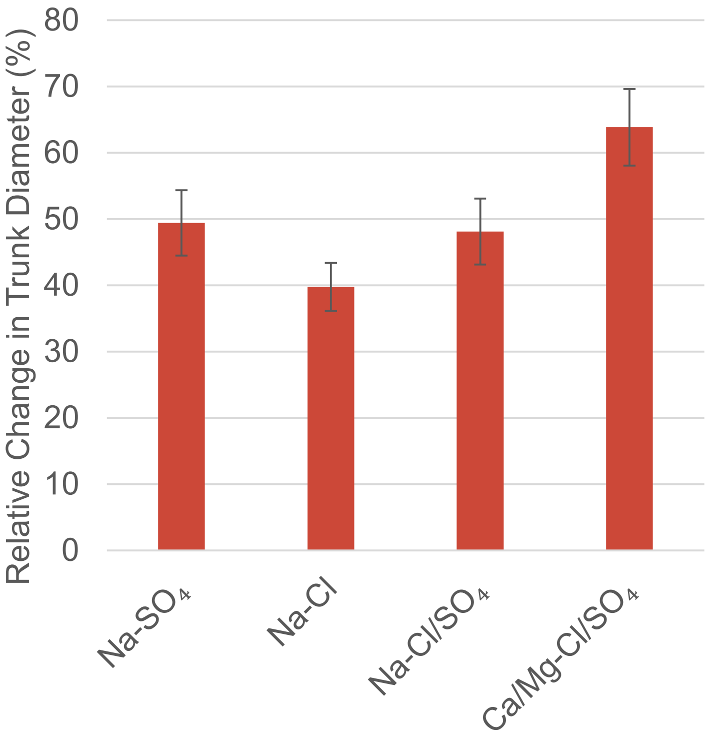


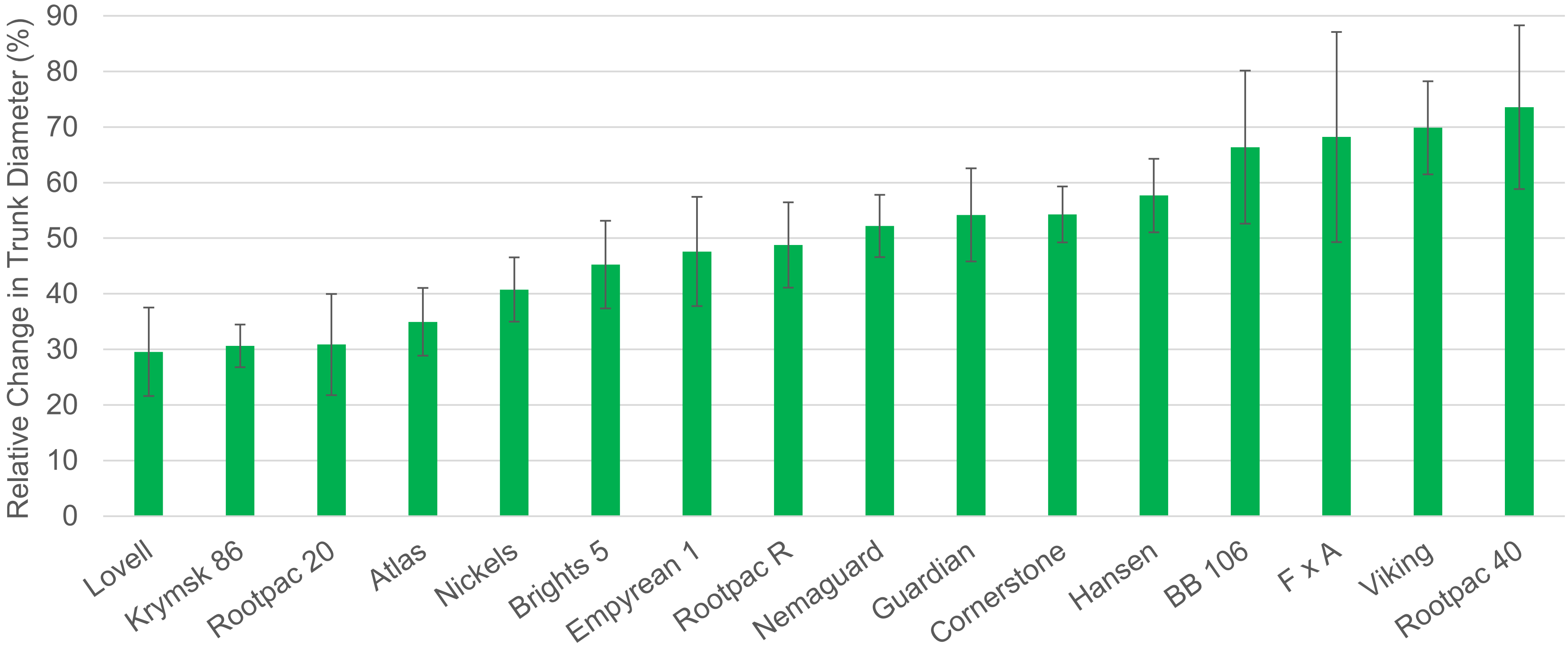


Screening 16 almond rootstocks in Na-Cl based treatment

Rootpac 40

Percent change in trunk diameter in different salt treatments





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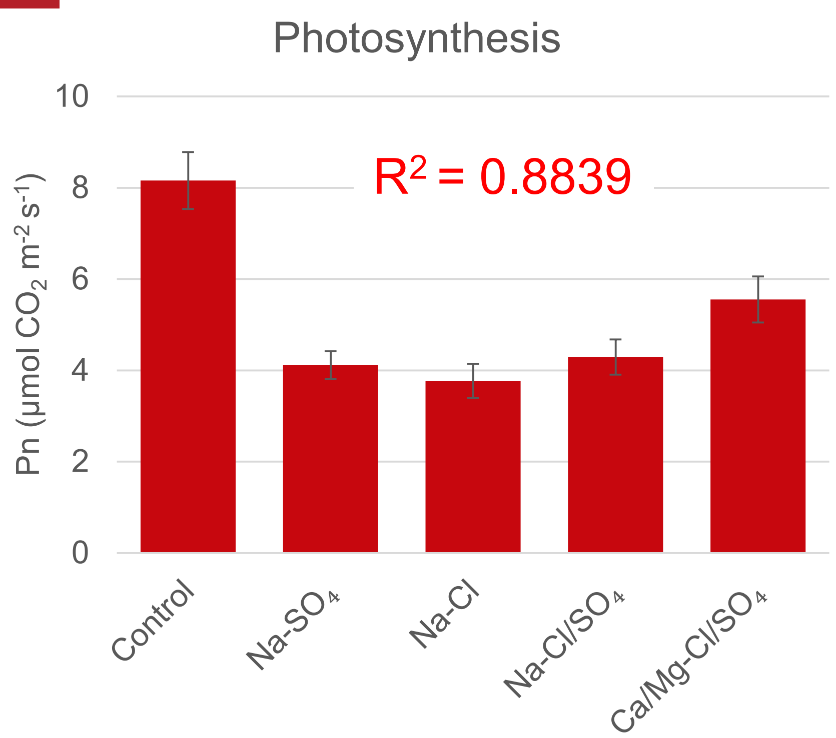
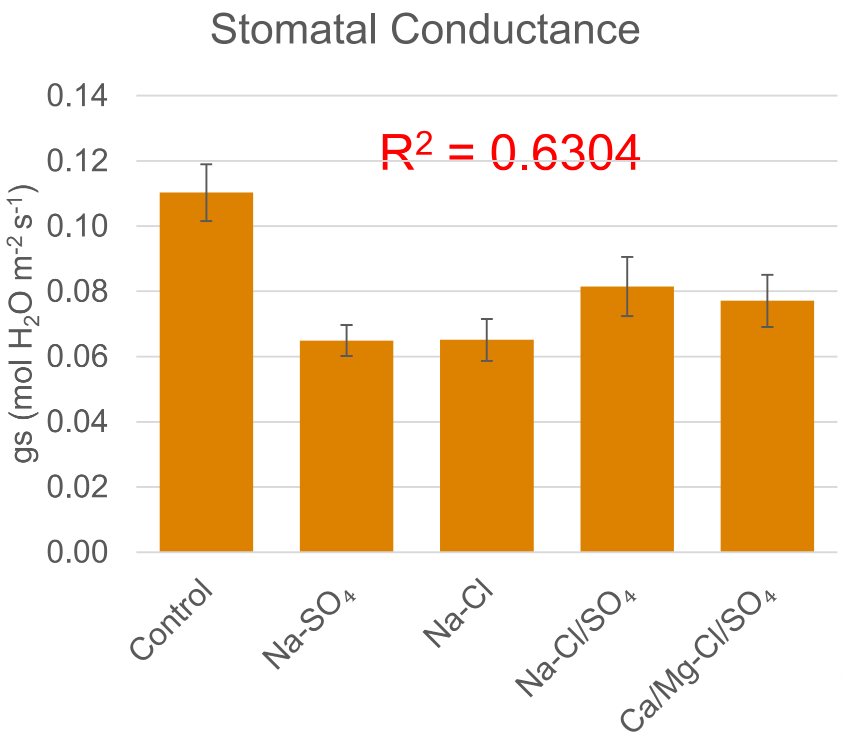
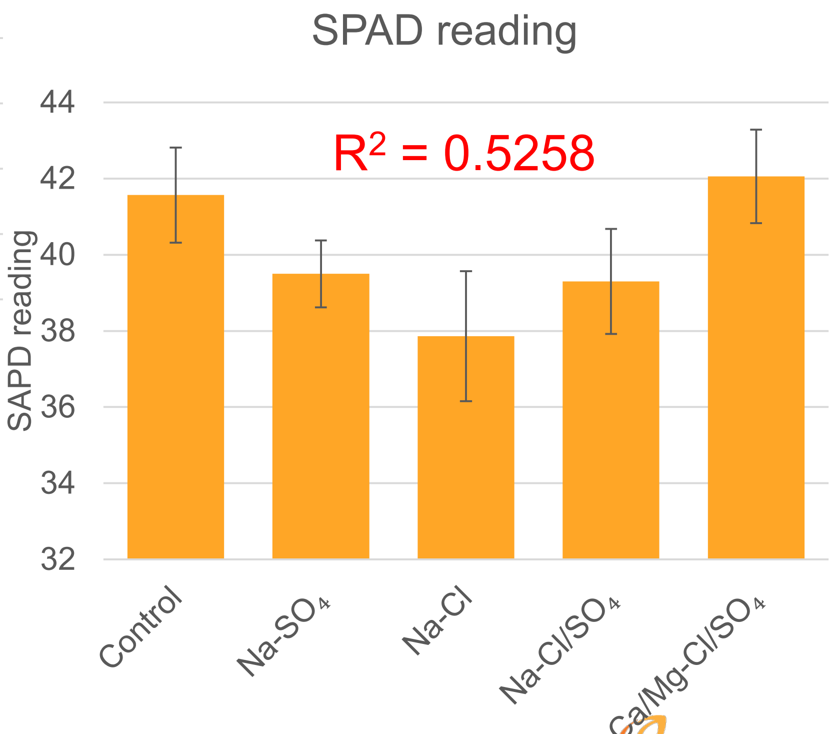
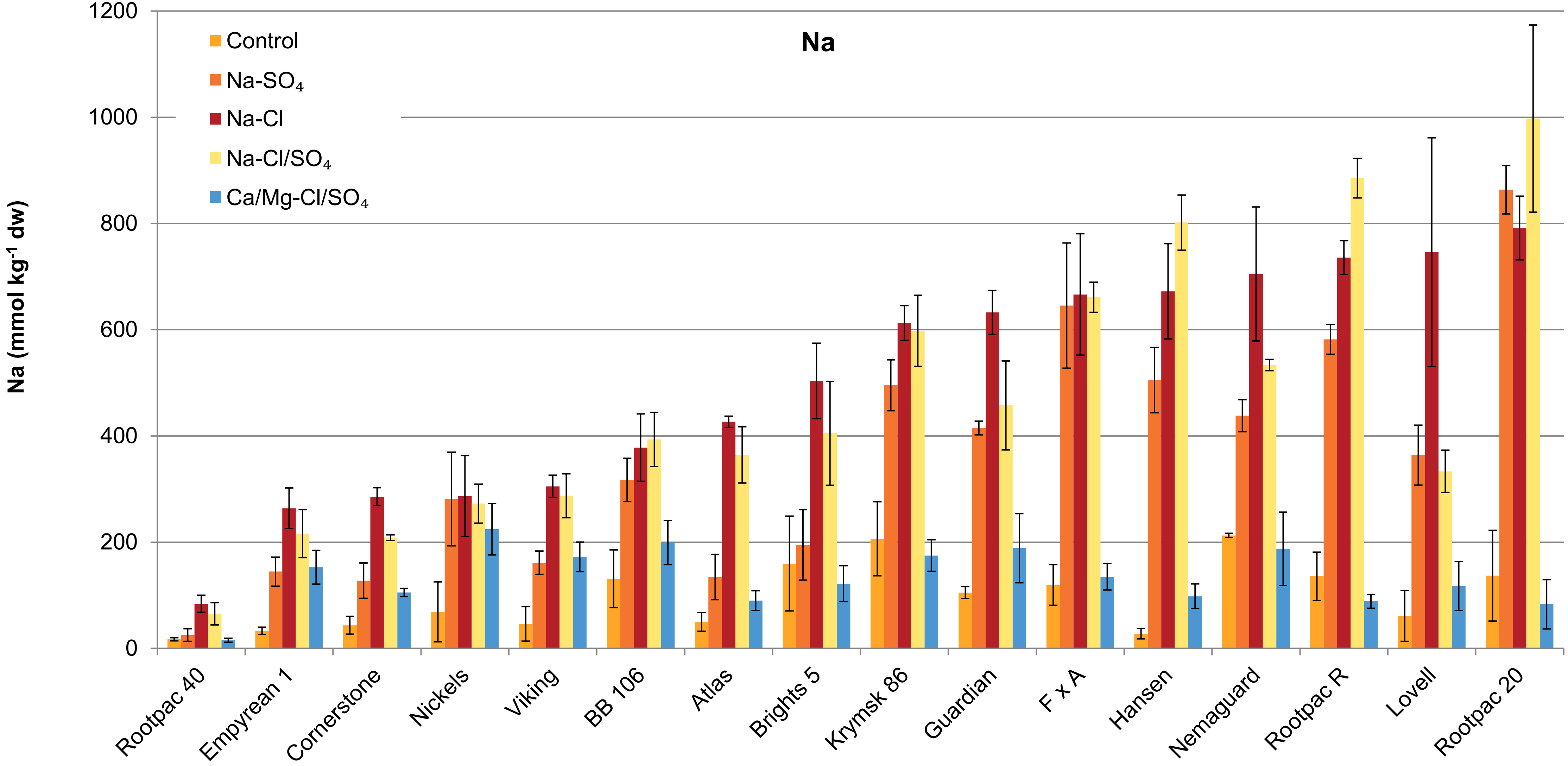
Physiological measurements in almond rootstocks under different salt treatments



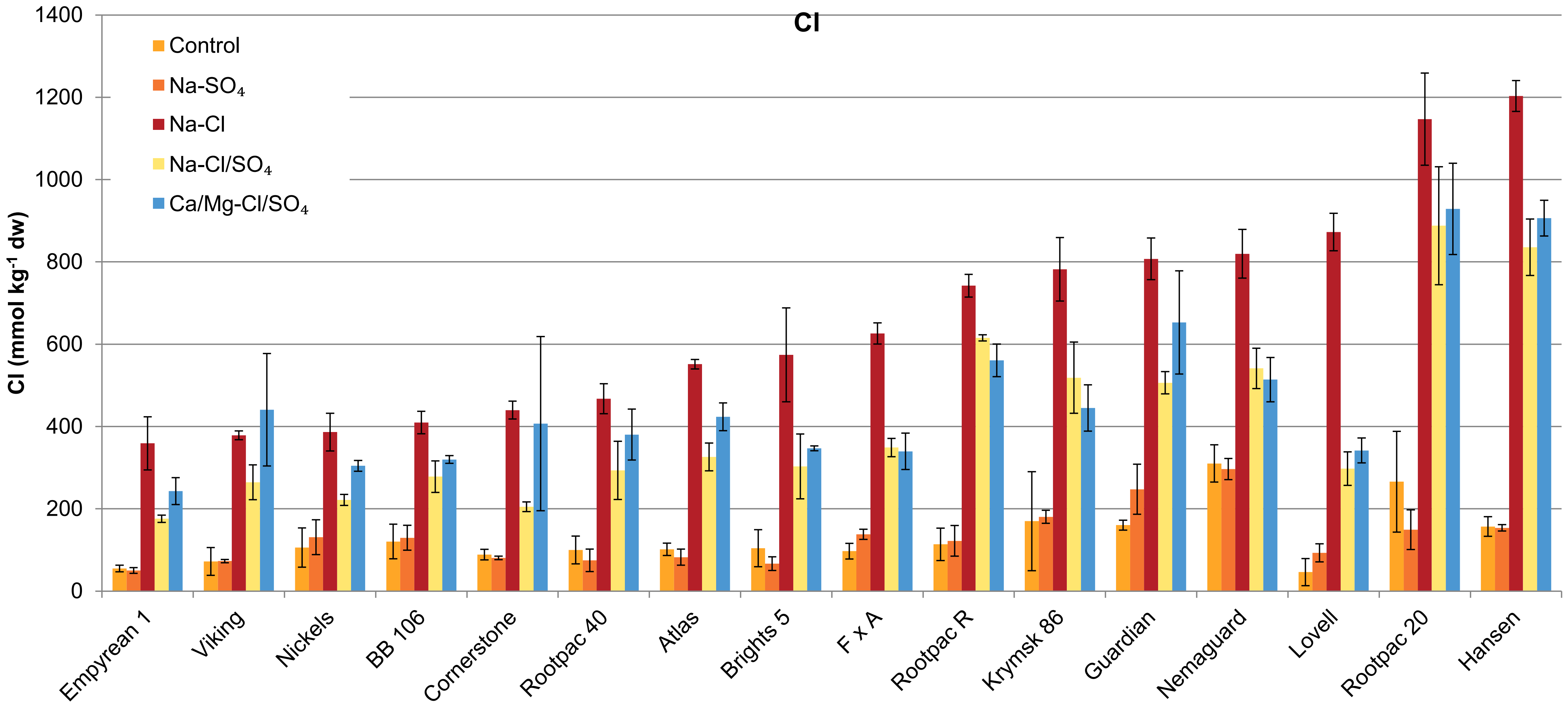




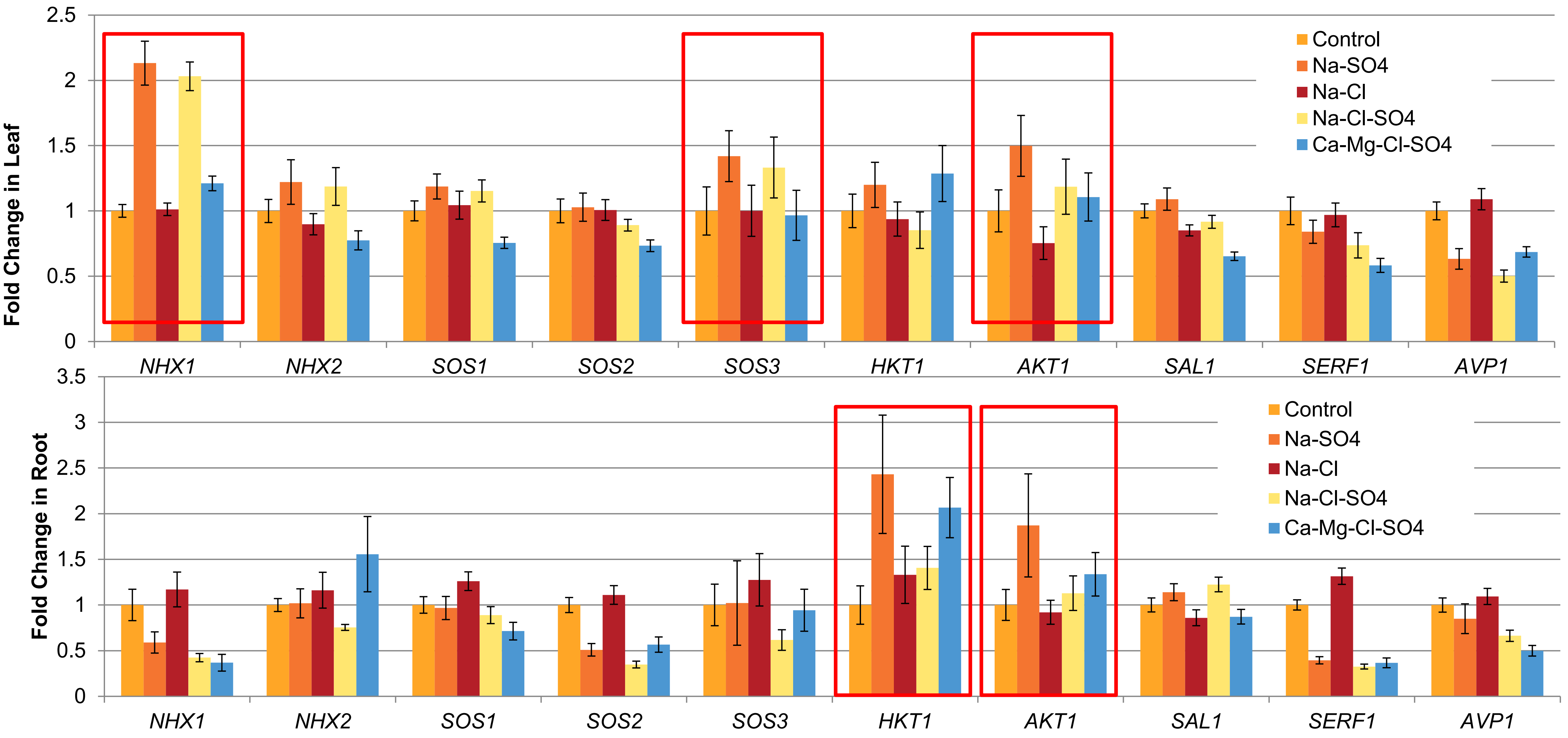
Tissue Na concentration in 16 rootstocks under different salt treatments



Tissue Cl concentration in 16 rootstocks under different salt treatments



Expression analysis of salt related genes in almond leaves and roots



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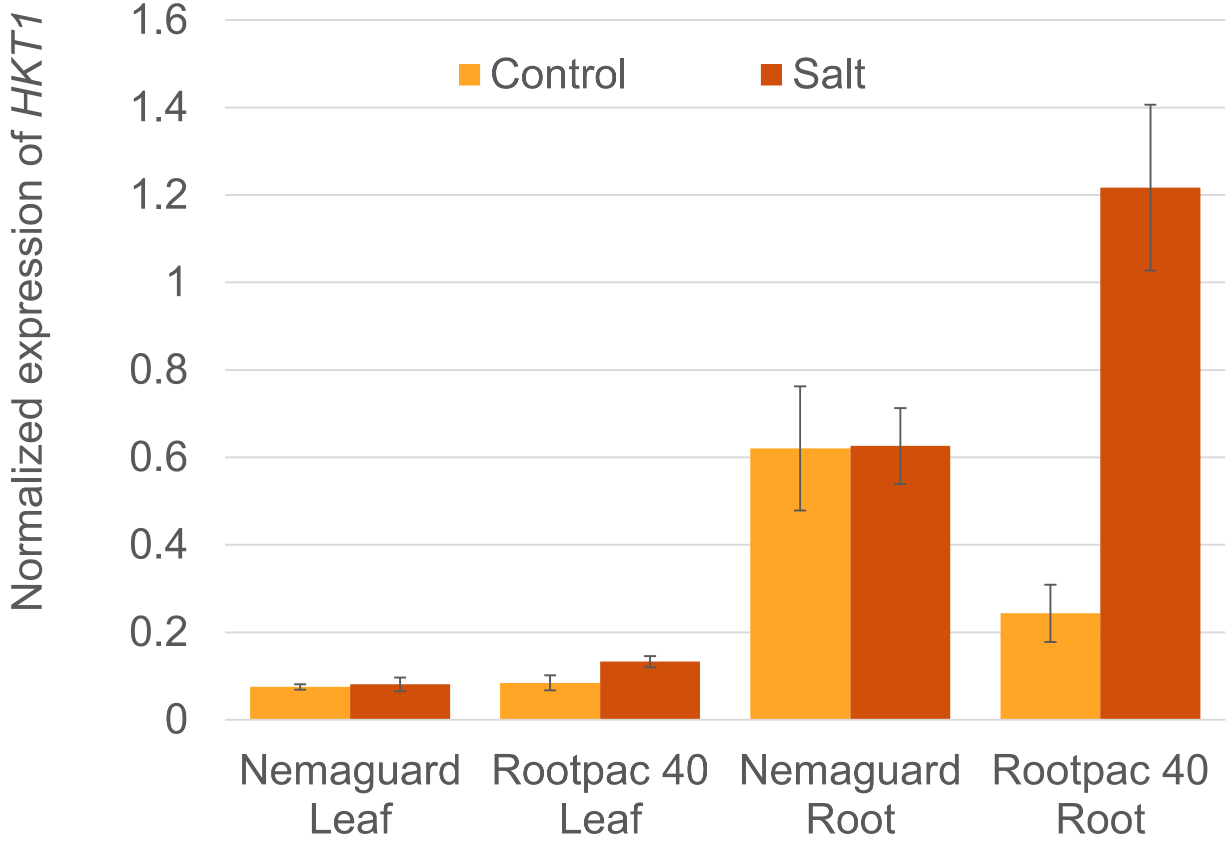
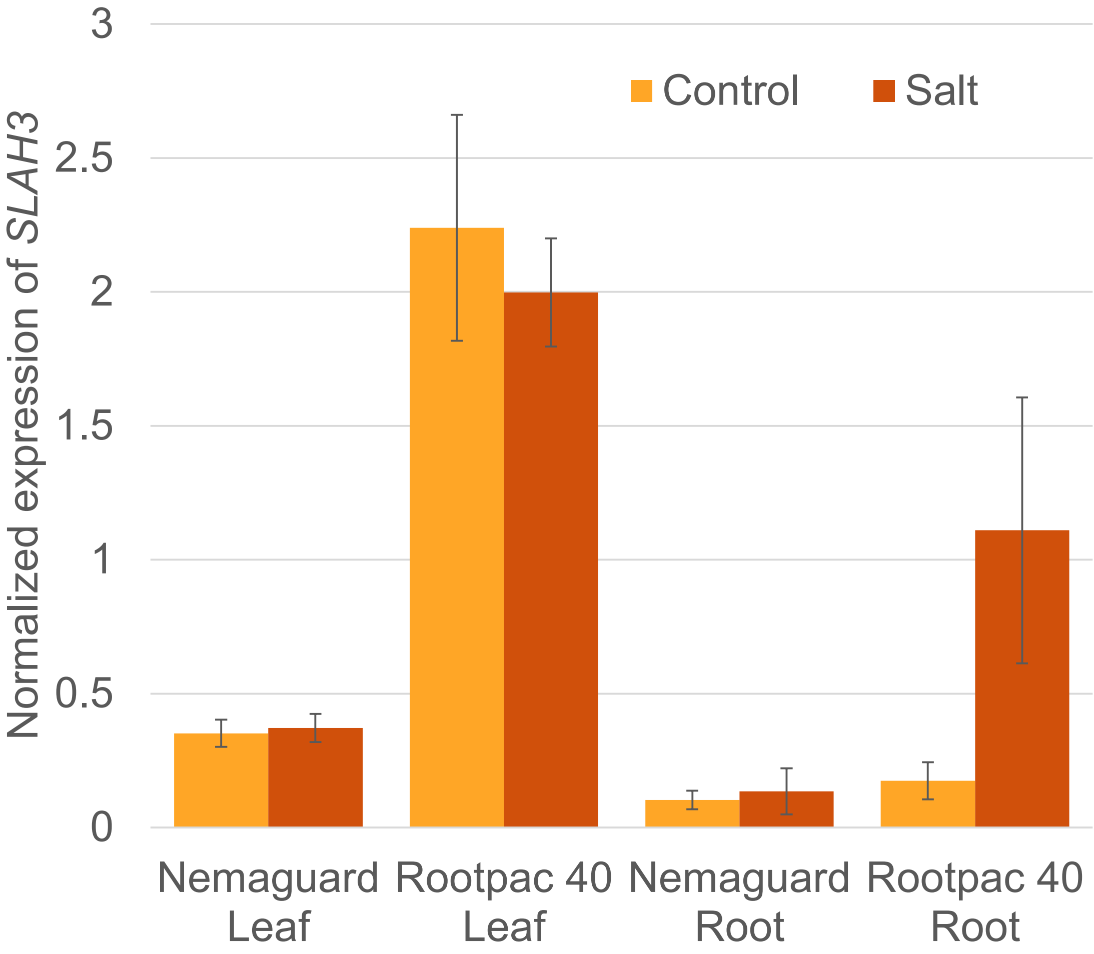
Expression analysis of *HKT1* and *SLAH3* in Nemaguard (salt-sensitive) and Rootpac 40 (salt-tolerant) rootstocks





Conclusions

- There was maximum reduction in trunk diameter when irrigation water was high in Na and Cl suggesting that mostly Na and to a lesser extent Cl concentrations in irrigation water are the most critical ion toxicities for almond rootstocks

- Photosynthesis showed the highest correlation with change in trunk diameter followed by correlations with stomatal conductance and chlorophyll content.

- NHX1, SOS3 and AKT1 were highly upregulated in salinity treatments in leaves and HKT1 and AKT1 showed the highest upregulation (expression) in salinity treatments in roots

Experiments in progress

- Fifteen almond rootstocks are being evaluated at three salinity levels (EC =1.4, 2.5 and 3 dS m^{-1}).

- RNA-seq analyses of a salt-sensitive (Nemaguard) and a salt-tolerant (Rootpac 40) rootstock under control and salinity treatment to study global changes in gene expression.

- Functional complementation of the Almond HKT1 (*PpHKT1*) and (*PpSOS2*) genes in the Arabidopsis *hkt1* mutant

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Acknowledgements

- **Almond Board of California**
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- Robert Curtis, Sebastian Saa and Debye Hunter

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Nurseries: Agromillora, Burchell, Dave Wilson, Fowler, Sierra Gold

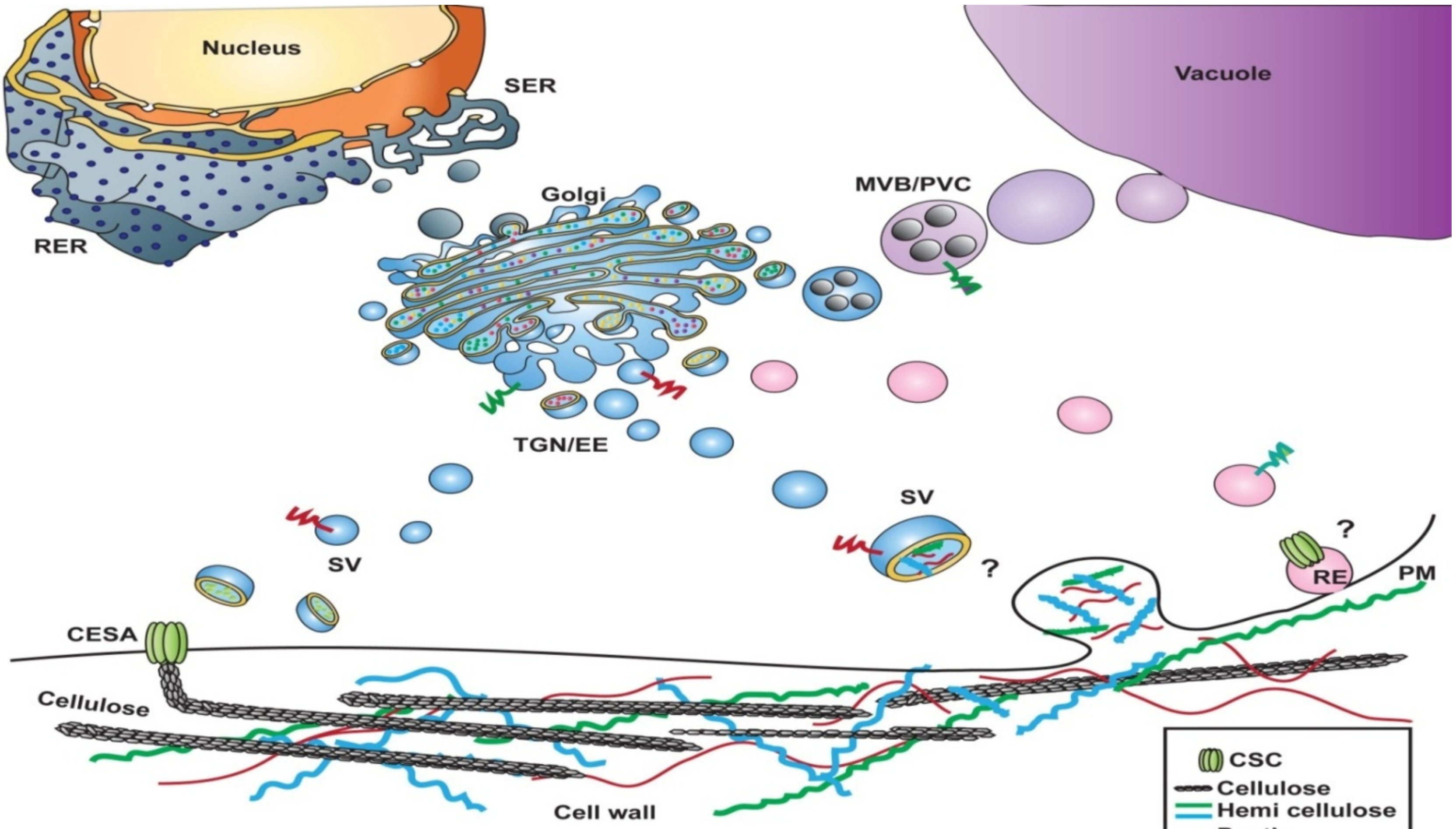
Subcellular Characterization of Salinity Tolerance in Almonds

Georgia Drakakaki

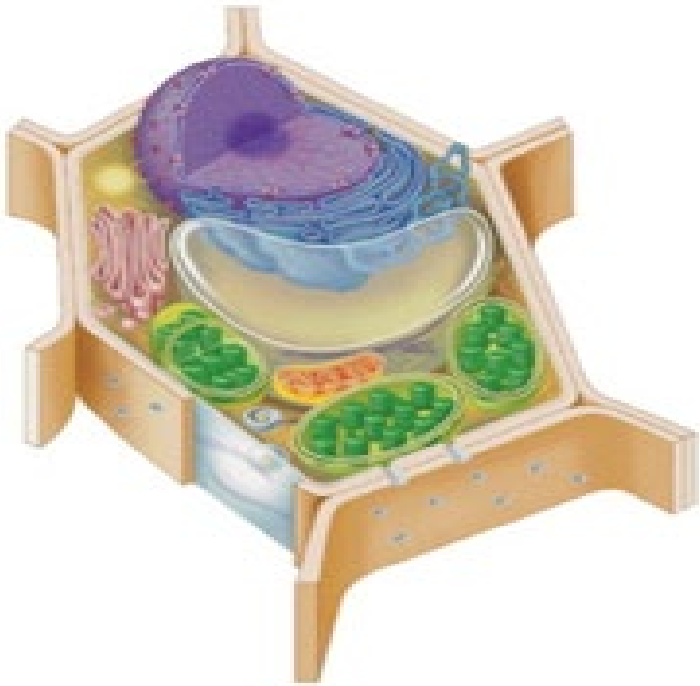
Department of Plant Sciences, University of California, Davis

gdrakakaki@ucdavis.edu

Questions in my Research Group:



Worden *et al*. 2012 JIPB
Rosquete et al., 2018



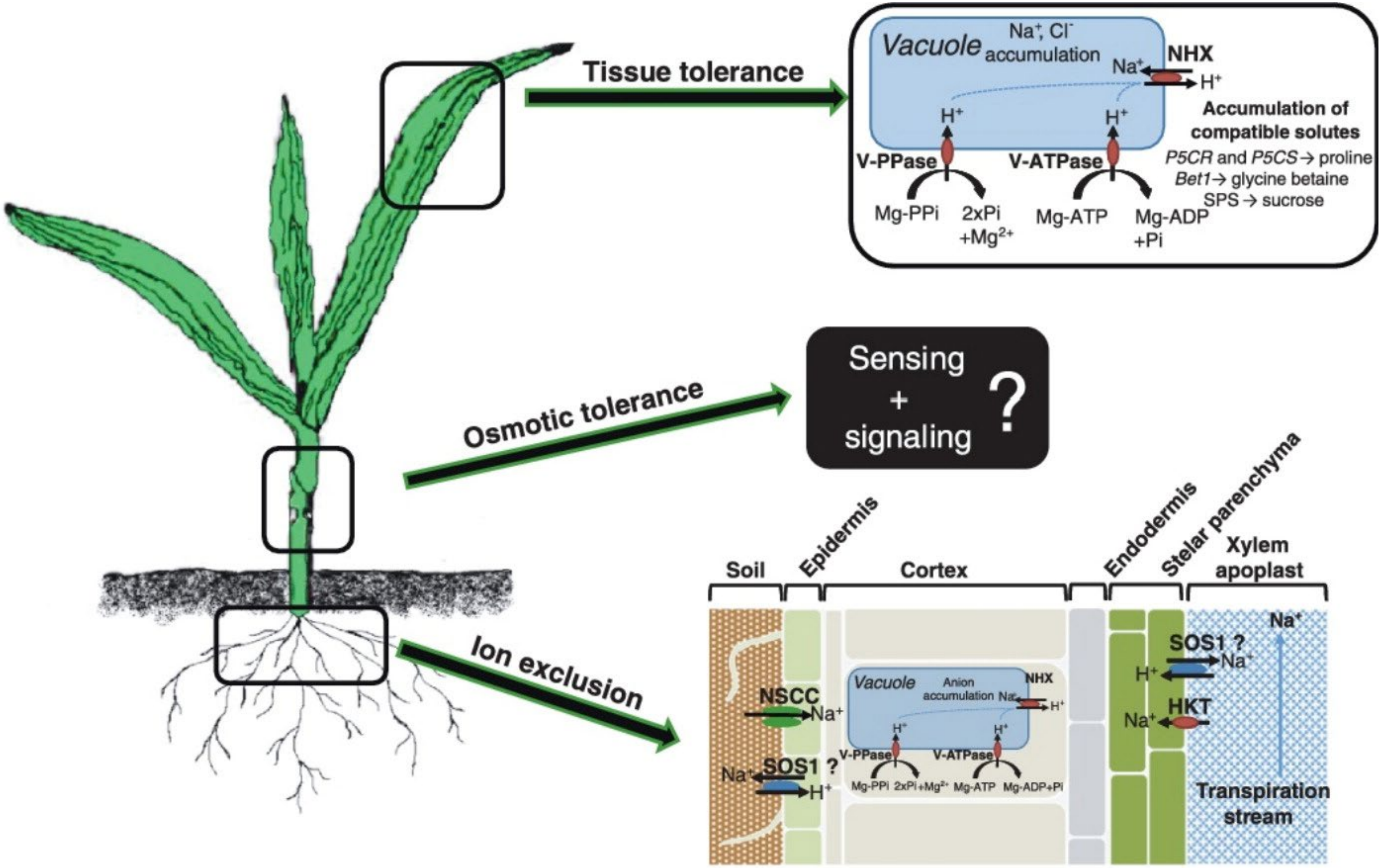
- ❑ **How plant cells respond to biotic and abiotic stress?**

Motivation

Almond plants are relatively sensitive to salinity stress

Need a comprehensive understanding of salinity tolerance

Salt resistant crop plants



Current Opinion in Biotechnology, Volume 26, 2014, 115–124

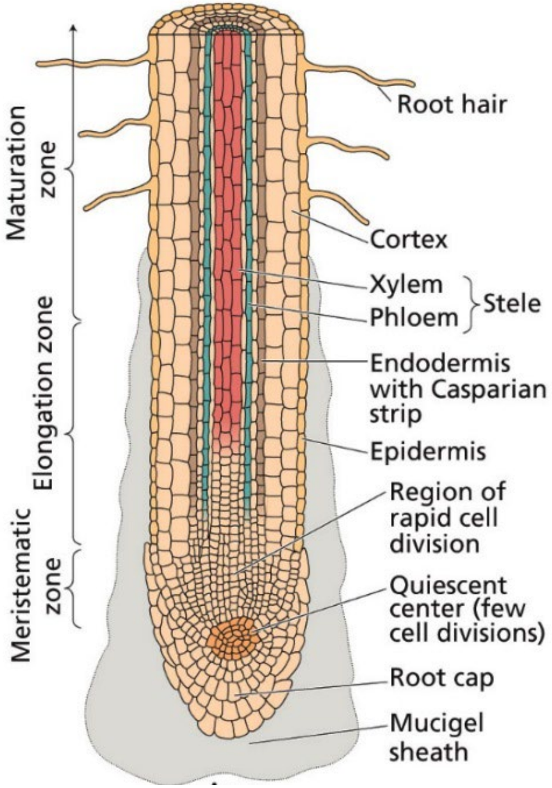
Stuart J Roy, Sónia Negrão, Mark Tester

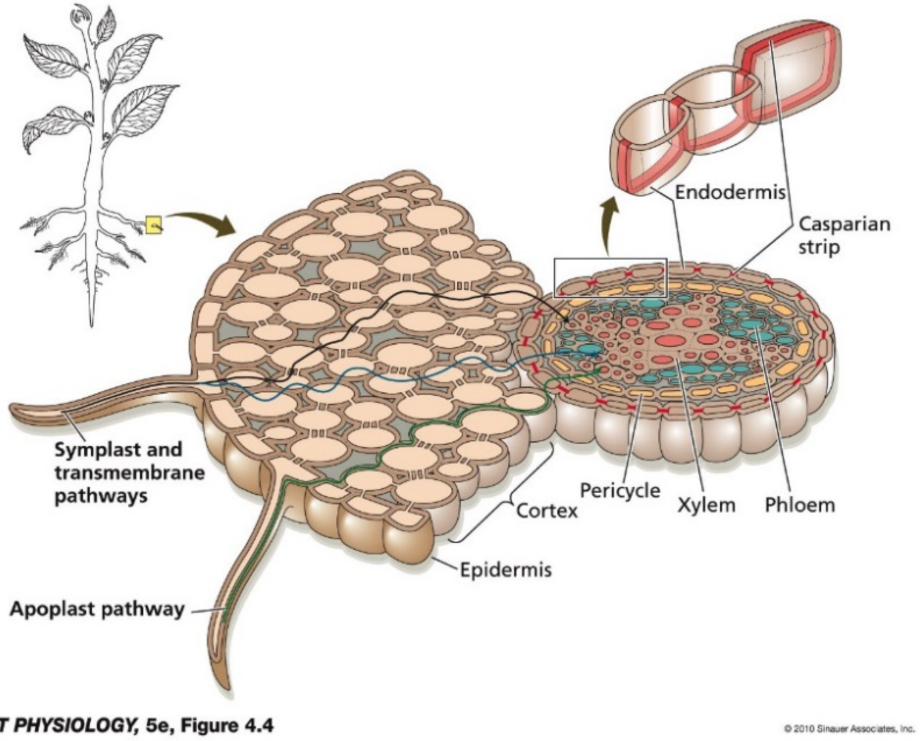
How different rootstocks respond to salinity?

- What happens under different environments?

- Where is sodium localized?

Rootstocks currently being characterized :
Empyrean-1
Controller-5
Hansen
Krymsk 86
Titan
Viking
Nemaguard
Bright’s hybrid





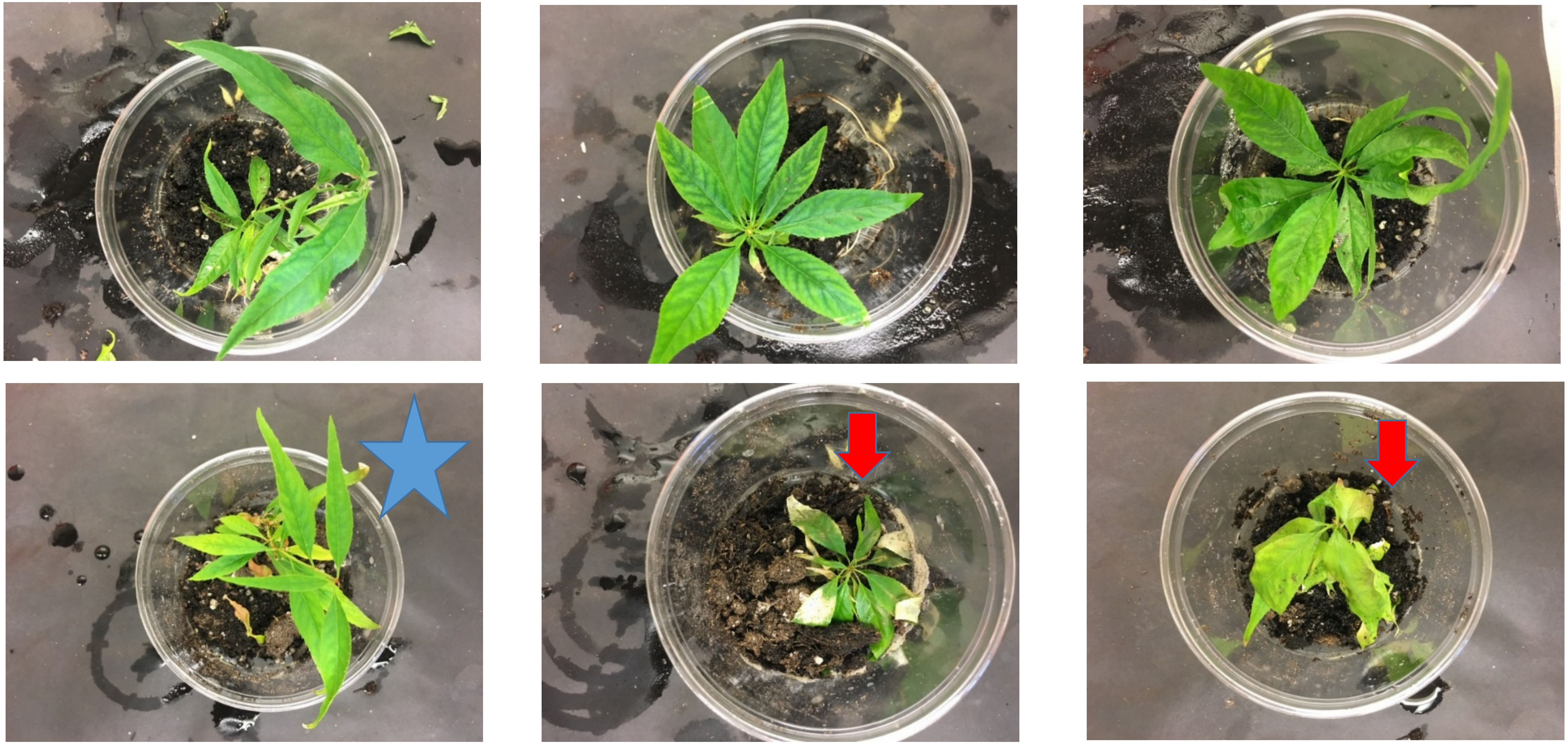
PLANT PHYSIOLOGY, 5e, Figure 4.4

Phenotypic characterization of rootstocks

Empyrean-1 | **Hansen** | **Controller-5**

0 mM NaCl (control)

150 mM NaCl 2 weeks

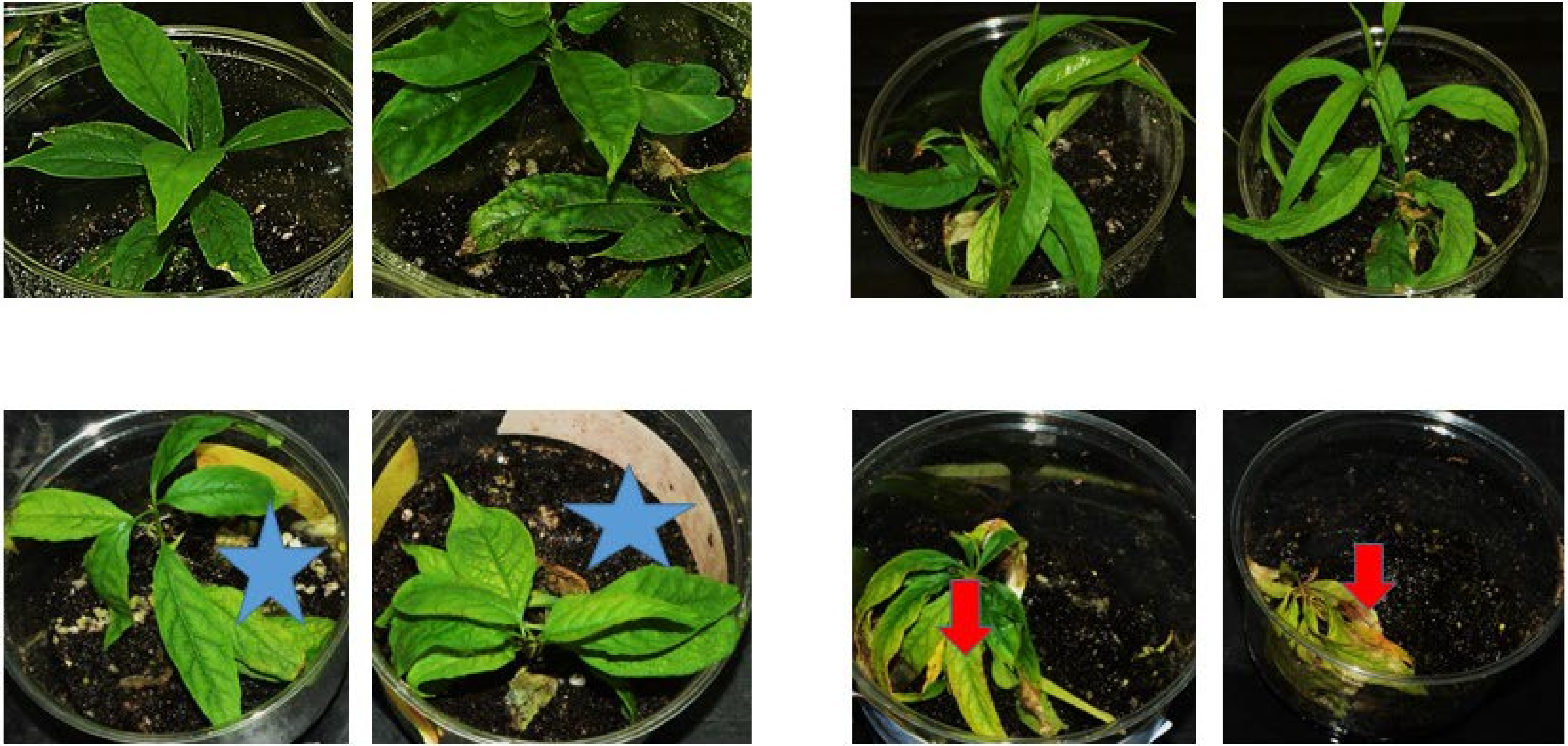


Phenotypic characterization of rootstocks

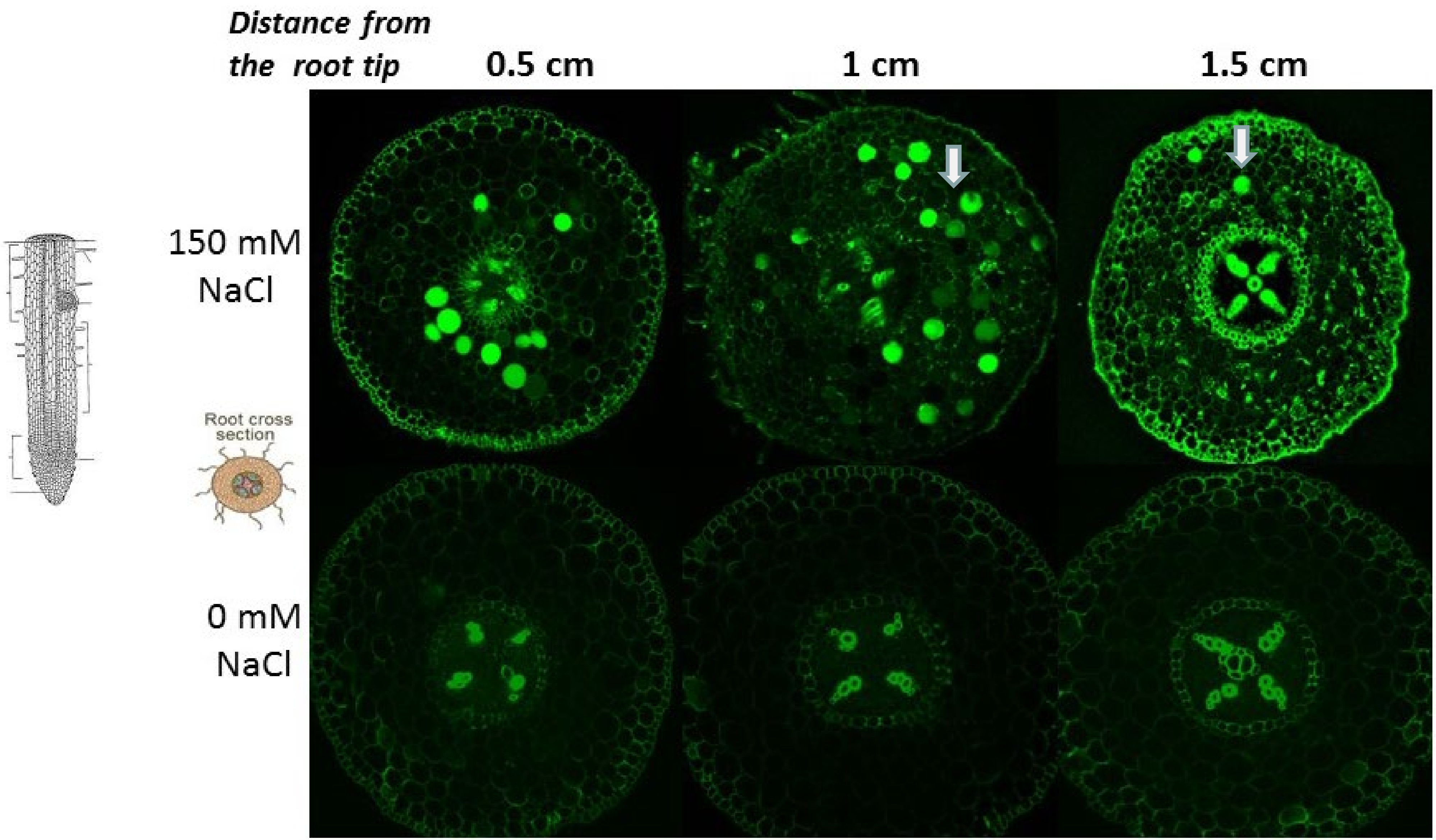
Krymsk 86 | Nemaguard

0 mM NaCl (control)

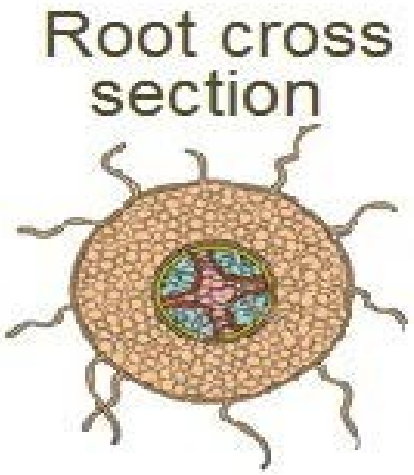
150 mM NaCl 2 weeks

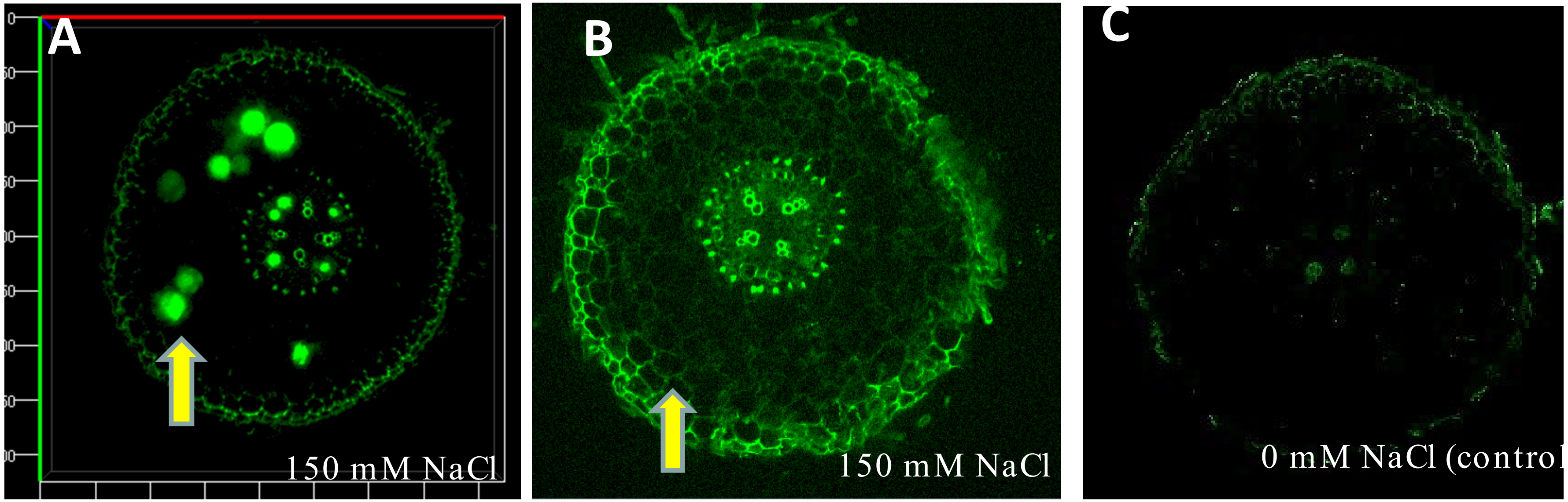


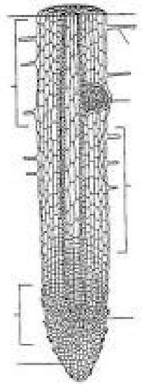
Sodium localization in Controller-5 under salinity treatment



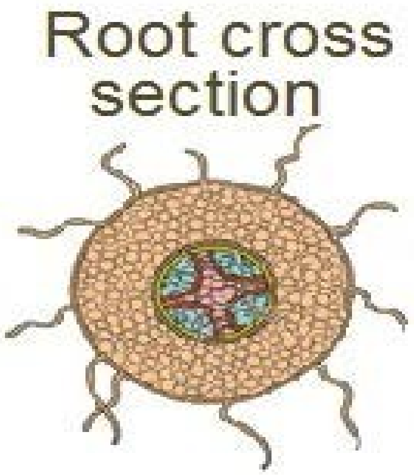
Sodium localization in Bright's –Hybrid under salinity treatment

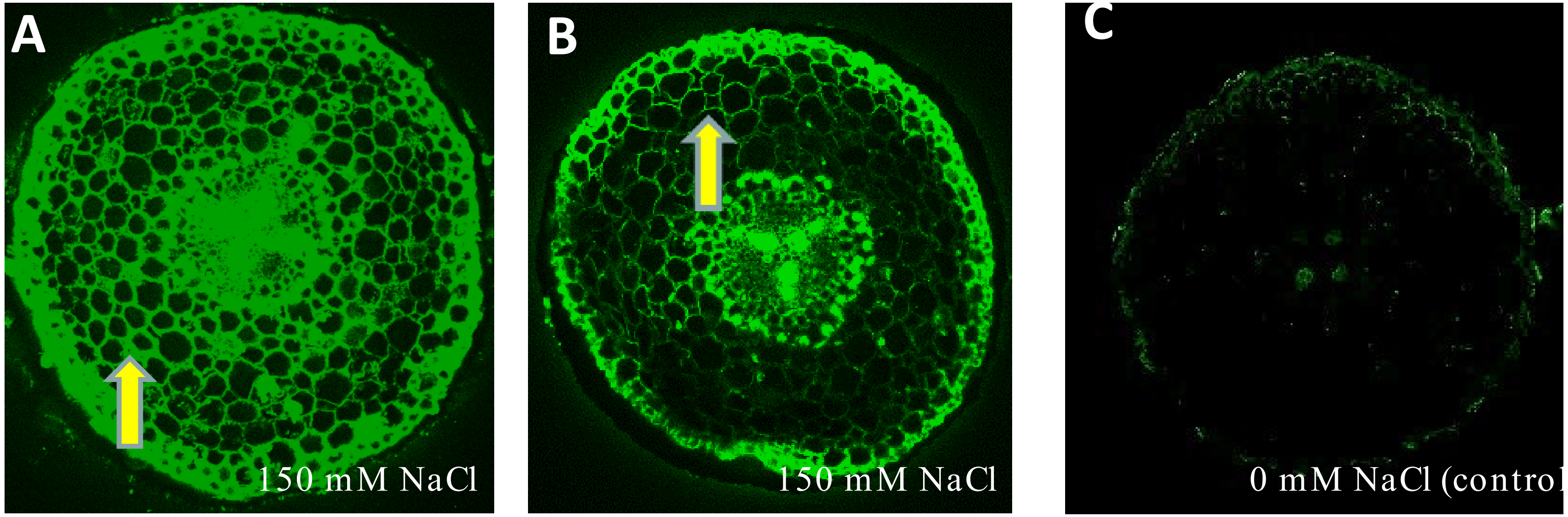


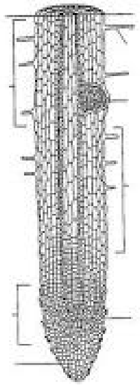




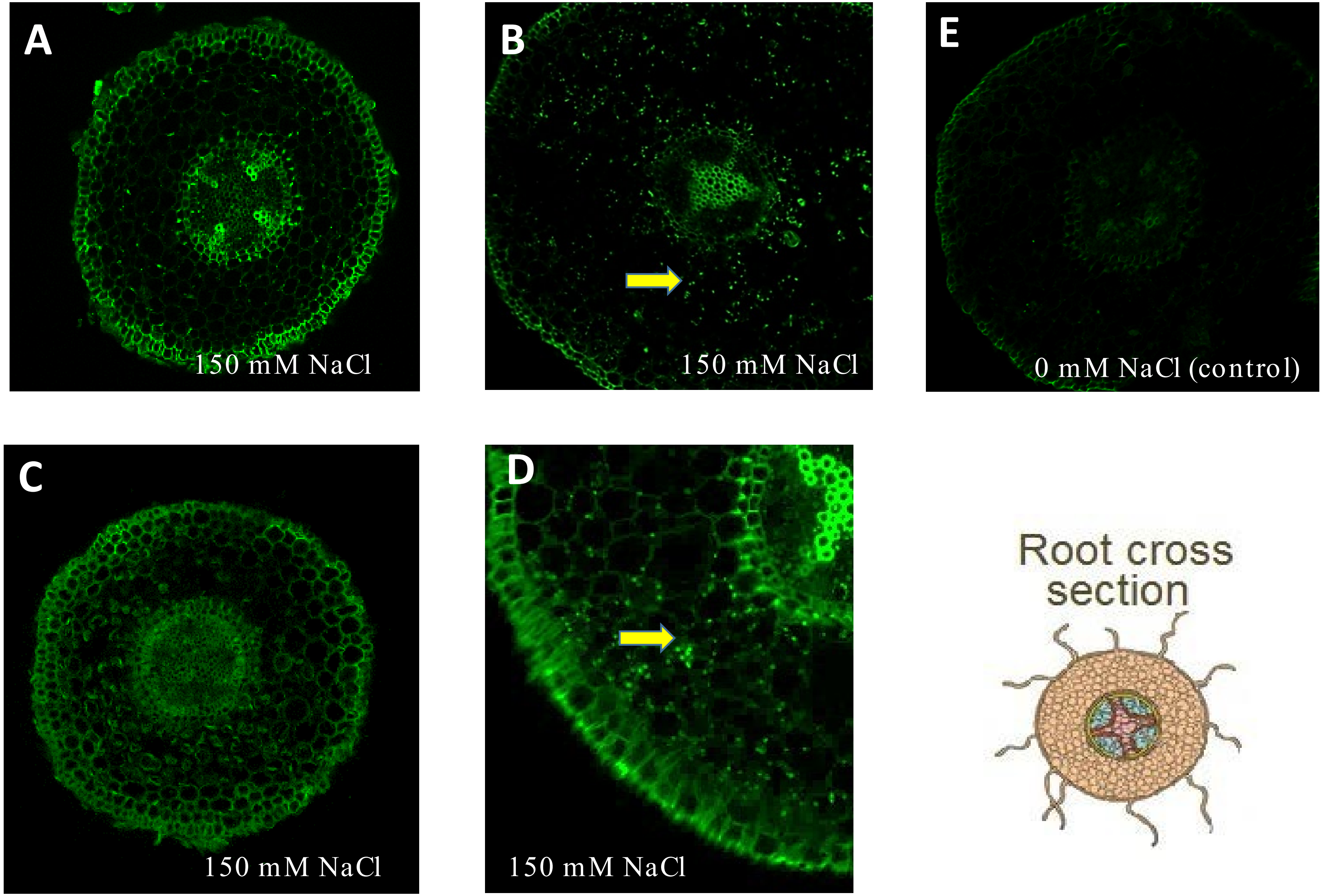
Sodium localization in Nemaguard under salinity treatment



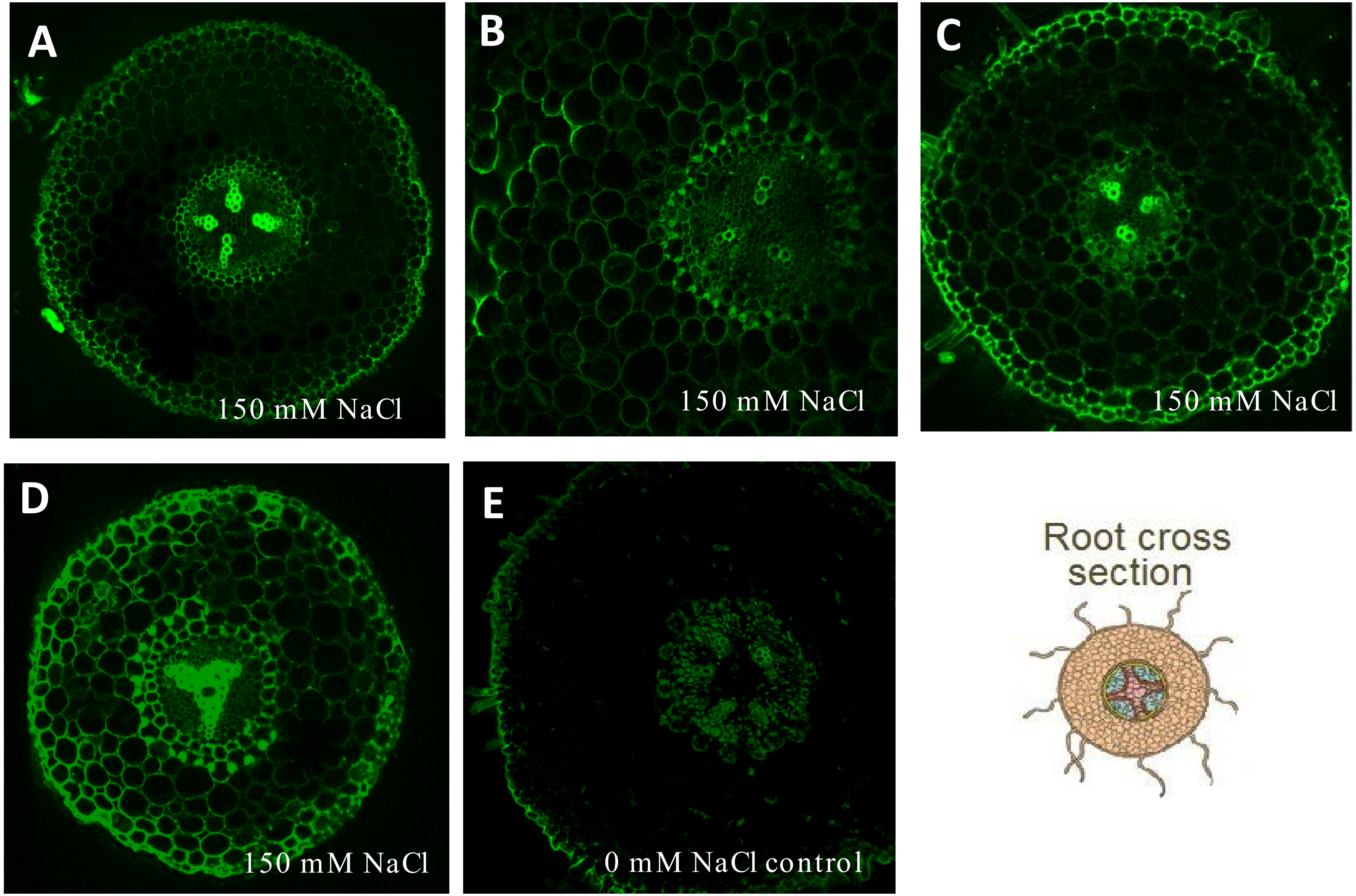




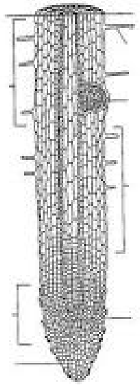
Sodium localization in Krymsk 86 under salinity treatment

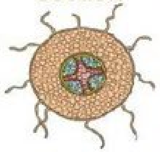


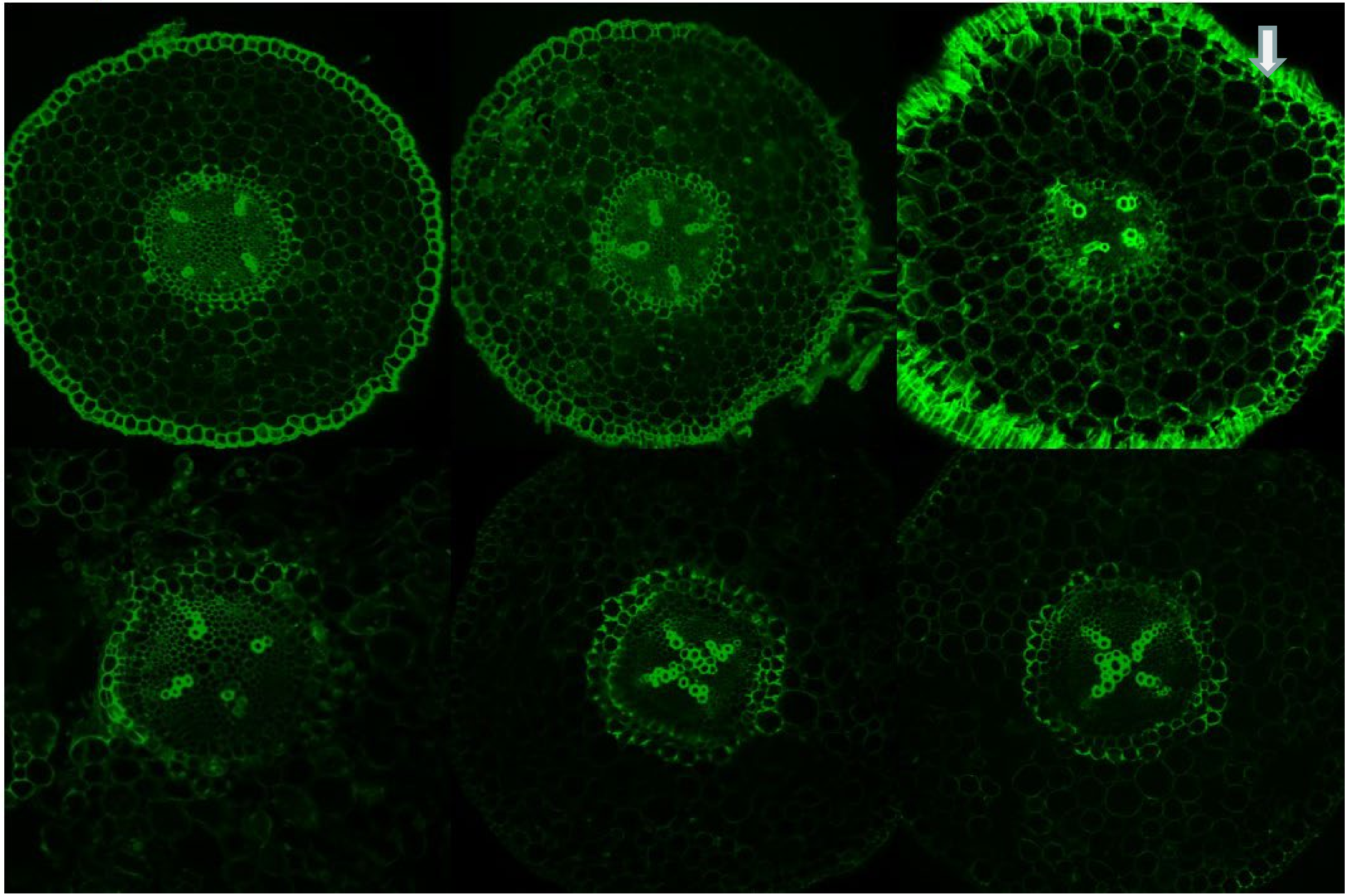
Sodium localization in Titan under salinity treatment



Sodium localization in Empyrean-1 under salinity treatment







Summary

- Unique subcellular distribution patterns of sodium were observed in the evaluated rootstocks
- Nemaguard, Controller-5 and Bright's Hybrid show enhanced sodium staining
- The results suggest that an exclusion mechanism of sodium transport takes place in Empyrean-1
- Titan, and Krymsk-86 show patterns distinct from Nemaguard
- Validation experiments are in progress to better understand mechanisms of sodium uptake and sequestration

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DEPARTMENT OF PLANT SCIENCES
College of Agricultural and Environmental Sciences

SG
Sierra Gold Nurseries

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Integrated Conventional and Genomic Approaches to Almond Rootstock Development

Malli Aradhya, Craig Ledbetter, Dan Kluepfel and Greg Browne, USDA-ARS
Andreas Westphal, KARE, UC Riverside

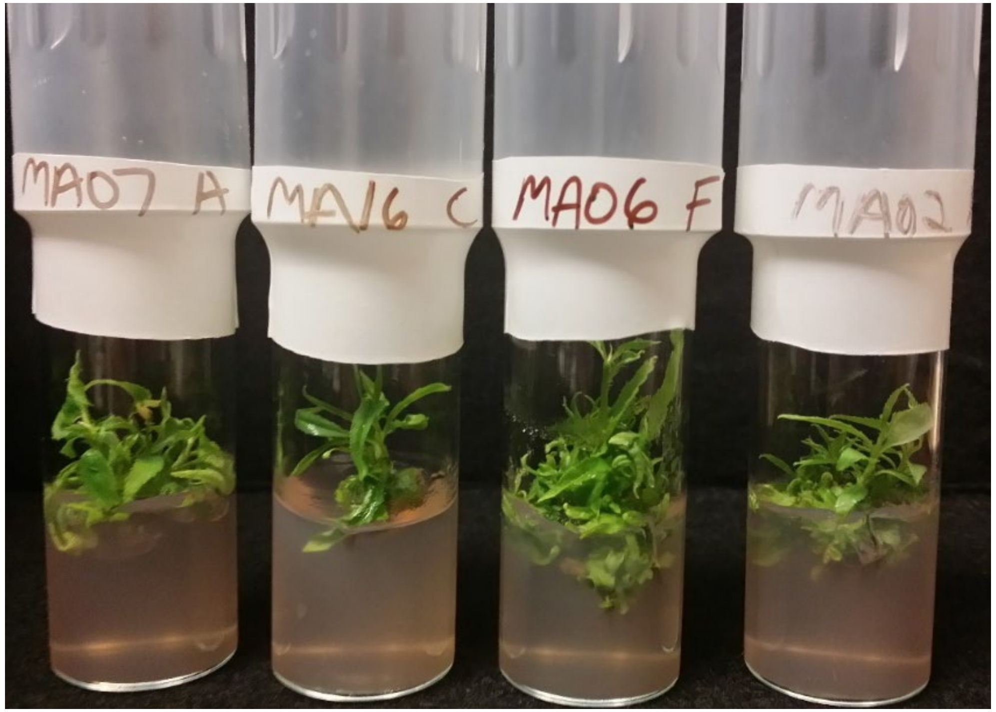
Objectives

- Produce genetically diverse interspecific hybrids to enlarge diversity among hybrids.
- Disease testing of commercial and experimental rootstocks to produce high-quality disease phenotype data.
- Intensify high-density genotyping of rootstock breeding populations.
- Develop and use effective marker assisted selection strategies for rapid development of improved rootstocks.

Prunus hybrids (2018 spring)

Pistil Parent	Pollen Parent	Hybrid ID	No. of hybrids
P. cerasifera	*P. fenzliana*	CF	9
P. cerasifera	*P. kuramica*	CK	20
P. cerasifera	*P. argentea*	CA	21
P. cerasifera	*P. arabica*	CB	14
P. cerasifera	*P. bucharica*	CB	22
P. cerasifera	*P. davidiana*	CD	2
P. dulcis	*P. mira*	DM	1
P. dulcis	*P. angustifolia*	DA	1
P. dulcis	nemaguard	DN	1
P. dulcis	*P. persica (FG)*	DP	1
P. persica	*P. tomentosa*	PT	2
P. persica	*P. tangutica*	PG	2
P. persica	*P. arabica*	PA	14
Total			110

Embryo rescue and micropropagation



5 months

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Embryo Rescue to Plants Ready for Evaluation 12-15 months

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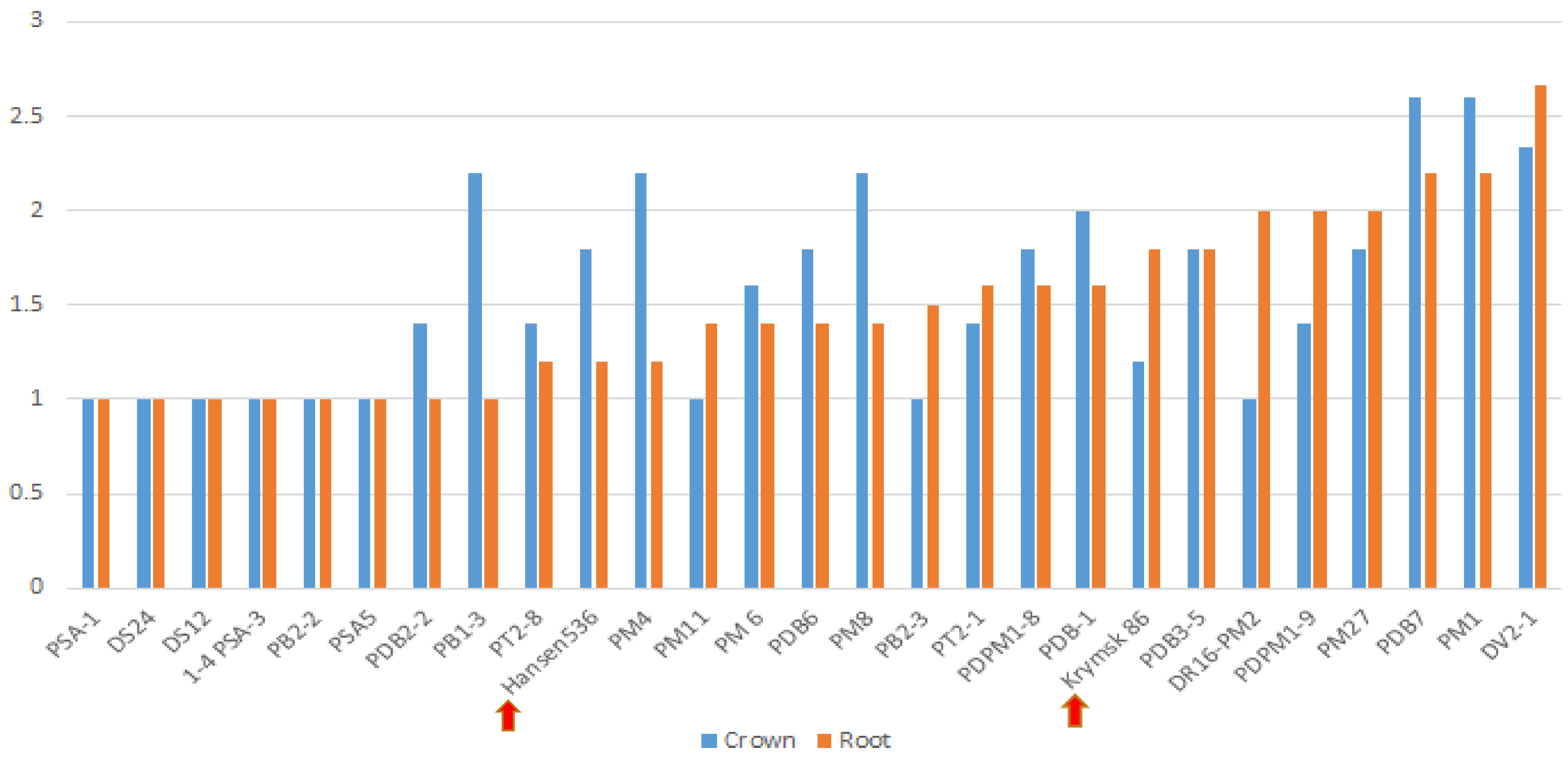
Crown Gall Evaluation



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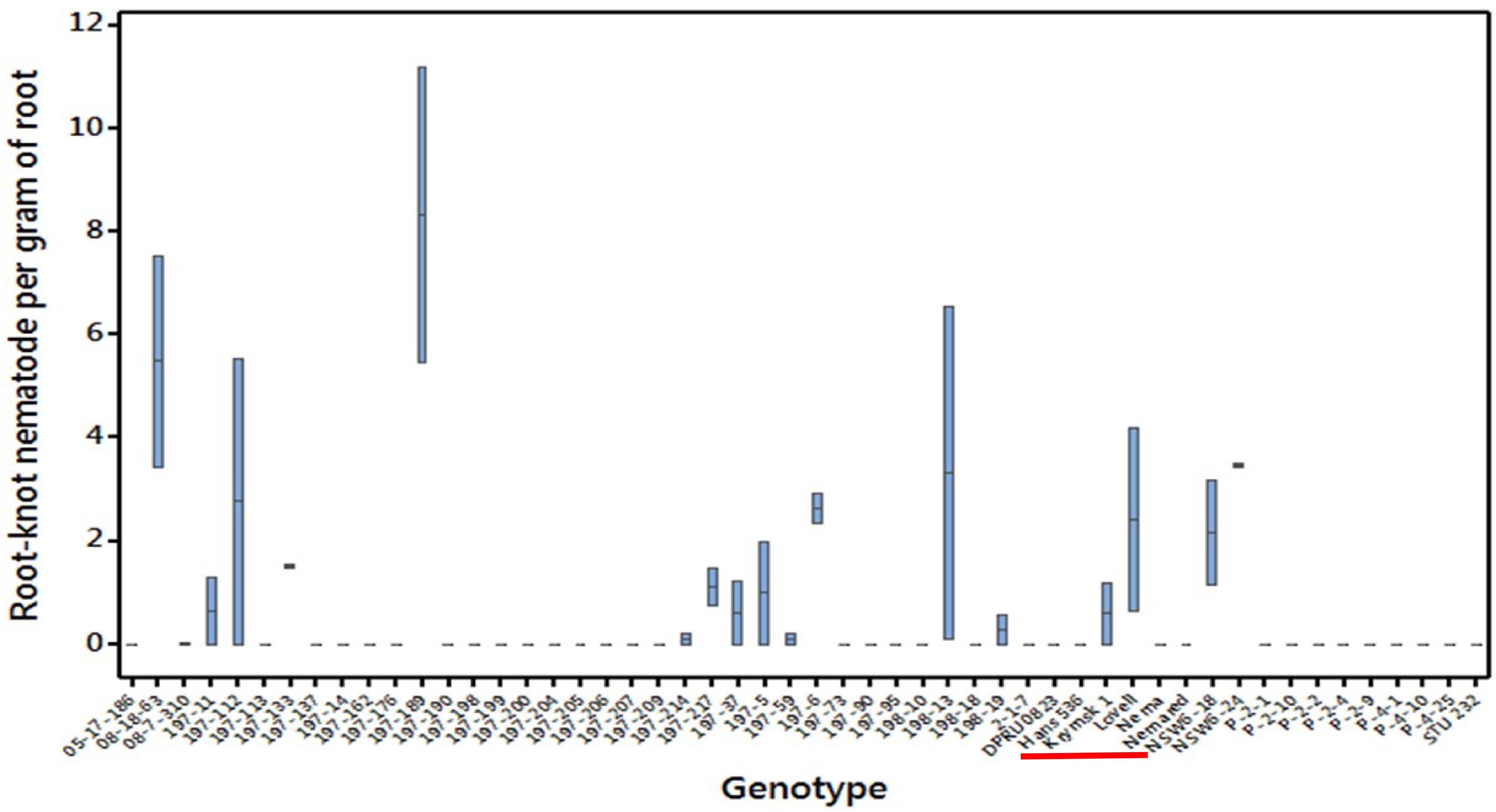
Root-knot Nematode Resistance Evaluation



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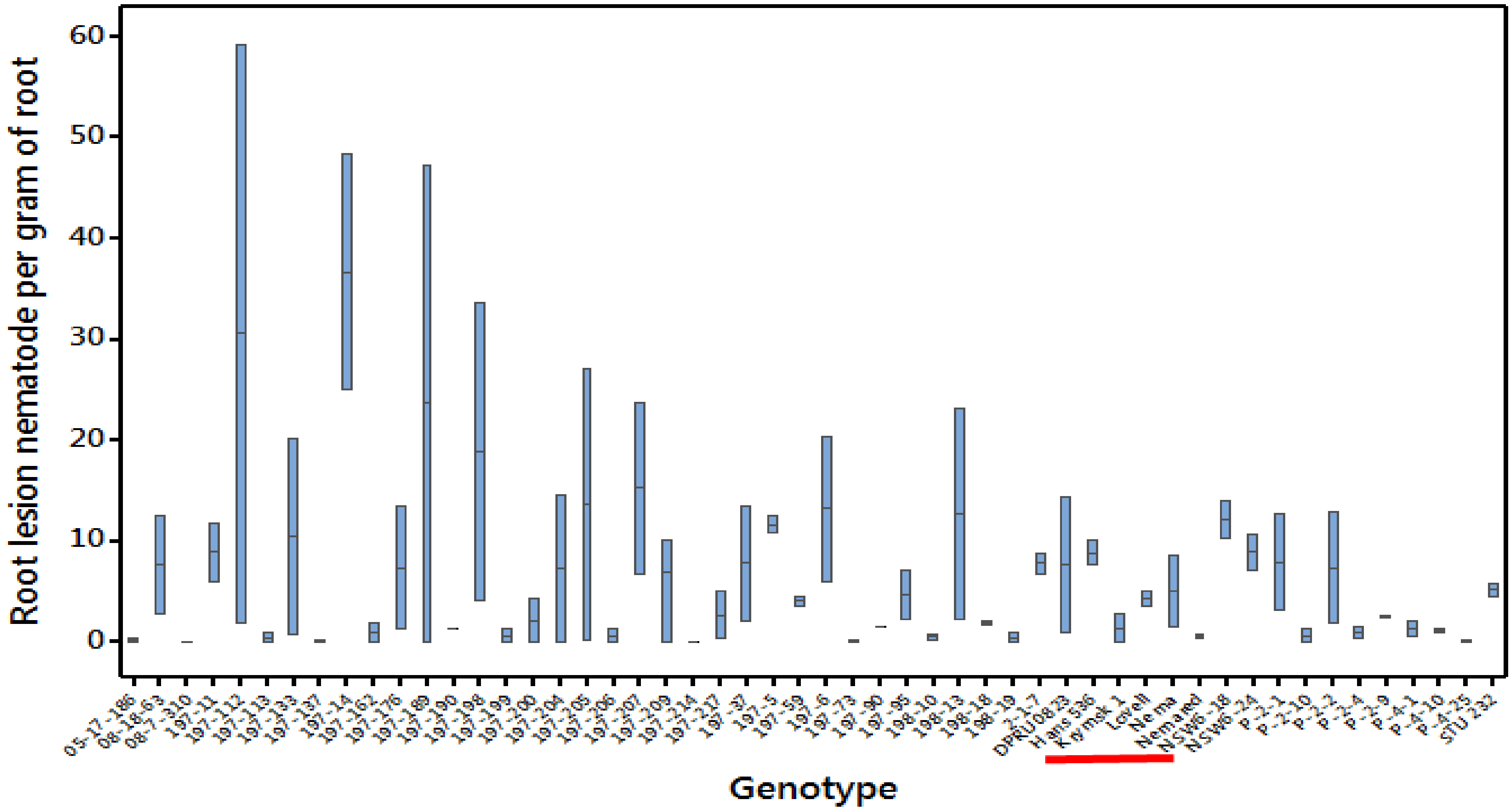
Root-lesion Nematode Resistance Evaluation



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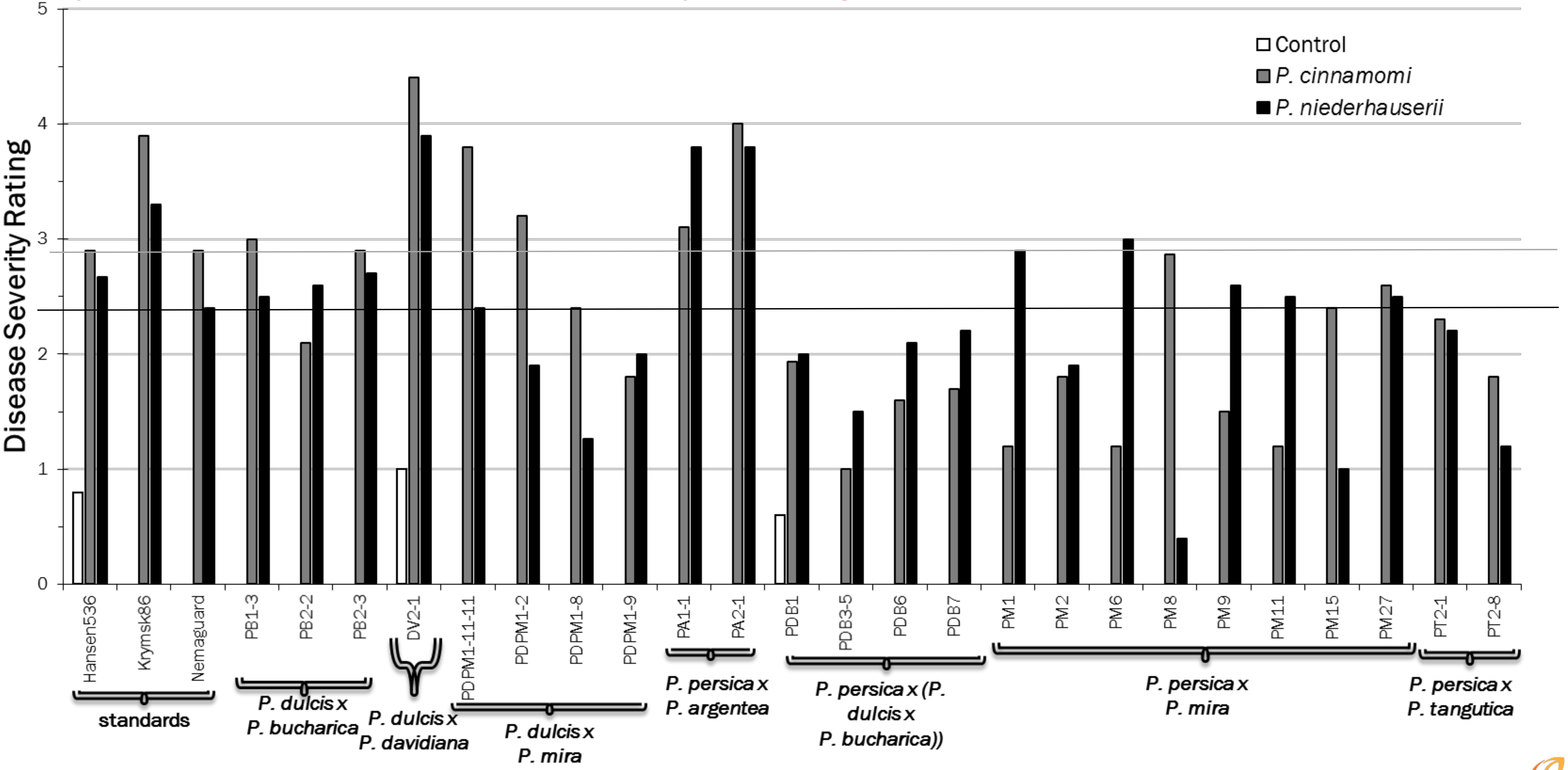
Phytophthora: Disease Severity Rating



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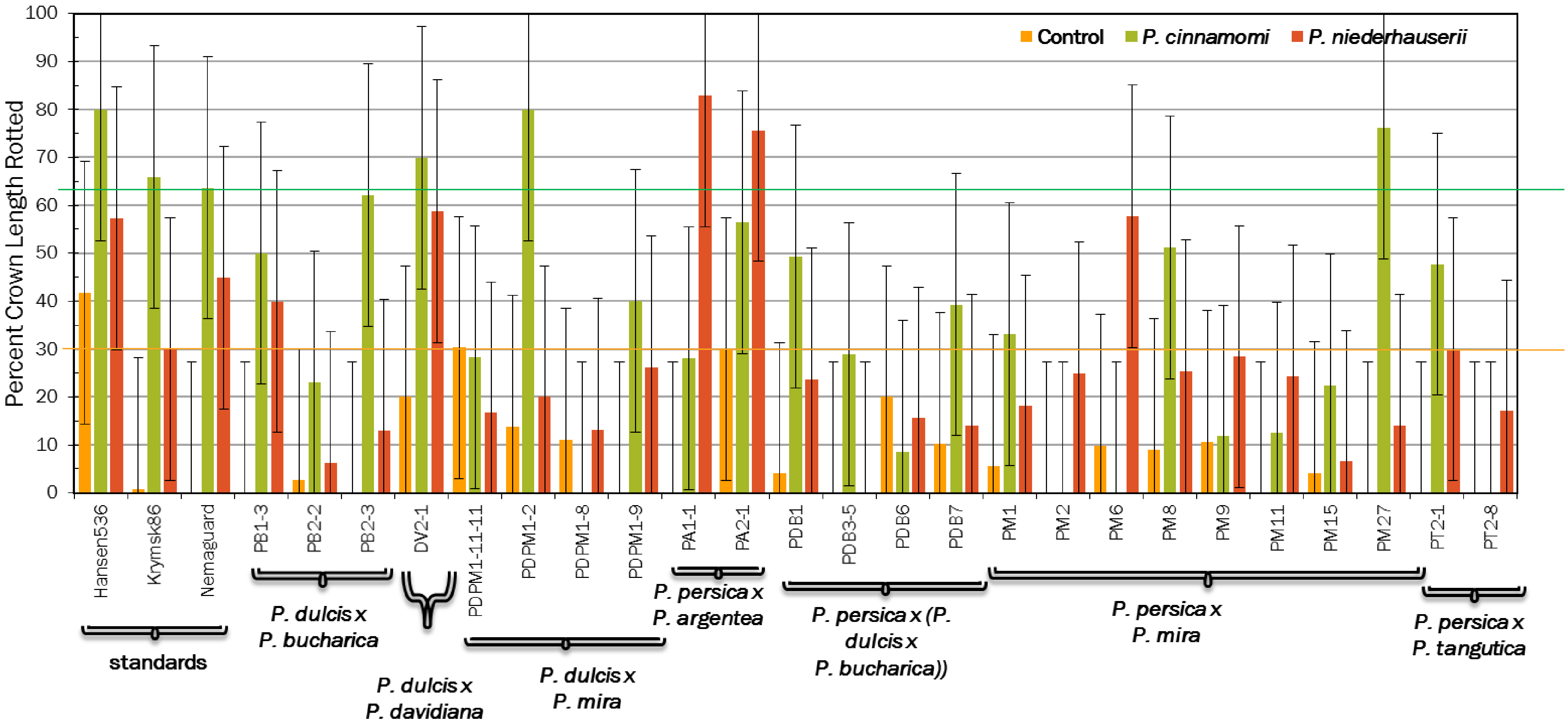
Phytophthora: Percent Crown Length Rotted



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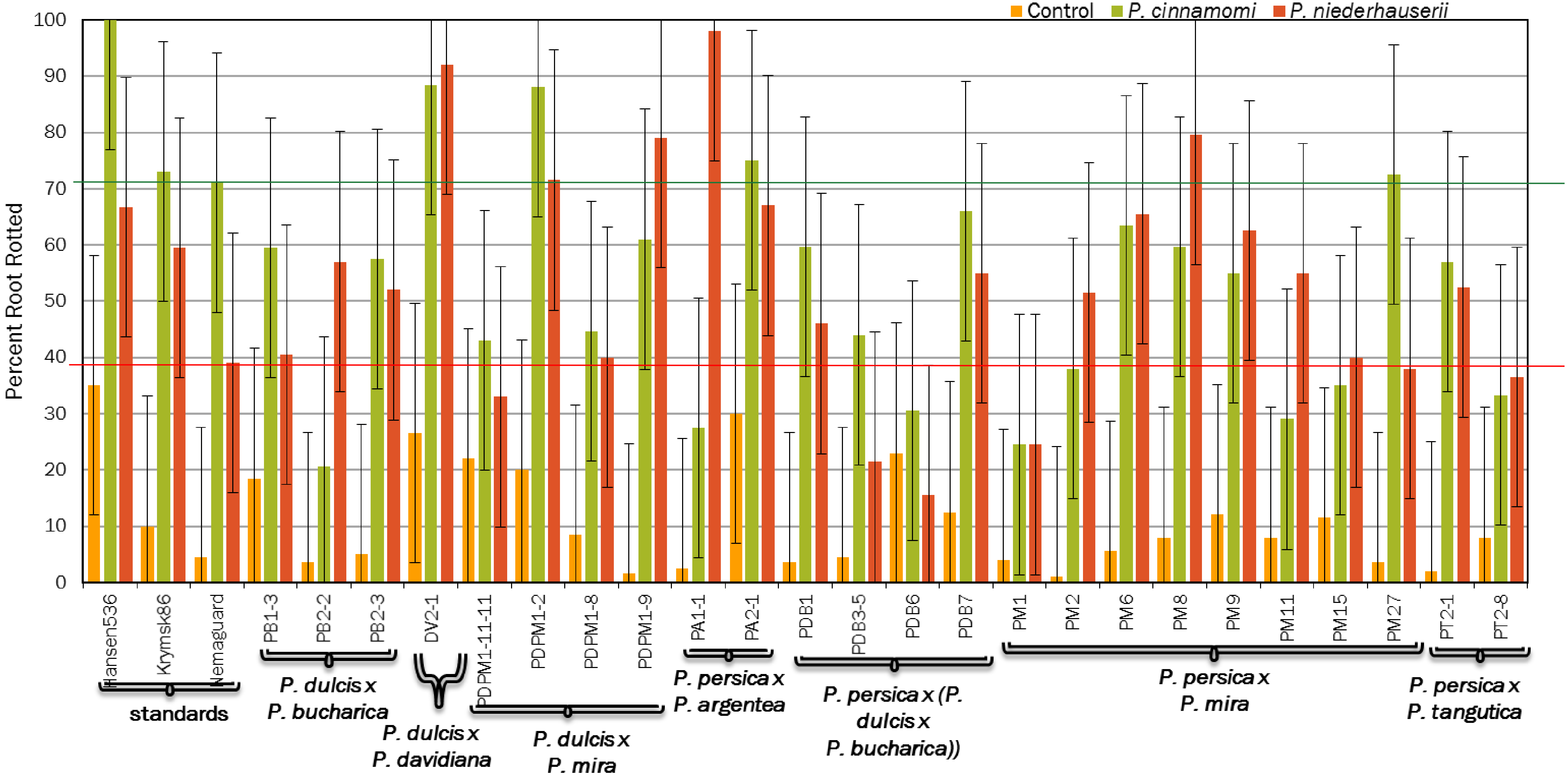
Phytophthora: % Root Rotted



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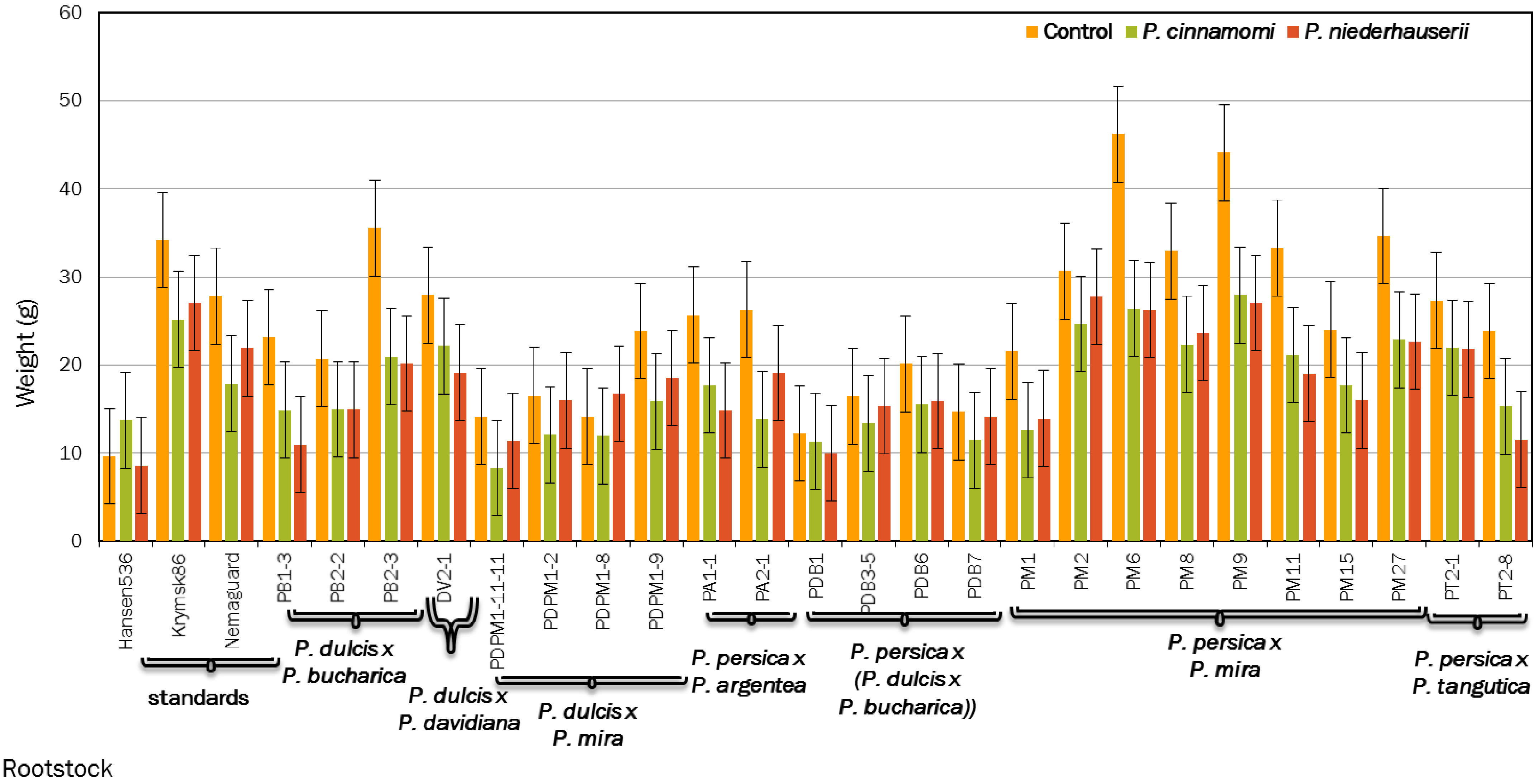
Phytophthora: Root Weight



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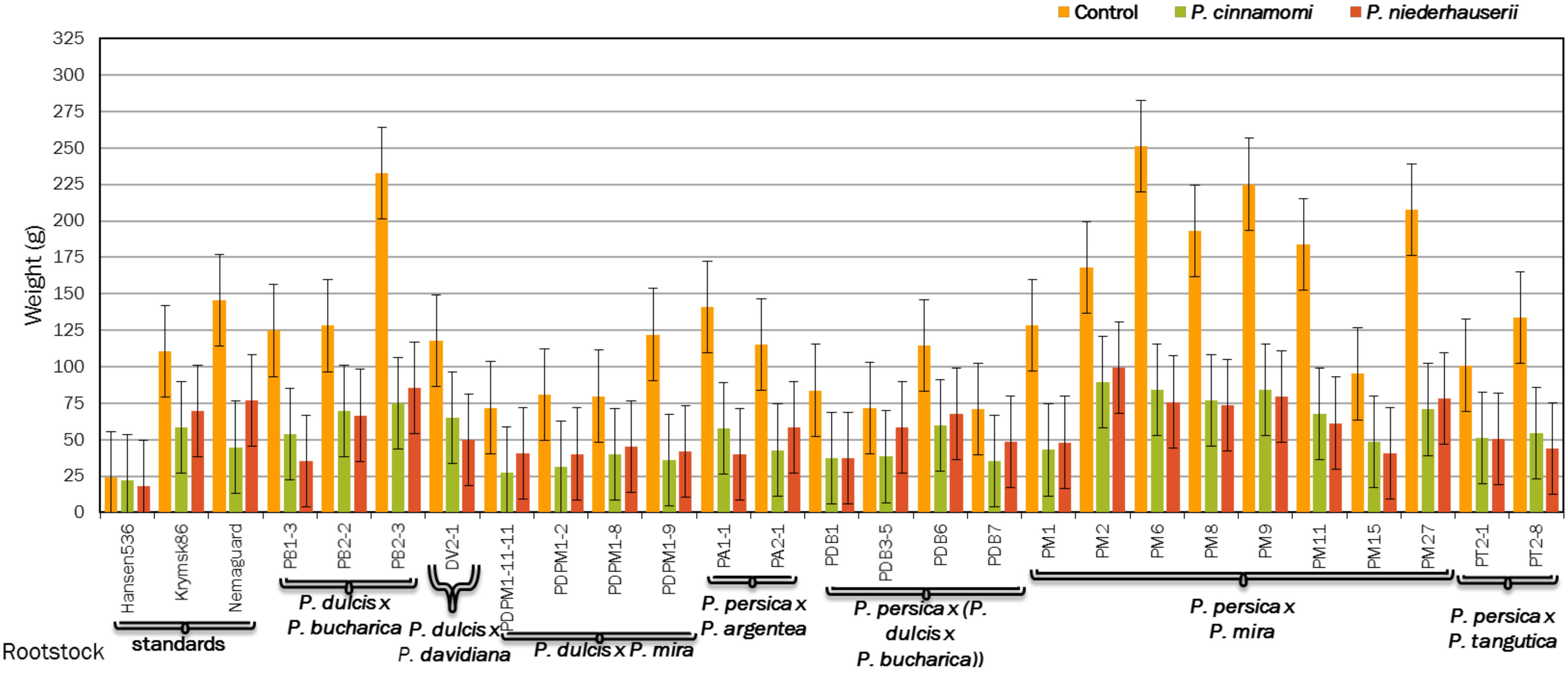
Phytophthora: Total Plant Weight



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Species background of *Prunus* rootstocks tested for susceptibility to *Meloidogyne floridensis*

<u>Peach</u>	*Prunus persica* X	*P. argentea* (2x)
		P. davidiana
		P. fenzliana
		P. mira (2x)
		P. keramica (2x)
		P. kansuensis
		P. tomentosa
<u>Almond</u>	*Prunus dulcis* X	*P. salicina*
		P. davidiana
		P. bucharica (2x)

Contd.

Prunus cerasifera x *P. mira*

Hansen 536

Lovell

Nemaguard

Myrobalan (*P. domestica*)

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Gene prediction and genome functional annotation of ‘Nonpareil’

Jonathan Fresnedo

The Ohio State University

Almond Board of California

Genome sequencing of ‘Nonpareil’

THE OHIO STATE UNIVERSITY

- Partnership with Dovetail Genomics

DovetailGenomics

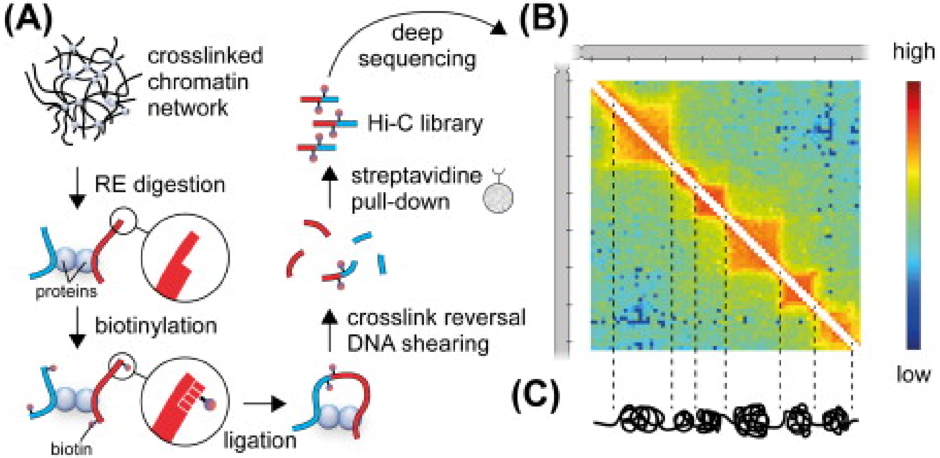
In collaboration with

Prof. Thomas Gradziel (Tom)
UC Davis

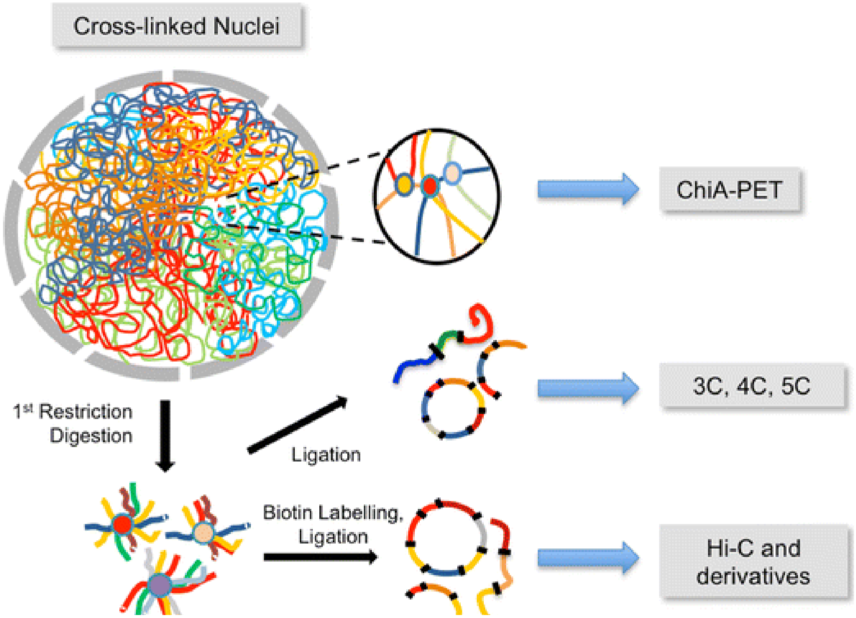
Dr. Mysore Sudarshana (Sudhi)
USDA-UC Davis

‘Nonpareil’ genome

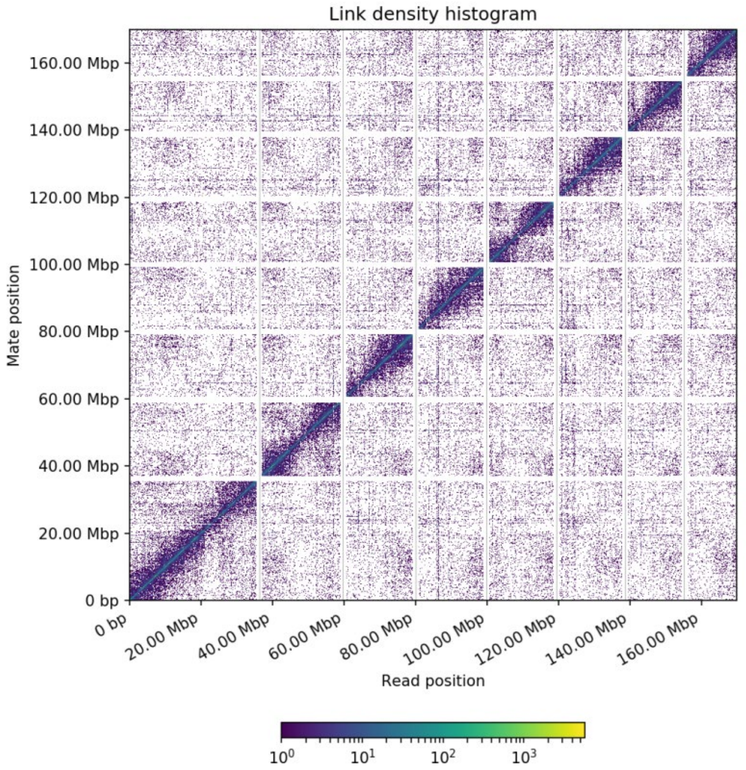
- Illumina sequencing + Chromosome conformation capture (Hi-C): using chromatin spatial organization in the cell



Ulianov et al. (2015) Int Rev Cell Mol Biol 315:183-244. https://doi.org/10.1016/bs.ircmb.2014.11.004



Sati, S. & Cavalli, G. Chromosoma (2017) 126: 33. https://doi.org/10.1007/s00412-016-0593-6



Annotating Nonpareil's genome

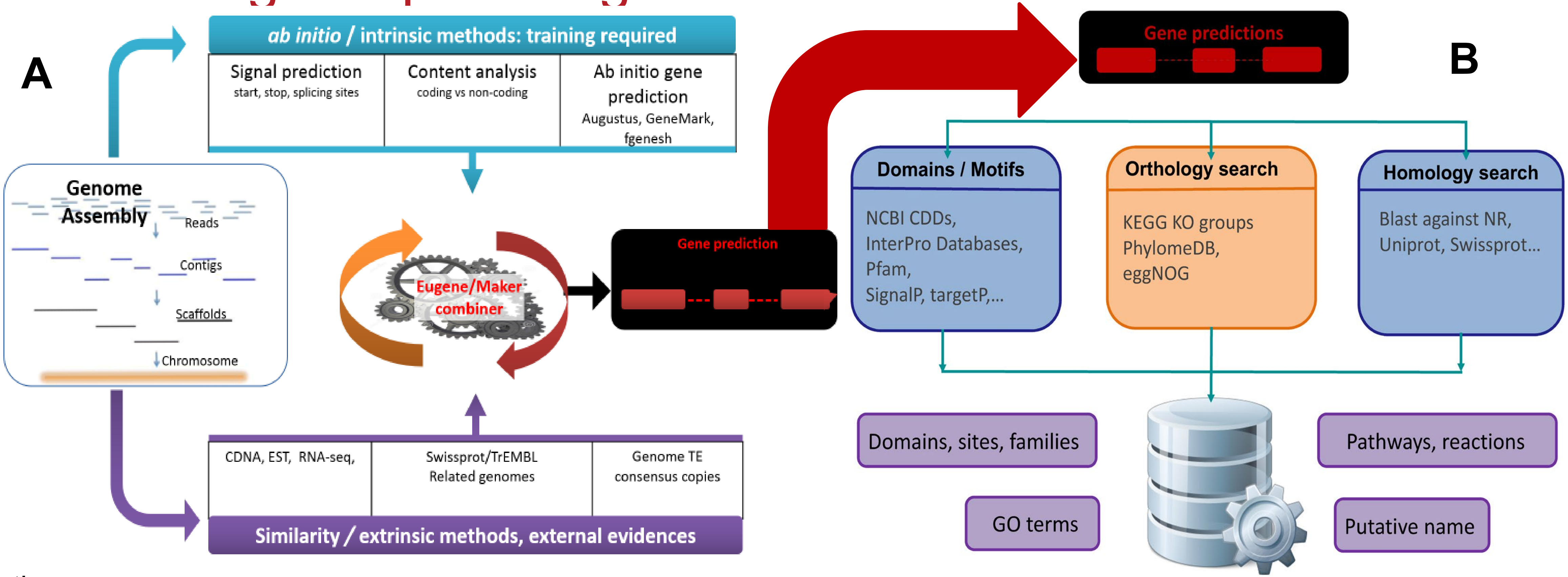


Diagram based on Dominguez Del Angel *et al.* Ten steps to get started in Genome Assembly and Annotation. *F1000Research* 2018, 7(ELIXIR):148 (https://doi.org/10.12688/f1000research.13598.1)

Objectives

1. Develop a gene prediction model for the genome assembly of 'Nonpareil'.
2. Develop a transcriptome with full length transcripts of genes in 'Nonpareil' using single-cell RNA sequencing technology.
3. Develop a gene functional annotation of the 'Nonpareil' genome.

Preliminary results

Using the current version of the 'Nonpareil' genome it has been found:

- 44.5% of the genome does not code for proteins, then this DNA may be:
  - Repetitive sequences
  - Transposable elements
- 55.5% (~165 Mb) of genome is coding DNA, and the first estimations suggest:
  - Approximately 28,000 genes
  - Approximately 32,000 proteins

The sequencing of RNA through this project will allow a more precise determination of the number of genes and number of proteins coded, as well as the annotation of such proteins.

How the sequences and annotated genome of Nonpareil will be used?

This resource will allow researchers

- Guide the development of resources tailored for almond
- Address relevant traits such as self-compatibility
- Enhance breeding strategies for tolerance/resistance to abiotic and biotic stressors
- Develop resources needed to address elusive issues such as non-infectious bud failure.

The ultimate goal is to enable the scientific community to perform genomics-informed research. Our vision is that this tool will contribute to the formulation of solutions of almond production issues, and ensure the sustainability and resiliency of the California almond supply chain.

Thanks for your attention

Analysis of small RNA profiles to understand noninfectious bud failure syndrome in almonds

Kurtis Dluge, Julia Vo, Evan Dumas and Mysore R. Sudarshana
USDA-ARS, Department of Plant Pathology, University of California, Davis, CA 95616

Noninfectious Bud Failure

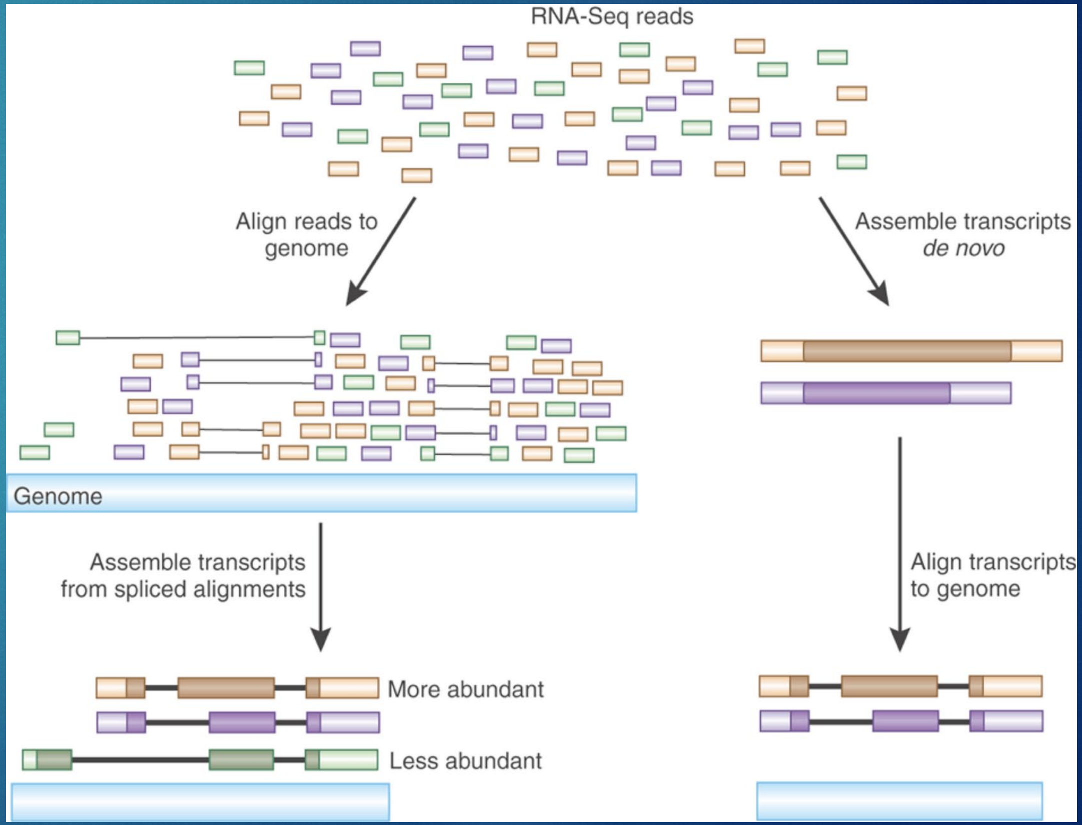
- Differs from infectious bud failure as it is a genetic disease
- Does not spread through grafting but is not eliminated when planting from a clone.
- Nonpareil and Carmel cultivars are prone to NBF
- Can cause significant (40%) yield loss

Noninfectious Bud Failure

- It is likely that the gene(s) involved in the development of dormant buds into shoots might be differentially regulated or simply fail to express because of silencing.
- possible that epigenetic changes trigger expression of a transactivator that may cause premature programmed cell death.
- The degree of BF has been associated with DNA methylation and age
- Changes in methylation is likely to influence gene expression patterns.

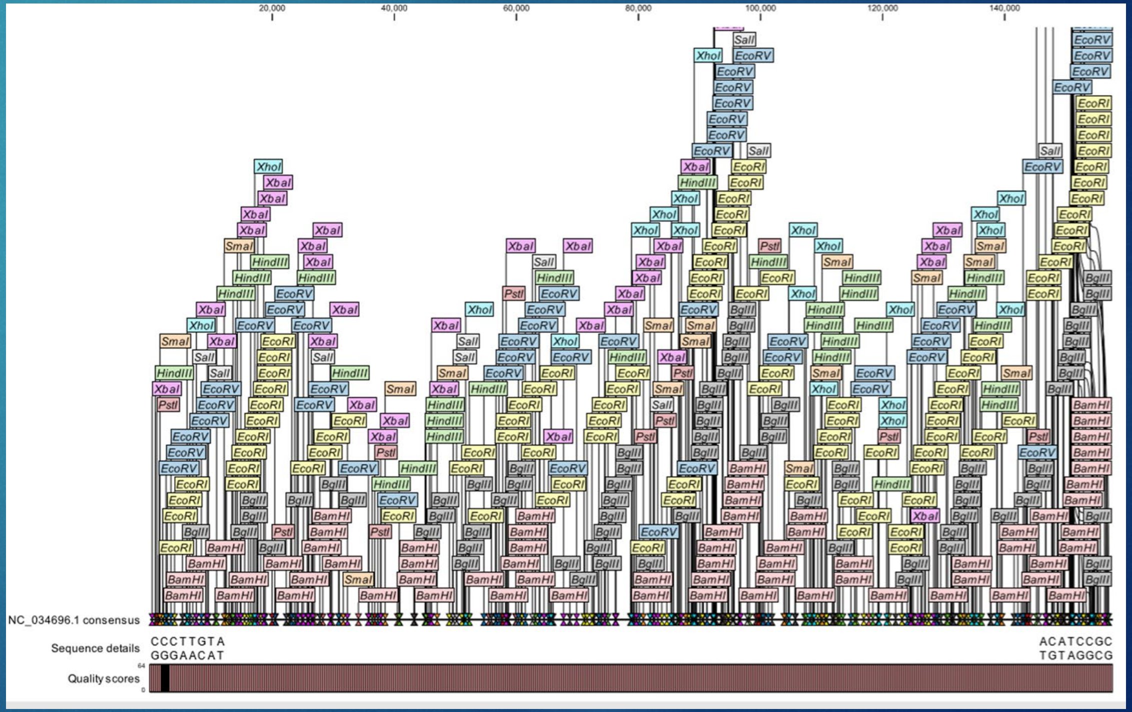
Noninfectious Bud Failure

- RNASeq and smallRNA profiling of trees with NBF has the ability to provide insights into the NBF phenomenon. Genetic elements either responsible for or influenced by the NBF and its epigenetic changes should exhibit differential expression. Shoots from Nonpareil and Carmel almond trees exhibiting BF and from control NonPareil plants without BF will be collected from trees at all four seasons. RNA-seq and sRNA-seq will be performed. Specific sequencing and assembly of almond chloroplast and mitochondria may help in identifying the problem



Goals and Current work

- Extract and sequence small RNA profile of almond trees exhibiting noninfectious bud failure.
- Conduct bioinformatics analysis of the small RNA fraction.
- Sequencing and assembly of chloroplast and mitochondrial genomes.
- Find differences in the RNA profile between normal and bud failure expressing almond trees.
- Develop genetic markers or altered ("resistant") cultivars based on this data.



Thank you

Questions?