UCR Avocado Rootstock Program Update: Towards Developing Disease and Salinity Resistant Rootstocks

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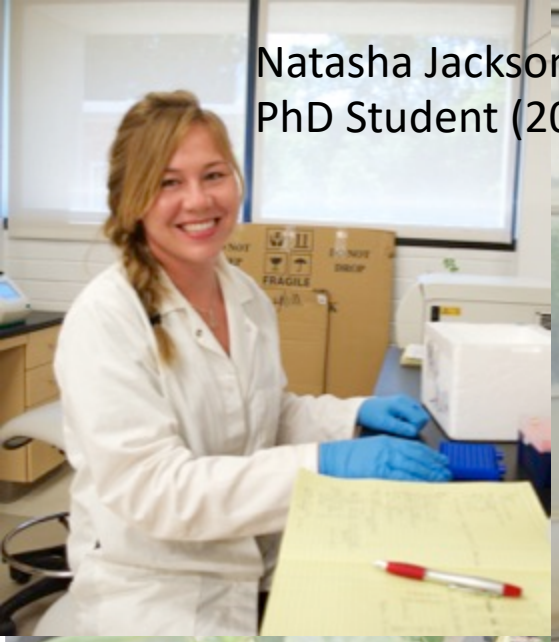


Natasha Jackson,
PhD Student (2021)

Brandon (former SRA)

Dr. Rodger
Belisle (2018)

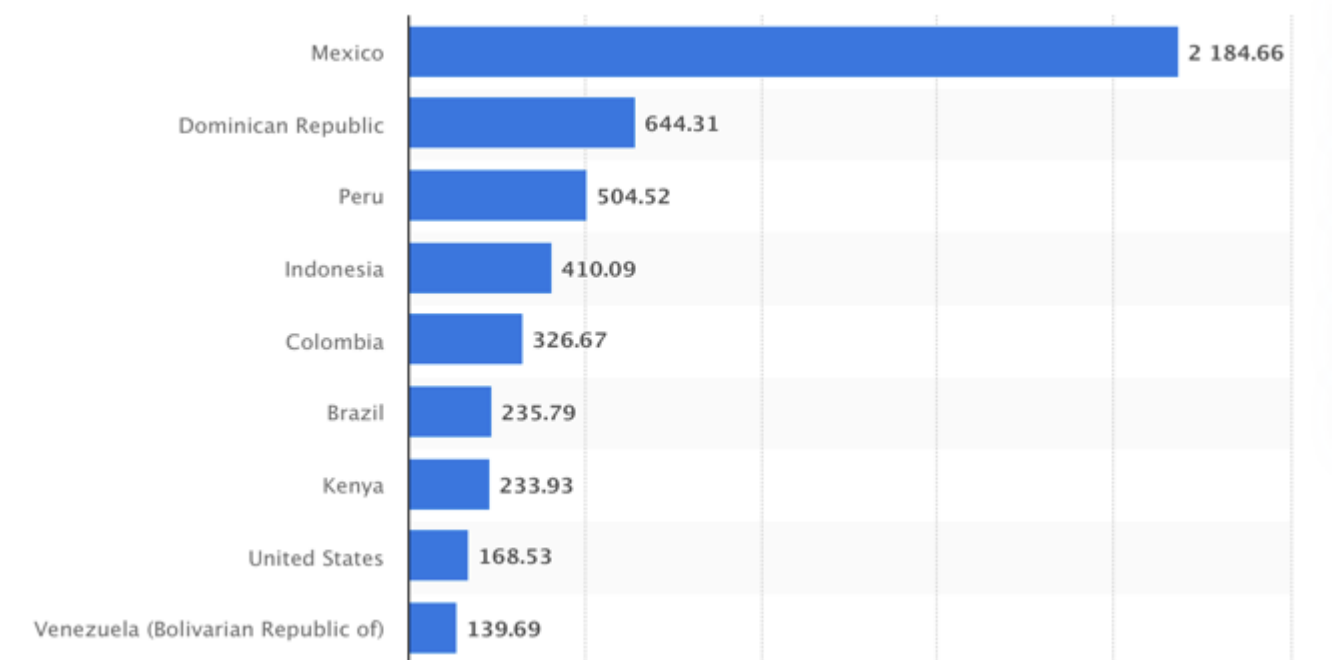
**Dr. Abeysekara,
former (2020)**

**Aidan Shands
PhD Student (2022)**

**Dr. Guangyuan Xu
Former Postdoc
(2019)**

The market share for USA-produced avocado has decrease!!!

In 2006 and 2010 USA was the top 2 global producer.



Currently, USA is number 8. California produces 90% followed by Florida, and Hawaii.

UCR Rootstock Breeding Program

George Zentmyer
UCR 1943 – 1983

Mike Coffey
John Menge
Greg Douhan

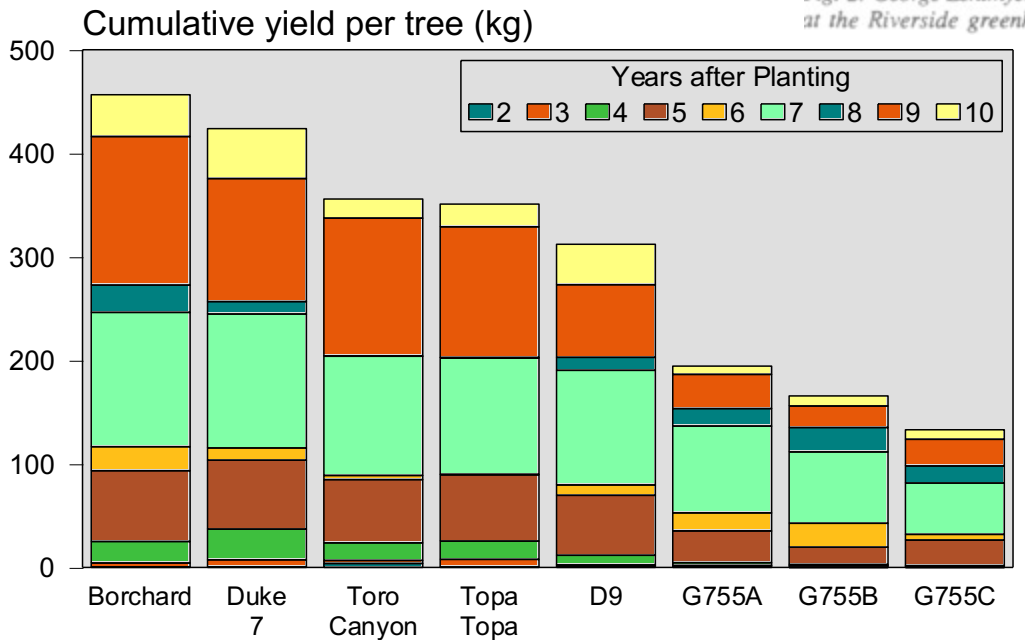
Dr. Patricia Manosalva (2015)

Rootstock influences yield, tree size, nutrient uptake and alternate bearing

Mickelbart et al, 2007

Martin Grande (G755 seedlings)
P. schiedeana seedligs (1970s-1980s).

Fig. 2. George Zentmyer and Fred Guillemet observing the Martin Grande rootstock at the Riverside greenhouse (1978). Photo by Schieber, 1978.



Mary Lu Arpaia

The evolution of clonal rootstocks

(Past)
Duke 7

Thomas
Toro Canyon

G755 (martin grande)
G6
Duke 9

(Present) Most available at Brokaw
Dusa (SA)
Uzi (UCR)
Zentmyer (UCR)
Steddom (UCR)
Tami (VC801),
Miriam (VC218),
and Ben-Ya'
Acov1(Israel)

Califonia and UCR clonal rootstocks

Rootstock	Race	Year	Maternal Parent	Origen	Phenotype
Duke	M	1912s	Unknown	UCR, Zentmyer	Good Phytophthora Root Rot (PRR) resistance (moderate resistance, MR) caused by *Phytophthora cinnamomi* in CA, cold and wind tolerance, vigorous, productive, large trees.
Duke 7	M	1970s	Duke	UCR, Zentmyer	Good PRR resistance (comparable with Dusa, CA standard), cold and wind tolerance, vigorous, Hass:duke7 is productive, large trees, susceptible to waterlogging. Available at CA, South Africa, Israel, Spain, and Chile.
Duke 9	M	1990s	Duke (gamma irradiation)	UCR, Zentmyer	Good PRR resistance (comparable with Dusa, CA standard), vigorous, poor yield (Hass:Duke 9) in CA but similar to Hass:Duke 7 in South Africa, large trees.
Barr Duke	M	1990s	Duke 6	UCR, Zentmyer	Moderate PRR resistance, susceptible to salinity.
Thomas	M	1980s	Fuerte	UCR, Mike Coffey/Guillemet	Highly resistant when selected back in the 1980s but currently is susceptible to the new PRR pathogen population in CA, highly susceptible to salinity. Susceptible to *P. citricola*.
Toro Canyon	M x G	1984	Topa Topa seedling	Royden Stauffer	Moderate PRR resistance (CA), tolerant to salinity, vigorous, currently used in CA, good productivity under PRR and high salinity conditions.
Zentmyer	M	2011	Thomas	UCR, Menge et al	Good PRR resistance in some cases better than Dusa, vigorous, highly sensitive to salinity, good yield under PRR conditions but poor yield under no PRR conditions, ***good tree for replanting situation under high PRR incidence but no high salinity.***
Uzi	M	2011	G6	UCR, Menge et al	Good PRR resistance in some cases better than Dusa, extremely vigorous and fast-growing rootstock that is capable of supporting a 'Hass' tree growing to 15 ft. in 2 years. It's yields are generally high and consistent. 'Uzi' leaves exhibit burn due to salt damage, but this does not seem to affect the growth or yield of the 'Hass' variety.
Steddom	M x G	2011	Toro Canyon	UCR, Menge et al	Good PRR resistance in some cases better than Dusa, it is a slow growing rootstock having a heavy yield, has a high yield/canopy volume ratio. 'Steddom' has a small degree of salt tolerance, excellent rootstock with small stature and low vigor, making it desirable for high density or hedge-row avocado plantings.

Table 1. Field distribution of the rootstocks being tested for root rot resistance. PP numbers indicate rootstocks developed from this project. Dates indicate year of planting.

Southern CA

Rootstocks	1 (2002)	2 1(2003)	3 2(2005)	4 (2005)	5 (2006)	6 (2005)	7 (2000)	8 (2003)	9 (2002)	10 (2002)	11 (2004)	12 (2003)
Thomas	X	X				X	X	X	X	X	X	
Merensky II (Dusa)			X	X	X		X					
Merensky I (Latas)		X					X					
Duke 7							X					X
Parida	X											X
Topara												
Toto Canyon		X						X				
VC44		X										X
VC207		X		X							X	X
VC218	X		X									X
VC225		X		X						X		
VC241		X		X			X					
VC801	X		X	X		X				X		X
VC256						X				X		
Zentmyer PP4	X						X		X			
Berg PP5			X	X								X
PP14 Uzi		X		X			X	X		X	X	

Northern CA

Rootstocks	13 (2004)	14 (2004)	15 (2004)	16 (2005)	17 (2003)	18 (2003)	19 (2003)	20 (2006)	21 (2003)	22 (2001)	23 (2006)	24 (2002)	25 (2005)	26 (2005)
Thomas		X	X		X	X	X	X	X	X		X		
Merensky II (Dusa)							X	X		X	X		X	X
Merensky I (Latas)				X	X									
Duke 7	X			X										
Parida														
Topara											X			
Toro Canyon														
VC44														
VC207							X							
VC218														X
VC225														
VC241							X							
VC801														
VC256														
Zentmyer PP4		X		X	X	X	X		X	X	X	X		
Berg PP5														
PP14 Uzi					X	X	X	X	X		X			X

Douhan et al., 2015

Table 3. Summary table of avocado rootstocks tested during this project.

Rootstock	Years Tested	Locations Tested	Salt Tolerance	PRR Tolerance	Status	Vigor
VC207	***8***	***10***	***HT***	***T***	***Testing***	***Strong***
VC218	5	3	HT	T	Testing	Average
VC225	7	4	T	MT	Testing	Average
VC241	10	6	T	T	Testing	Good
VC256	12	8	T	T	Testing	Good
VC44	3	2	HT	S	Testing	Weak
VC801	***8***	***6***	***HT***	***T***	***Testing***	***Strong***
Velvick	4	3	T	S	Dropped	Weak
W14	4	1	MT	S	Dropped	Weak
Witney	8	12	T	MT	Dropped	Average
Zentmyer	***12***	***30***	***S***	***HT***	***Released***	***Strong***
Zutano	2	1	MT	S	Dropped	Weak

S = Sensitive, MT = mildly tolerant, T = tolerant, HT = highly tolerant, ND = not enough information to evaluate

Miriam (WI x M)

Tami (WI x M)

Douhan et al., 2011

"Avocado growers are facing major constrains that affect negatively their profitability and sustainability"

- **Rootstock attributes**

Phytophthora root rot resistance (*Phytophthora cinnamomi*)

Salinity tolerance

Drought tolerance

Heat tolerance

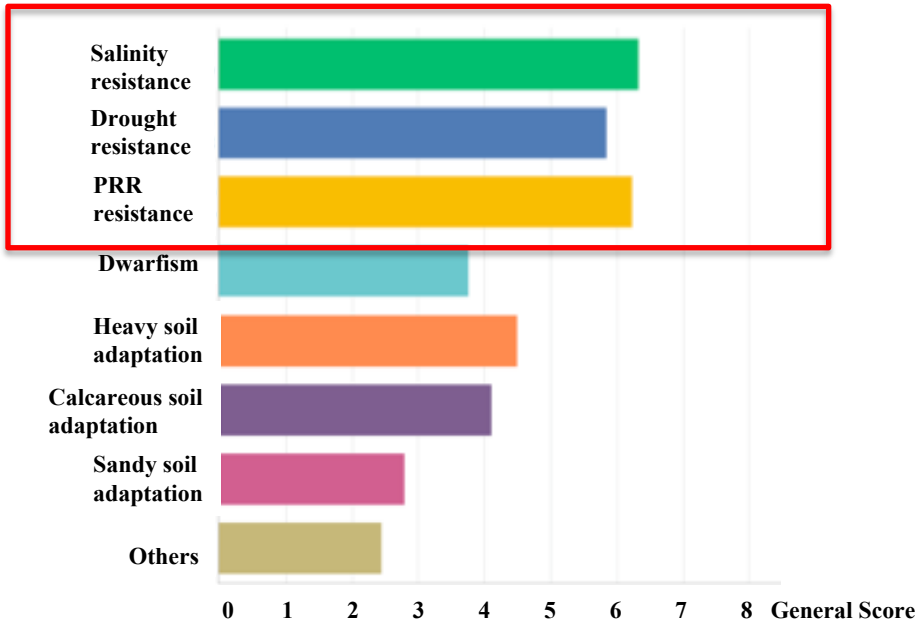
Alkalinity & high pH tolerance

Waterlogging/flooding tolerance

Resistance to other pathogens and pest

Cold tolerance

Dwarf phenotypes (For high density planting)



Surveymonkey report for our grower survey conducted in CA. Growers were asked to rate the top priorities for desirable rootstocks traits. From 70 surveyed grower from all regions in CA, resistance to salinity, PRR, and drought were the top 3 priorities in CA (*) with scores of 6.3, 6.2, and 5.8 respectively.

The UCR rootstock avocado breeding program aim to improve avocado production by reducing yield losses and production inputs

UCR Rootstock Genetic Diversity

- *Genetic diversity is the **foundation (Heart)** of ANY genetic improvement program.*

- *Identify genetic sources for different traits that will aid growers face current and future challenges: diseases, pests, environmental, etc.*

General traits

	Mexican	Guatemalan	West Indian
Native Region	Mexican Highlands	Guatemalan Highlands	Tropical lowlands
Climate Adaptation	Subtropical	Subtropical	Tropical
Cold Tolerance	Most	Intermediate	Least
Salinity	Least	Intermediate	Most

FRUIT TRAITS

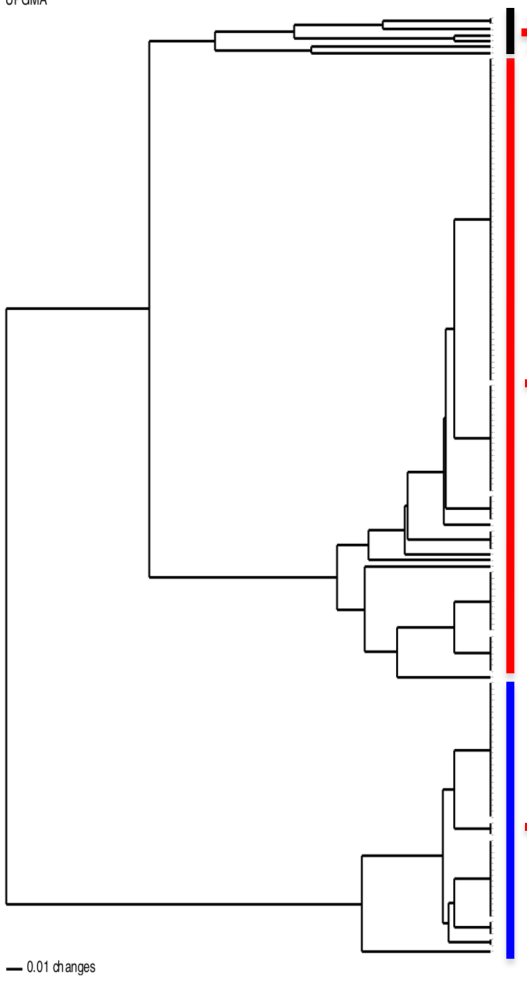
	Mexican	Guatemalan	West Indian
Size	Tiny-Medium	Small-Large	Medium-V. Large
Peel Color	Usually purple	Black or green	Green/maroon
Peel Thickness	Very thin	Thick	Medium
Seed Coat	Thin	Usually thin	Thick
Seed Tightness	Often loose	Tight	Often loose
Flavor	"Anise", spicy	Often rich	Sweet, mild
Oil Content	Highest	High	Low

Mary Lu Arapia

Phenotypic and genetic characterization of *P. cinnamomi* populations

Pagliaccia *et al*. (2013). Phytopathology 103 (1):91-97

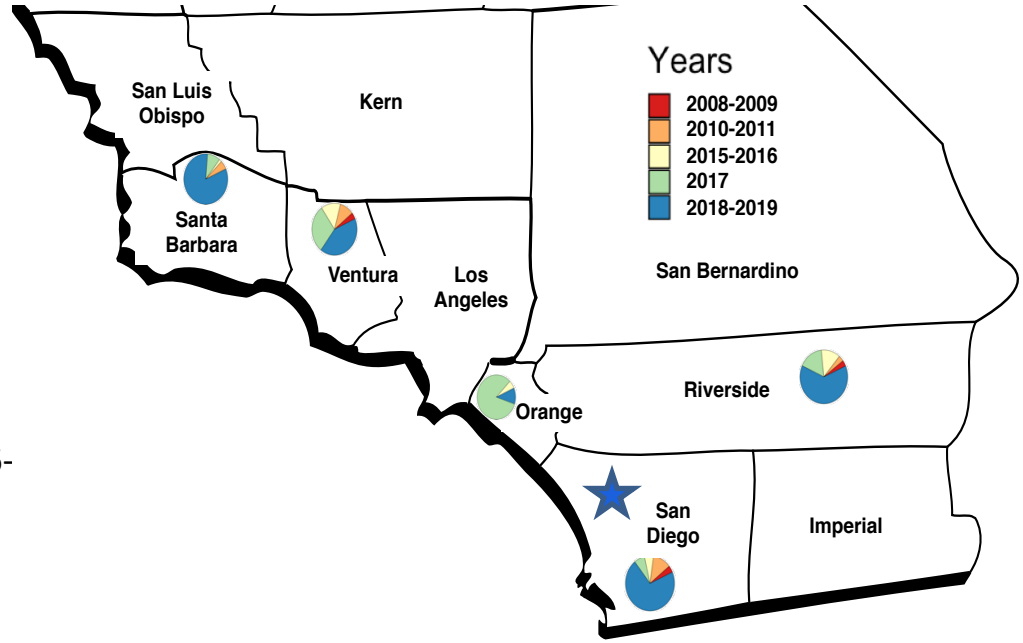
Collection of 308 isolates isolated from avocado orchards



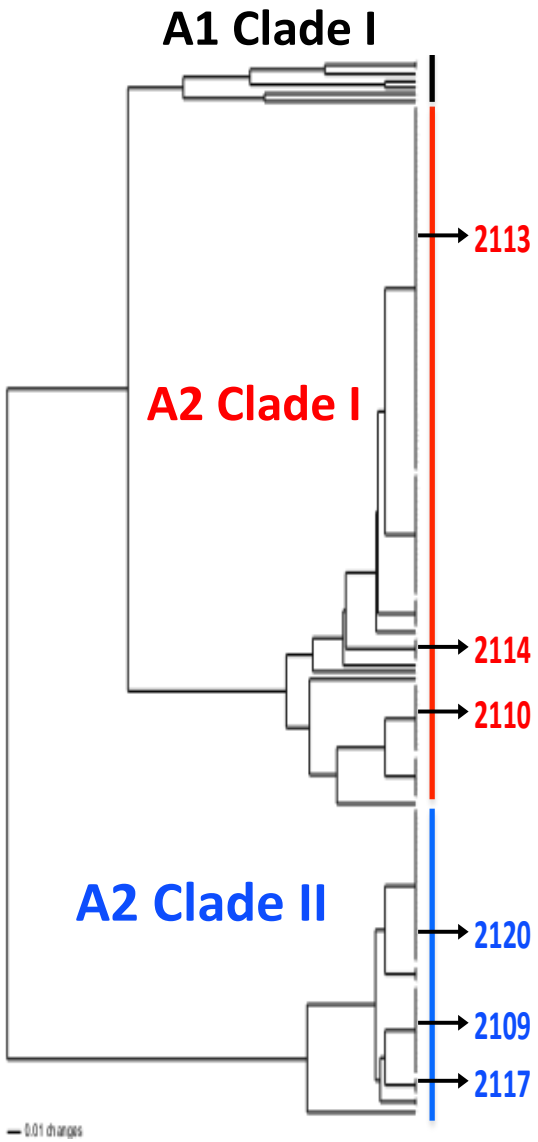
A1 Clade I
From avocado and different hosts from UCR WOC collection

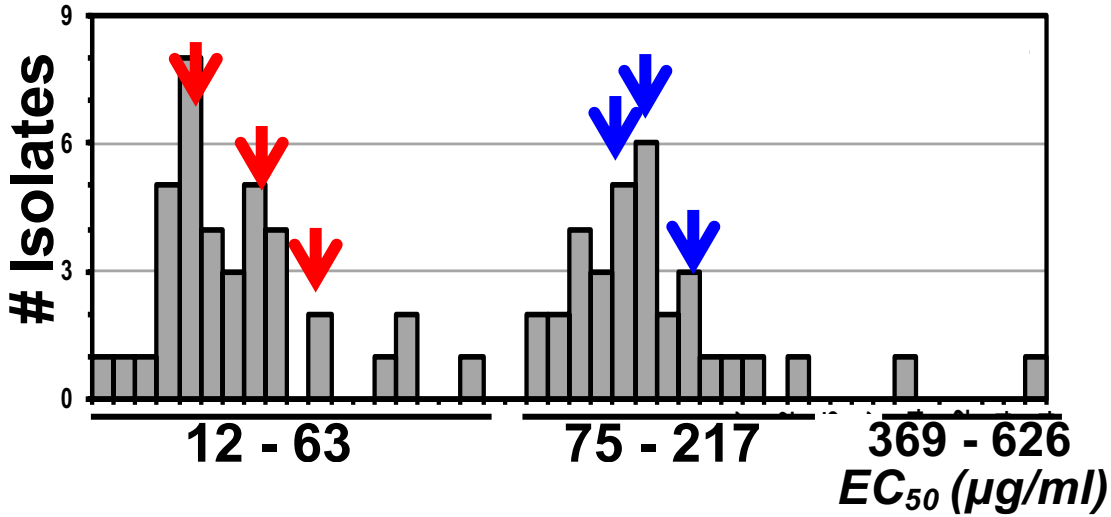
A2 Clade I
new S/N collections (2009-2010) & all older collections (1976-2007)

A2 Clade II ★
Only new Southern collections (2009-2010)



Phenotypic characterization of *P. cinnamomi* populations in CA



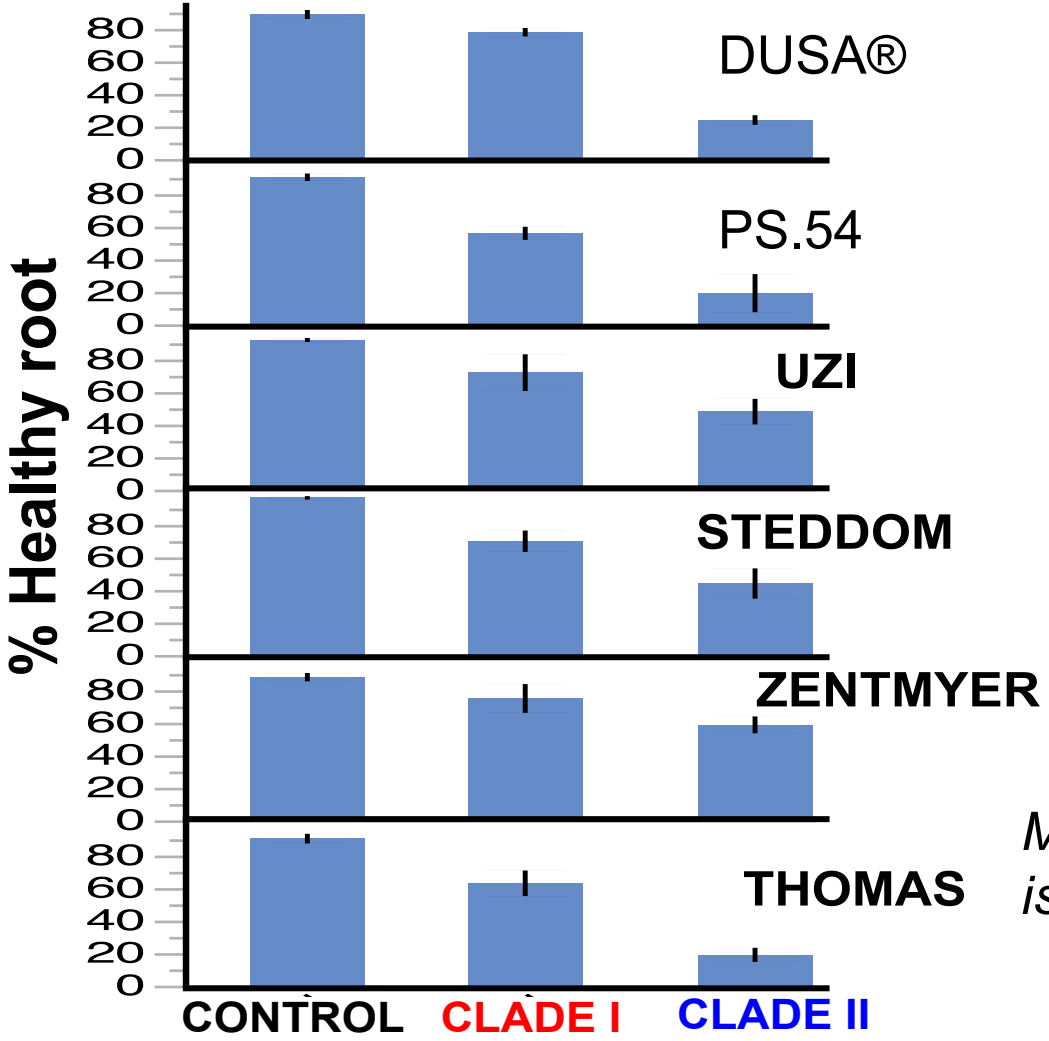


Pagliaccia *et al*. (2013). Phytopathology 103 (1):91-97

Belisle et al. 2019. *Phytopathology 109:384.*

Belisle et al. 2019. *Plant Disease 103(8):2024.*

Phenotypic characterization of P. cinnamomi populations in CA



Healthy root

100% **3%**

Mixture of A2 Clade II Southern isolates were more aggressive

Oxathiapiprolin (Orondis) exhibited the best activity against P. cinnamomi isolates

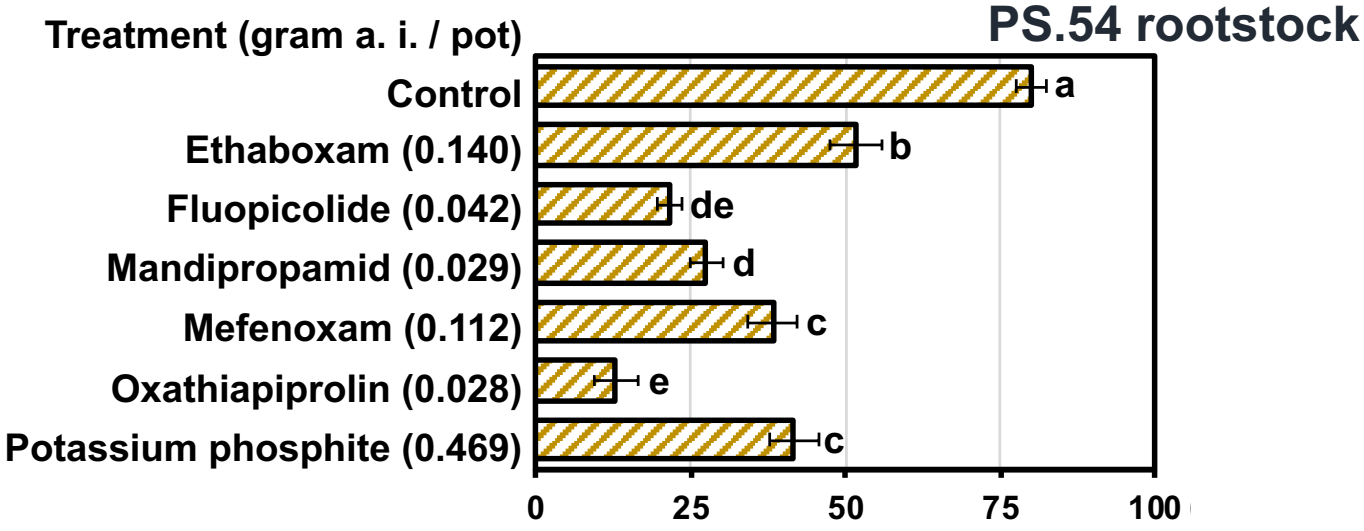
Belisle et al. 2019. ***Plant Disease 103(8):2024.***

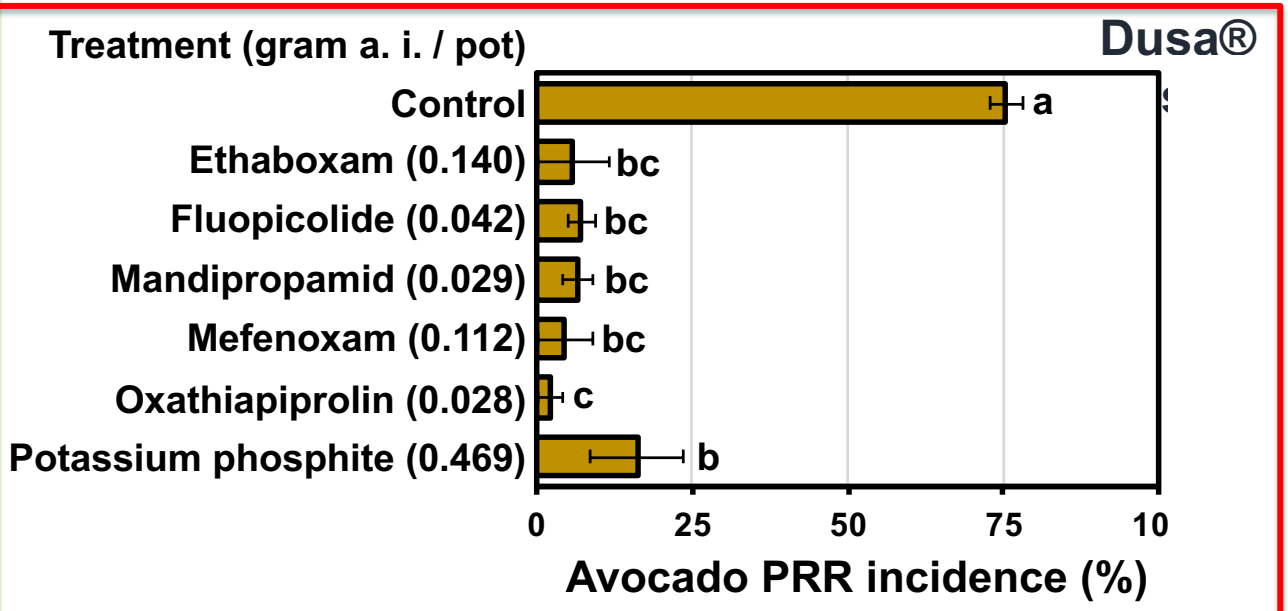
Fungicide EC_{50} (µg/ml)

Fungicide	All isolates (n=71)			Southern isolates (n=47)[w]			Northern isolates (n=24)[x]			Southern vs. northern means
	Range	Mean	Tukey	Range	Mean	Tukey	Range	Mean	Tukey	*P*-Value
Ethaboxam	0.017-0.069	0.035	d	0.018-0.066	0.034	d A	0.017-0.069	0.037	d A	0.362
Fluopicolide	0.046-0.330	0.133	b	0.046-0.330	0.131	b A	0.069-0.257	0.135	b A	0.637
Mandipropamid	0.003-0.011	0.005	e	0.003-0.011	0.005	e A	0.003-0.011	0.006	e A	0.217
Oxathiapiprolin	0.0002-0.0007	0.0004	f	0.0002-0.0006	0.0003	f A	0.0002-0.0007	0.0004	f A	0.053
Mefenoxam	0.023-0.138	0.061	c	0.026-0.138	0.061	c A	0.023-0.100	0.062	c A	0.866
Potassium phosphite	12.9-361.2	81.5	a	12.9-316.2	98.9	a A	16.6-266.2	47.3	a B	0.001

Fungicide efficacy using clonal rootstocks under greenhouse conditions

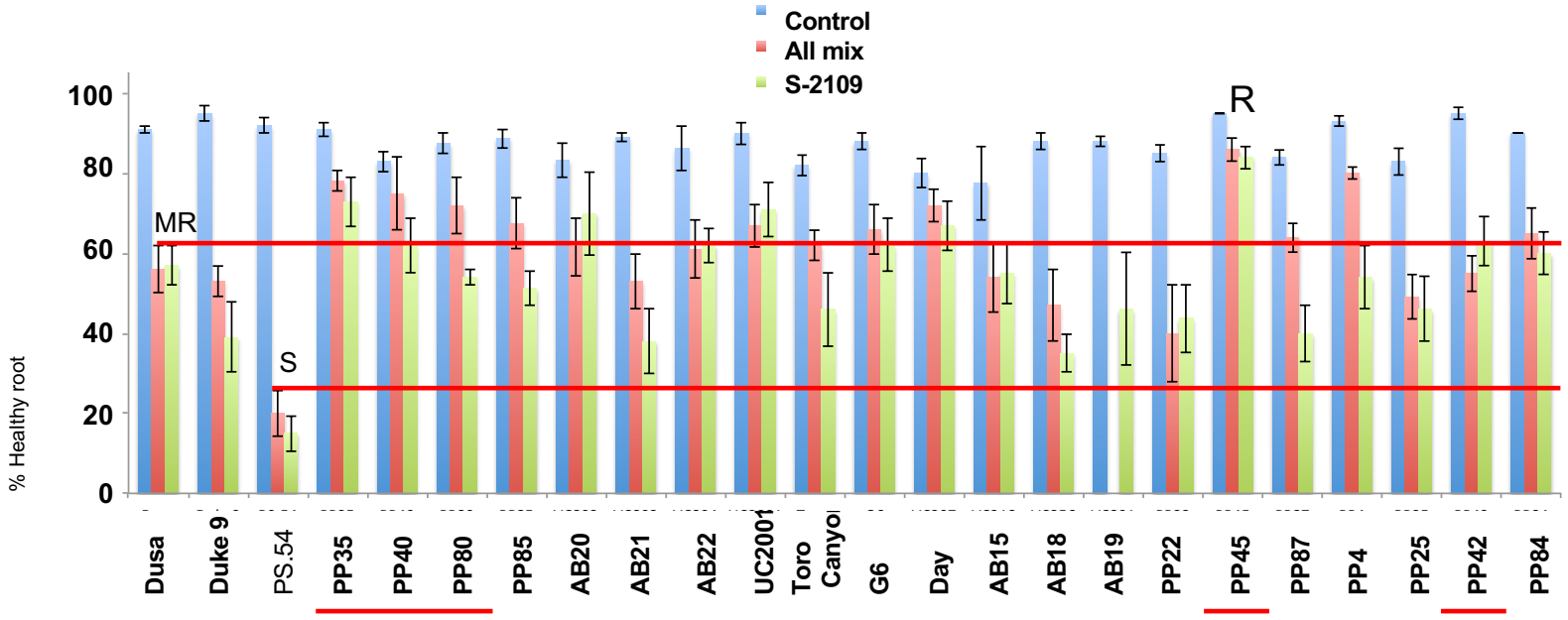
Belisle et al. 2019. *Plant Disease 103(8):2024.*





Re-screen/screen new rootstock for resistance to the current *P. cinnamomi* population

UCR Advance selection	Race	PRR	Salinity	Flower type	Years field data
Dusa (CA standard)	M x G	MR	T	B	4
PP35	M x G	MR	T	B	4
PP40	M x G	MR	T	B	4
PP80	M x G	MR	MT	B	4
PP42	M	MR	MT	B	4
PP45	M	R	S	B	4



- *Confirmation of resistance: PRR incidence, PPg/soil, pathogen biomass using qPCR*

AgOPs field salinity experiments (Dr. Peggy Mauk)

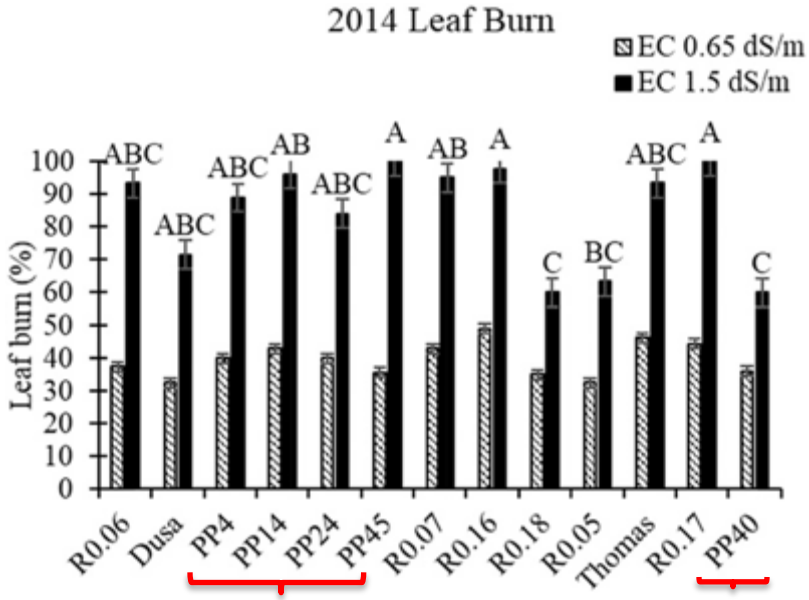
"Evaluation of rootstocks for salinity tolerance"

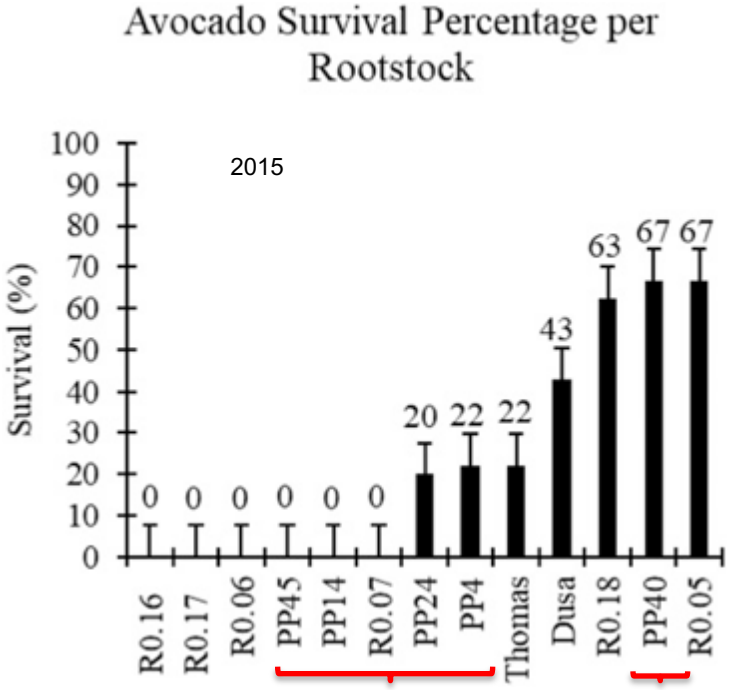
HortScience 53(12):1737–1745. 2018. https://doi.org/10.21273/HORTSCI13198-18

Salt Tolerance and Growth of 13 Avocado Rootstocks Related Best to Chloride Uptake

Nydia Celis[1] and Donald L. Suarez
U.S. Department of Agriculture–Agricultural Research Service, U.S. Salinity Laboratory, 450 W. Big Springs Road, Riverside, CA 92507

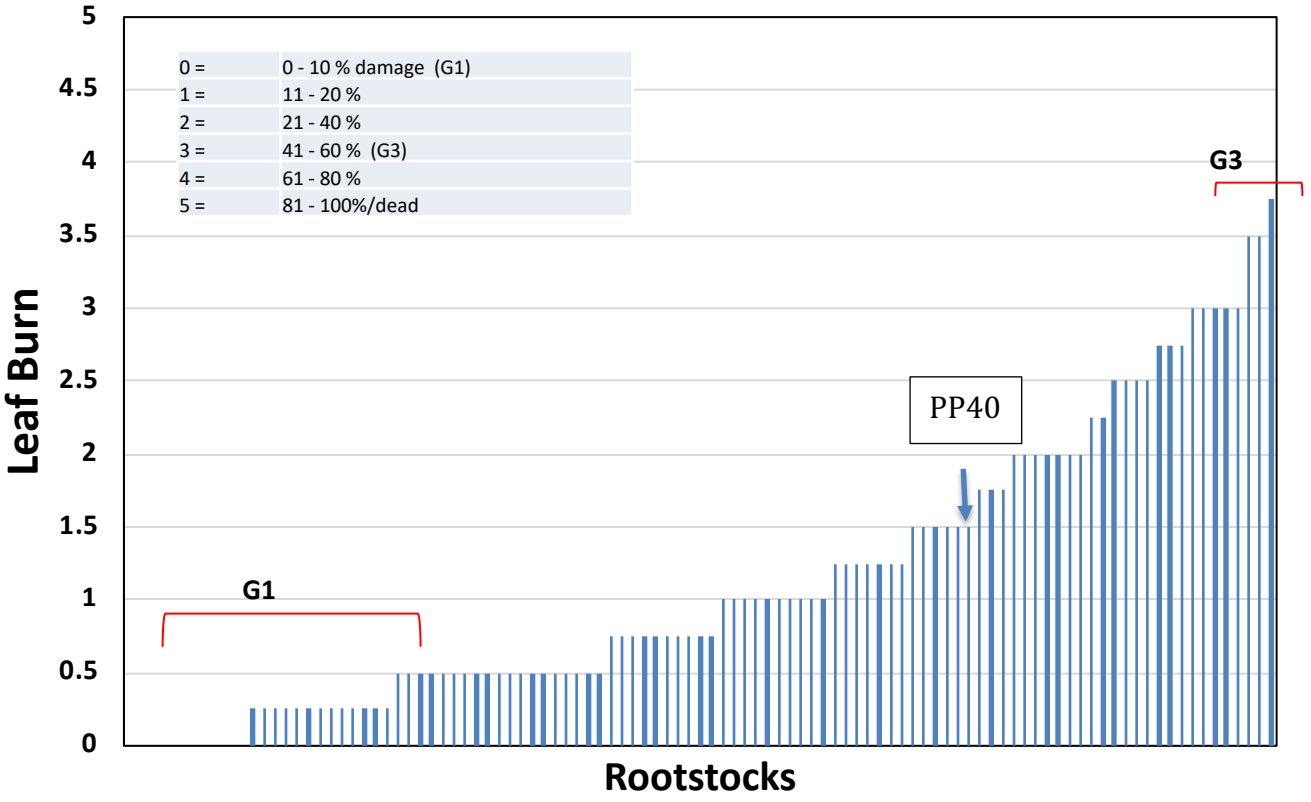
Laosheng Wu, Rui Li, Mary Lu Arpaia, and Peggy Mauk
University of California, Riverside, 900 University Avenue, Riverside, CA 92507





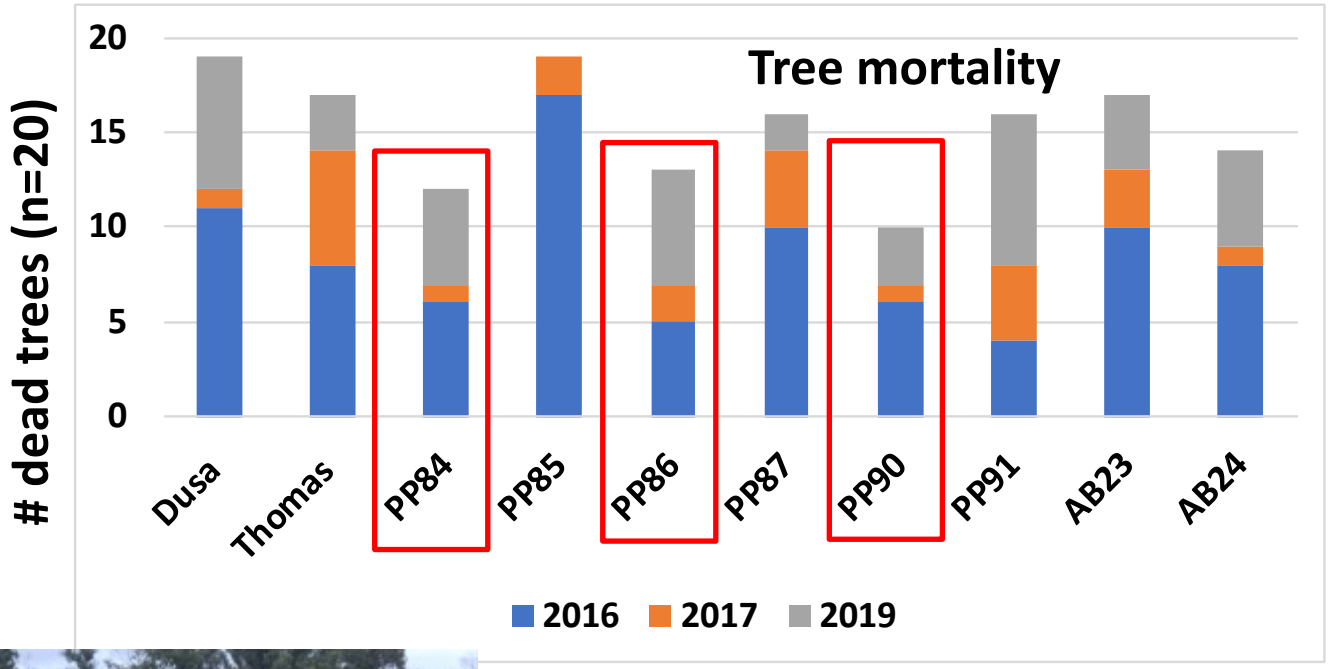
Field Evaluation for selection of heat resistant rootstock

G1= UC2001 and seedlings including PP80 and PP35, Duke 9 and seedlings, VC207
G3= Spencer, Spencer seedlings, and VC804.
PP40 intermediate phenotype



Leaf burn rating (August 2018) in Field 7 SCREC. Ratings were done using a score system of 0 = no heat or salinity damage to 5 = Dead. Rating occurred after severe heat spell. Rootstocks were grafted on Dusa.

Field Evaluation of rootstocks



Limoneria 3, Santa Paula (2019)

Field Evaluation of UCR rootstocks (small trials)

Field location (# plots)	County	Conditions
Santa Paula (5)	Ventura	*Phytophthora cinnamomi*, high pH (7.9-8.7), alkalinity (as CaCO3), high salinity and chloride.
Temecula (3)	Riverside	*P. cinnamomi*, high pH and alkalinity (as CaCO3), high salinity and chloride.
Ramona (2)	San Diego	High pH, alkalinity (as CaCO3), high salinityand chloride.
Fallbrook (1)	San Diego	*P. cinnamomi*, high salinity and chloride. 10’ x 10’ planting, organic

- Canopy measurements.
- Overall tree health (0 best - 5).
- Leaf necrosis: tip burn and heat burn (0 best -5).
- Tree mortality.
- Individual tree yield data (weight and fruit number).

Fig. 5. Overall tree health and leaf necrosis scoring system developed and used by the UCR avocado rootstock breeding program.

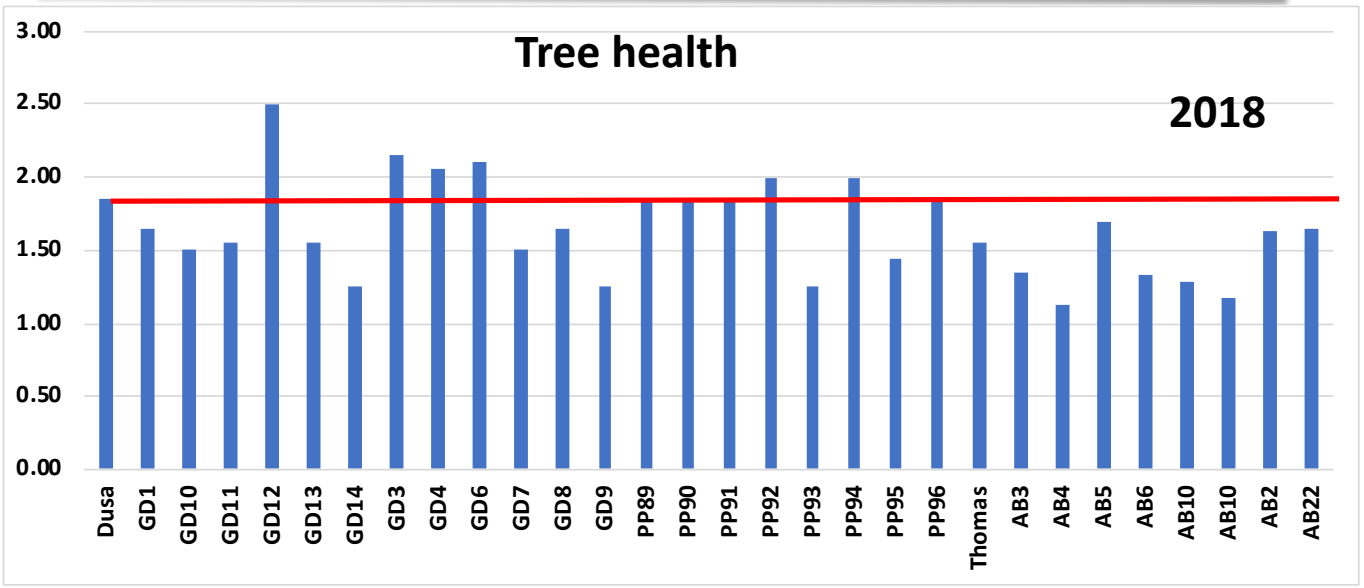
Score	Overall Health	Salinity/Heat
0	Perfect looking tree	0 - 5 % damage, perfect/healthy
0.5	Slightly off (less leaves/small leaves, lack of flush)	5 - 10 %
1	Yellow leaves and or small leaves	11 - 20 %
2	Exposed branches, wilting leaves, small yellow leaves	21 - 40 %
3	Branch dieback, very few leaves remaining, starting to die	41 - 60 %
4	Almost dead, won't last long	61 - 80 %
5	Dead	81 - 100 %

Overall tree health and leaf necrosis = 0

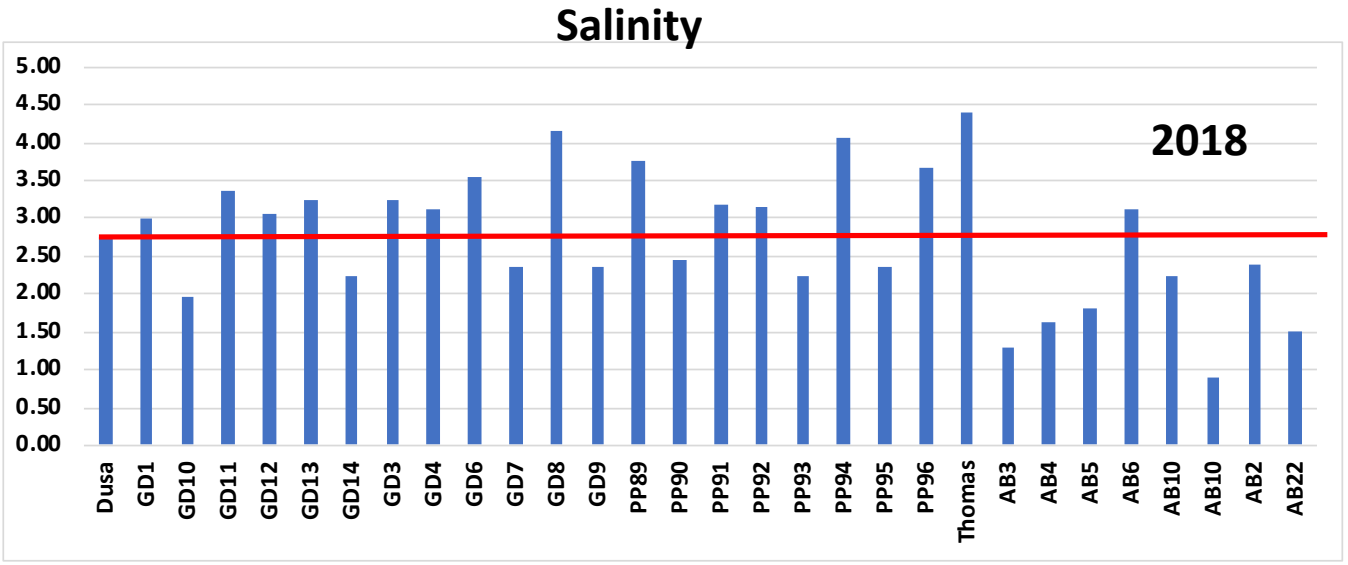
Overall tree health = 4
Leaf necrosis = 0

Overall tree health = 3.5
Salinity damage = 4

New selections evaluated in Ramona (2014). Tom Royden and Kozy



Overall tree health (0 best – 5). Leaf necrosis (salinity), heat damage (0 best – 5)



- *No Pc detection*
- *High pH*
- *High $CaCO_3$*
- *E.C 1.74 dS/m*
- *High Chloride*

(275 mg/L)

New selections evaluated in Ramona

Tom Royden and Kozy

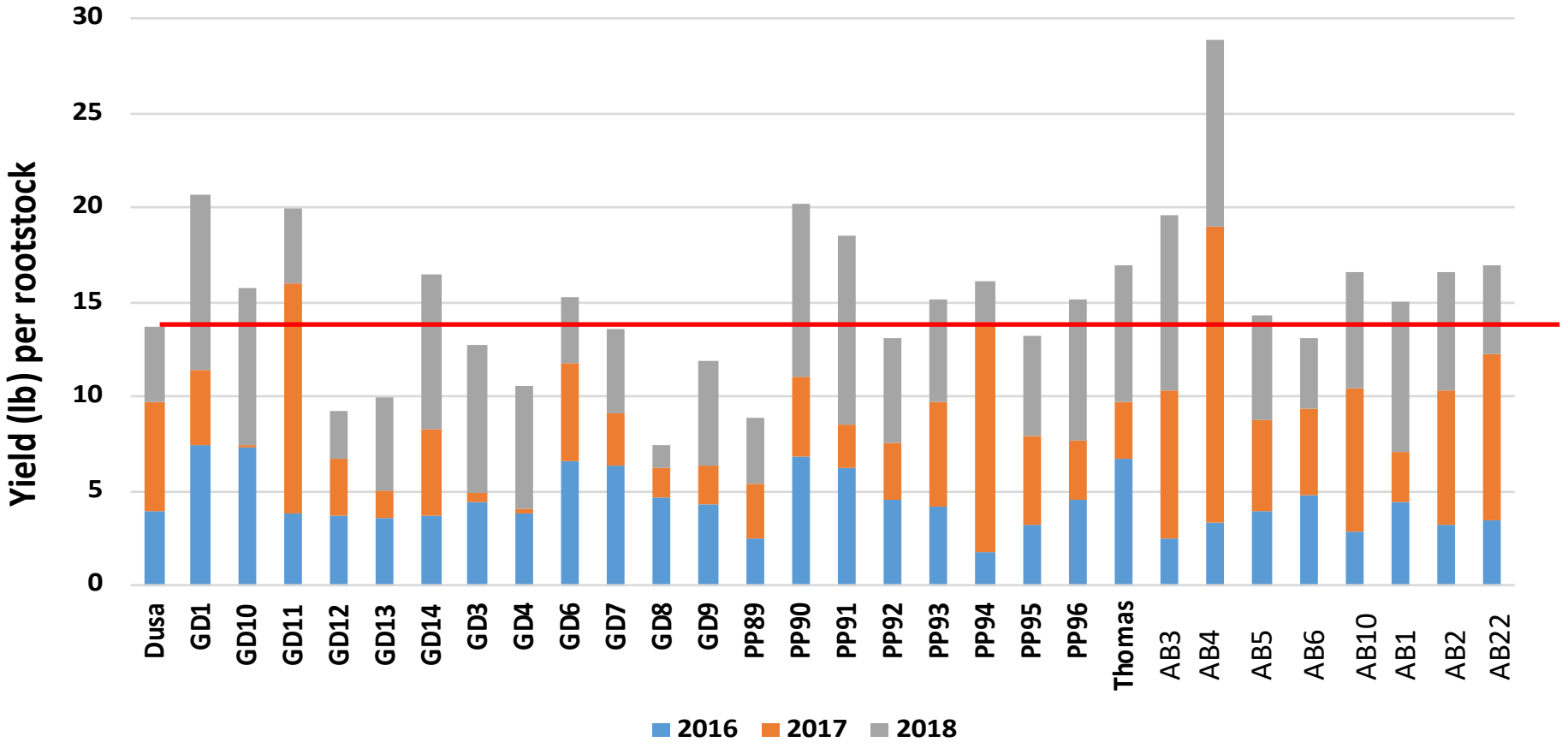
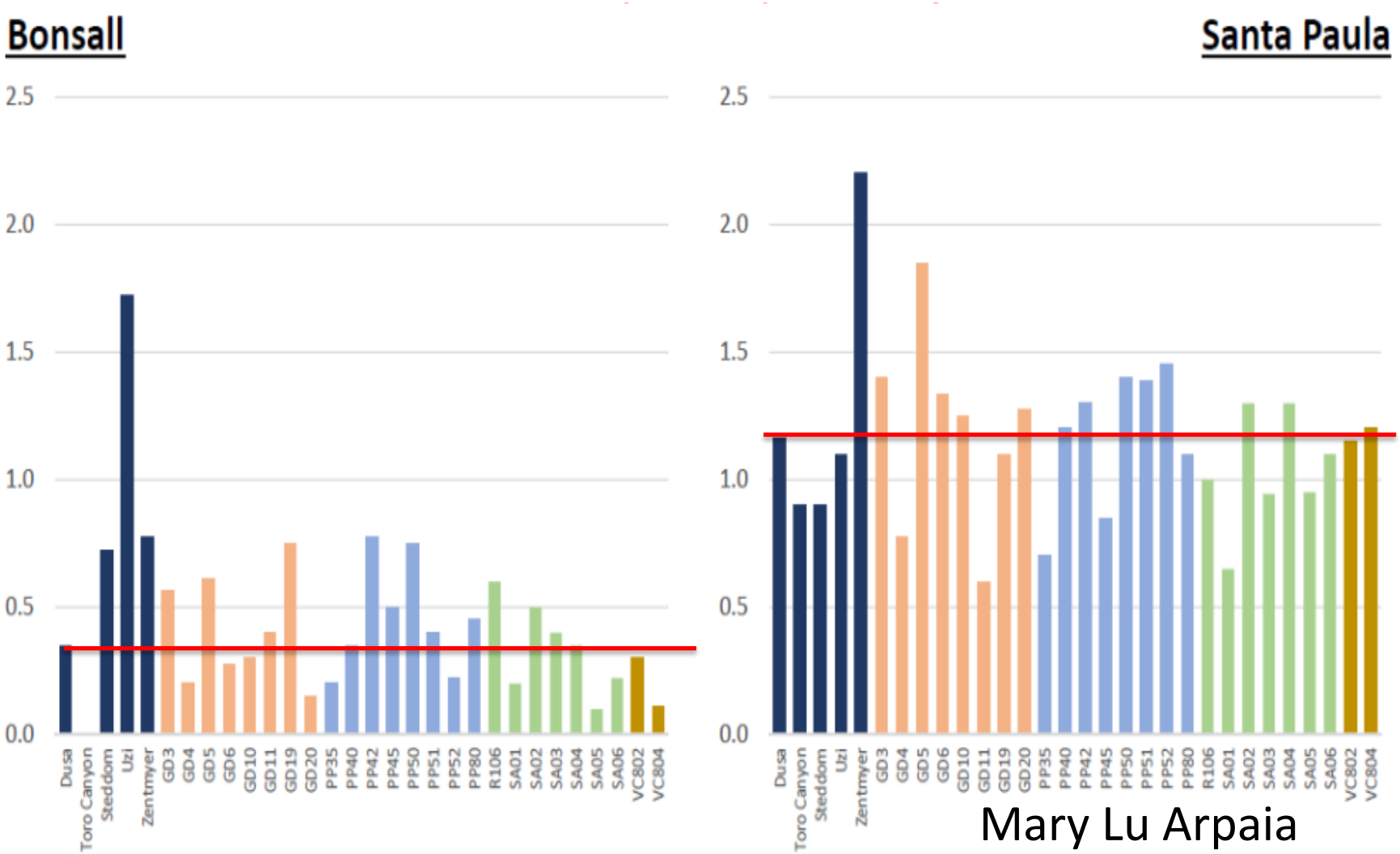


Fig. 68. Cumulative yield (Lb) per rootstock accession in Tom Royden #1 plot, Ramona.

Field Evaluation in Bonsall and Pine Tree_2017

Tree health ratings (0 – 5) for both sites in **July 2018** following the severe heat event. A score of 0 = healthy and vigorous and 5 = dead



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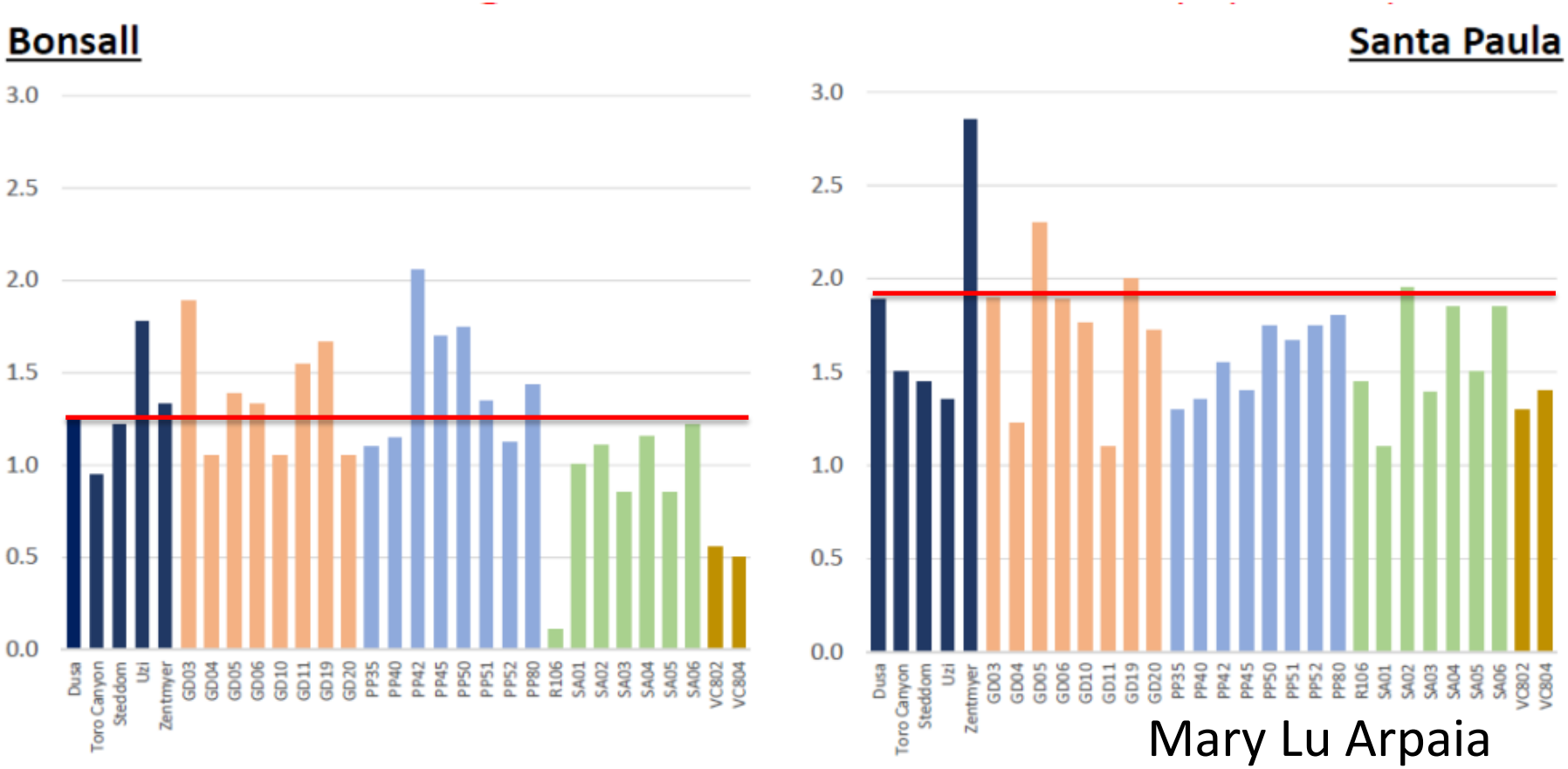
Heat/Salinity rating on a 0 – 5 scale for both sites in **July 2018** following the severe heat event. A score of 0 = no apparent damage, 3 = moderate leaf damage and some shoot dieback, 5 = moderate to severe leaf damage throughout the tree with extensive shoot tip dieback.



First harvest at Bonsall (May 2019)

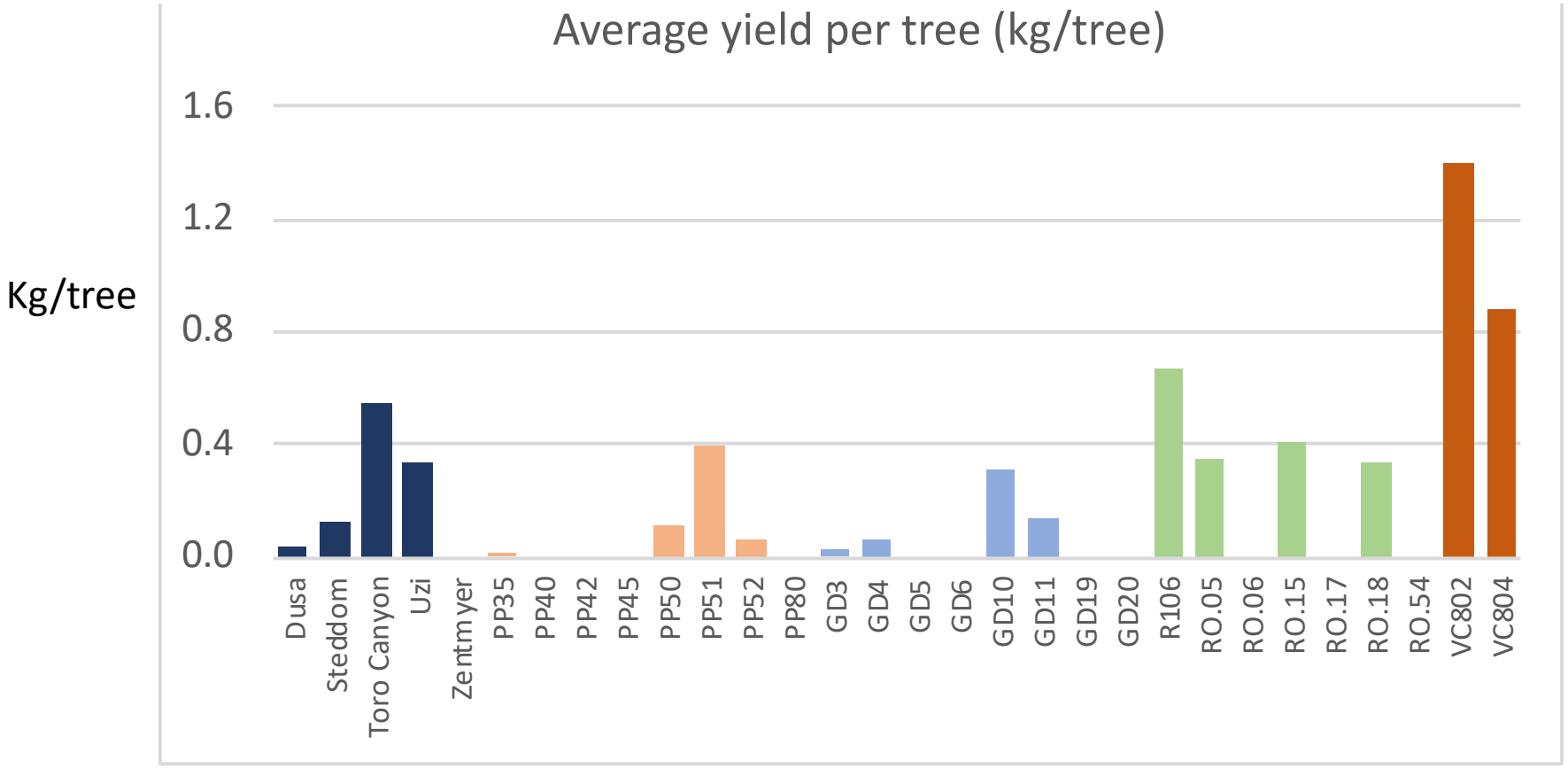


Figure 6C. Bonsall Research Site. Average kg/tree yield for trees harvested on May 16, 2019.

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October 2017

Pine Tree, Santa Paula

Krnich Plot, Fallbrook

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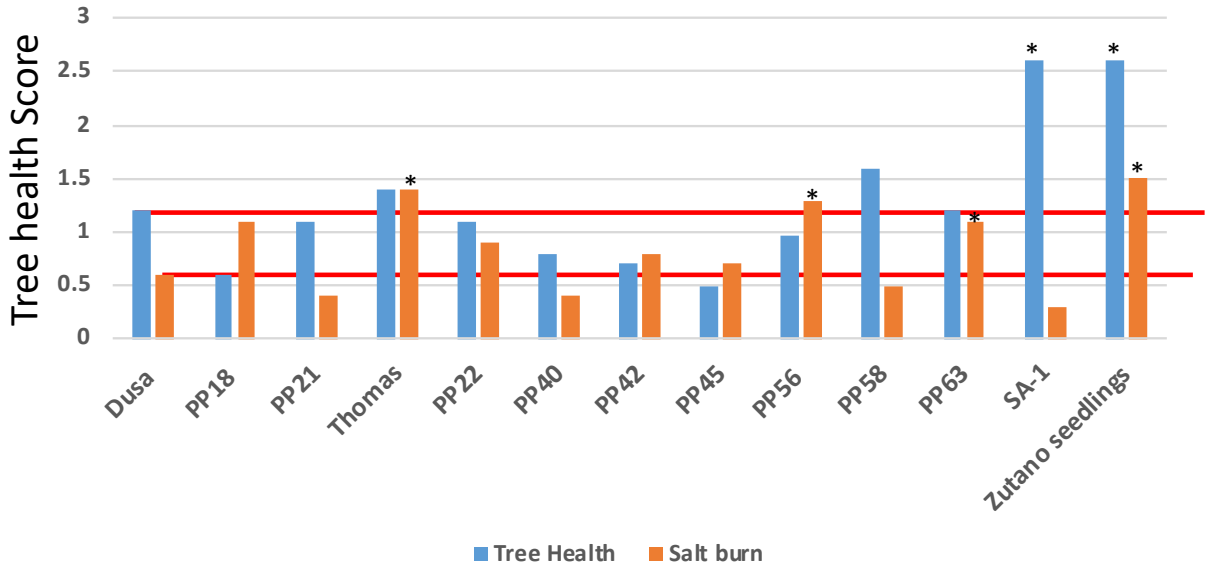
Field Evaluation of PP40,PP35, PP42, PP45, PP80

GUNDERSON (2019)

A **Tree Health and salt burn ratings at Gunderson April 2019**

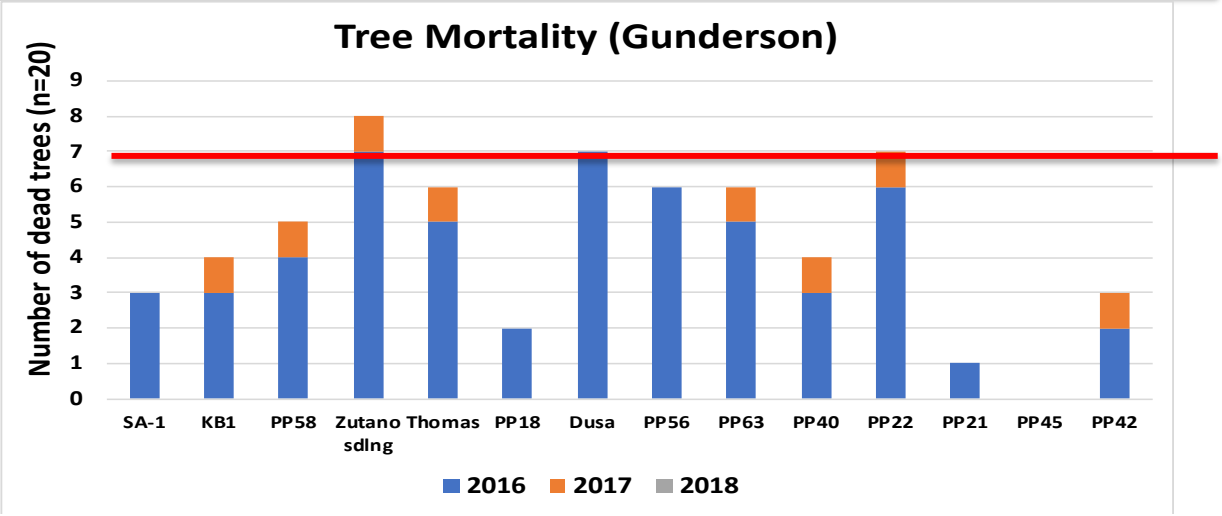


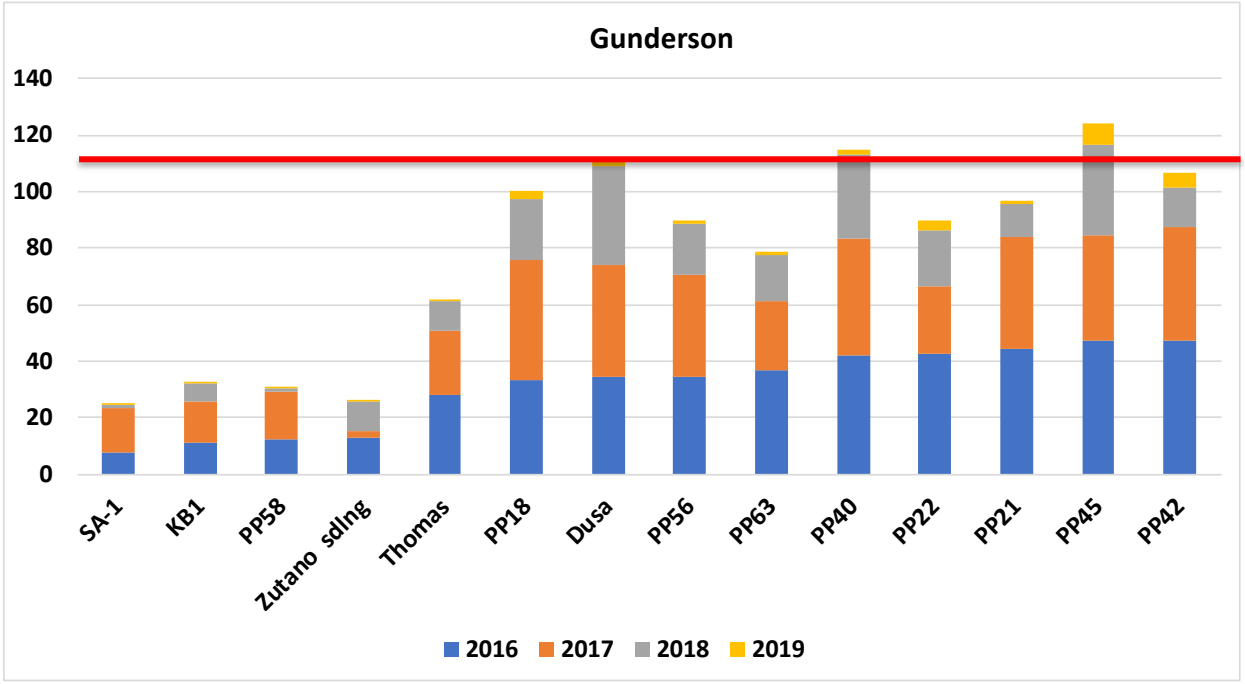
Overall tree health (0 best – 5).
Leaf necrosis (salinity), heat damage (0 best – 5)

* = Significantly different than Dusa

Field Evaluation of PP40,PP35, PP42, PP45, PP80

GUNDERSON (2019)





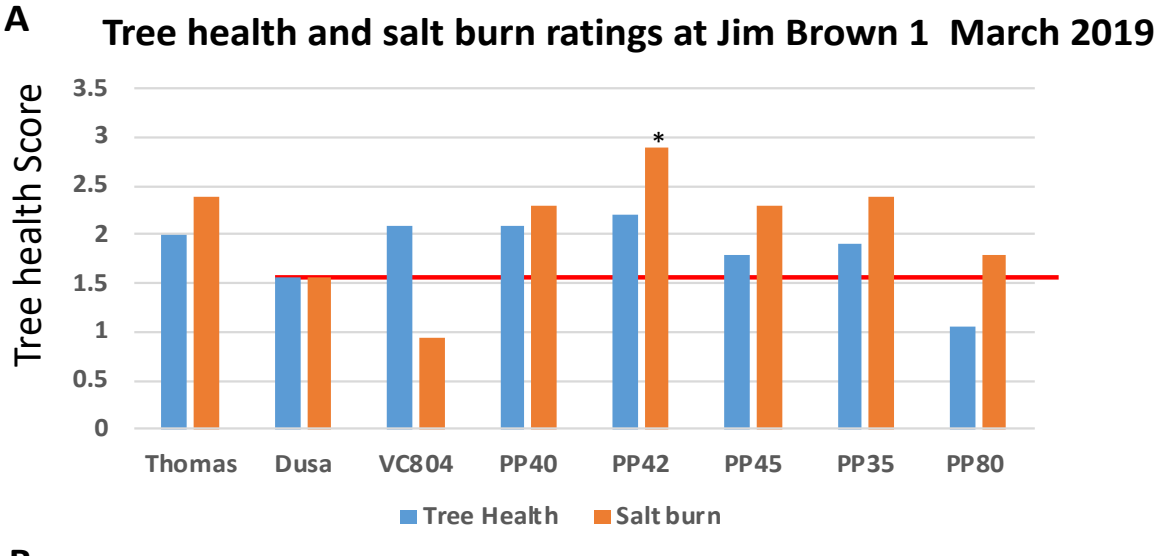
Field Evaluation of PP40,PP35, PP42, PP45, PP80

Jim Brown 1 (2019)

* = Significantly different than Dusa

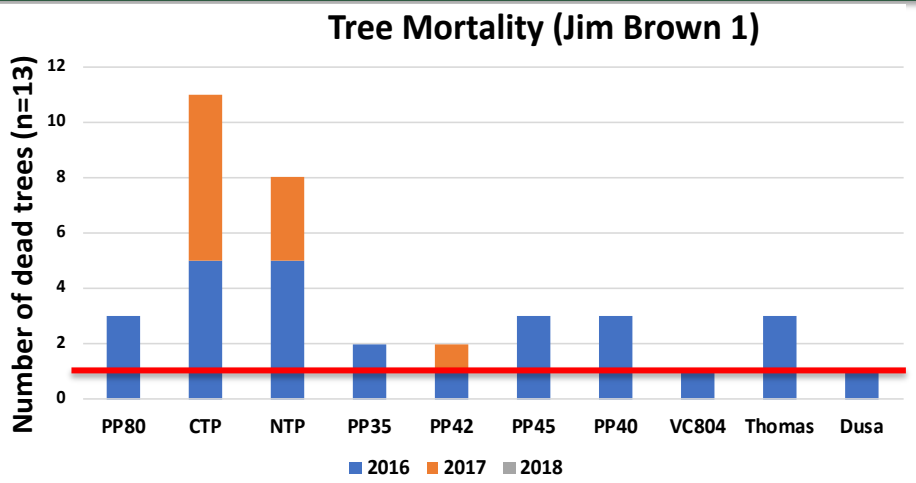
Overall tree health (0 best – 5).
Leaf necrosis (salinity), heat damage (0 best – 5)

A



Field Evaluation of PP40,PP35, PP42, PP45, PP80

Jim Brown 1 (2019)



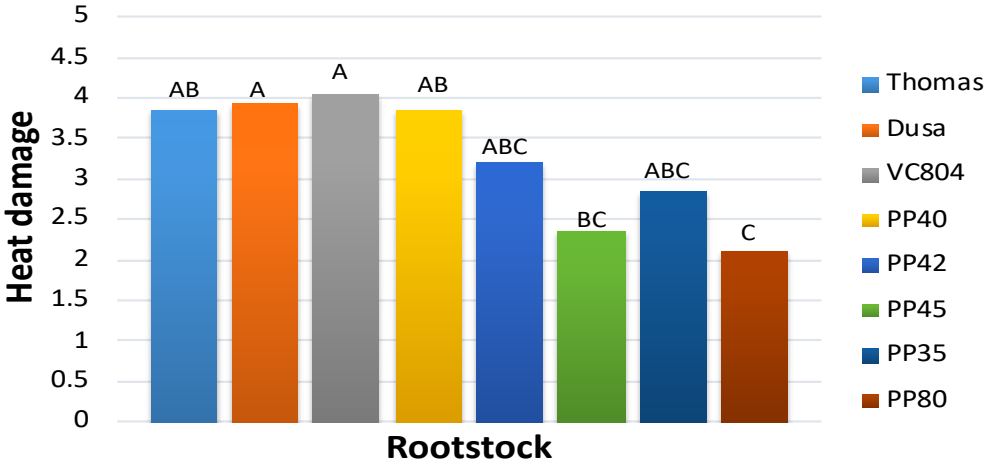


Fig. 66. Heat damage rated in July 2018 at Jim Brown ranch in Southern CA. Trees were score from 0 – 5: 0 = 0-10% heat damage, 1 = 11-20%, 2 =21– 40%, 3= 41–60%, 4= 61-80%, and 5 = 81–100%. Statistical analyses were done using ANOVA and significantly differences among rootstocks were tested using HSD test. Levels not connected by the same letter are significant different.

Field Evaluation of PP40,PP35, PP42, PP45, PP80

Jim Brown 1 (2019)

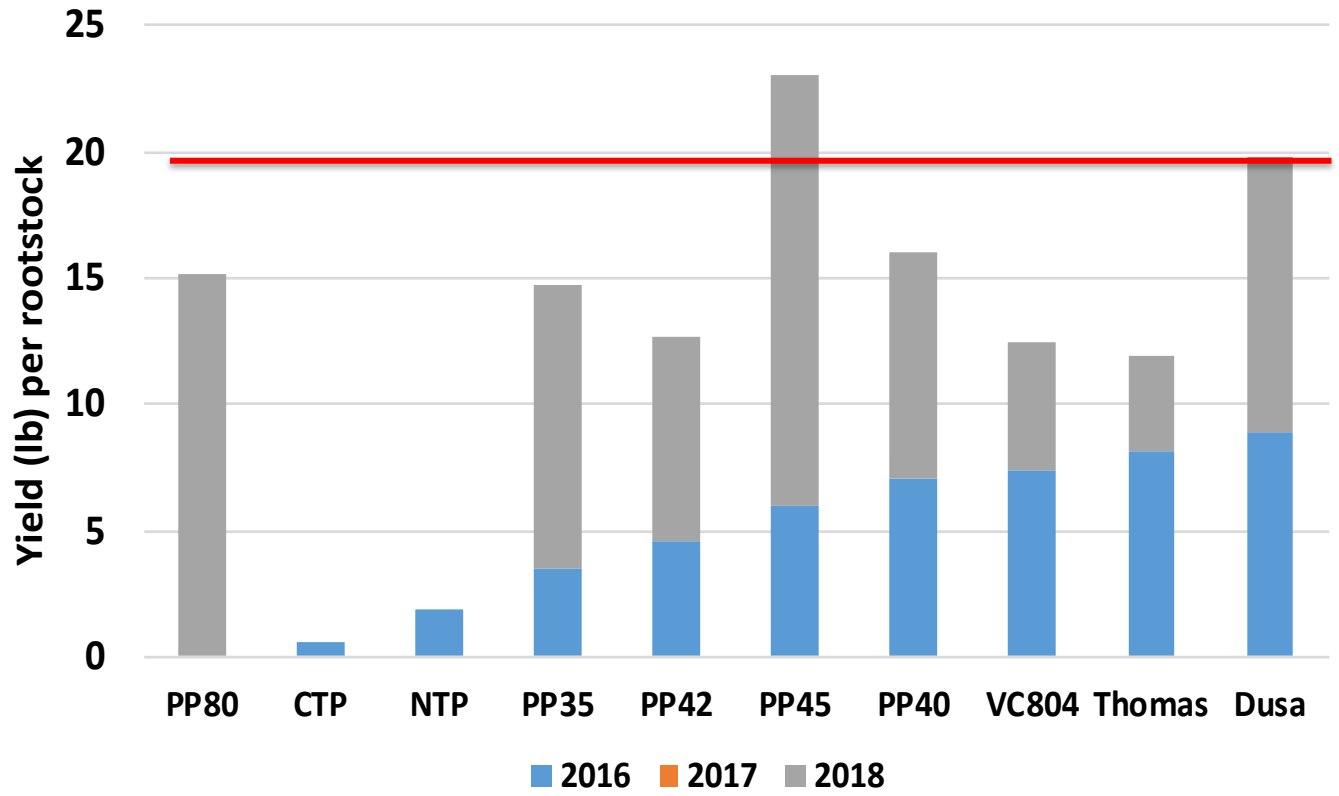


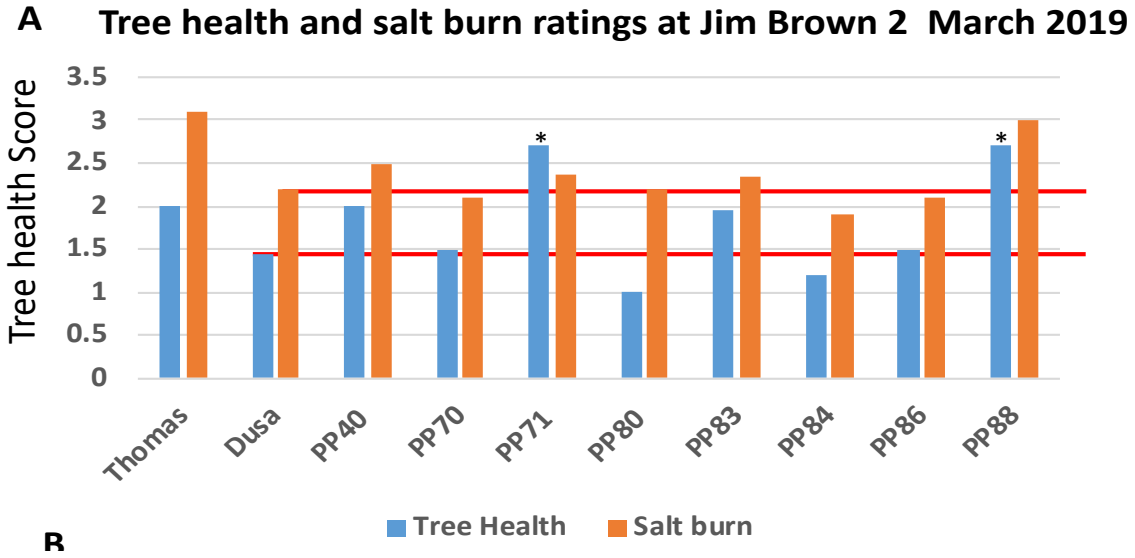
Fig. 64. Cumulative yield (Lb) per rootstock accession in Jim Brown #1, Temecula.

Field Evaluation of PP40,PP35, PP42, PP45, PP80

Jim Brown 2 (2019)

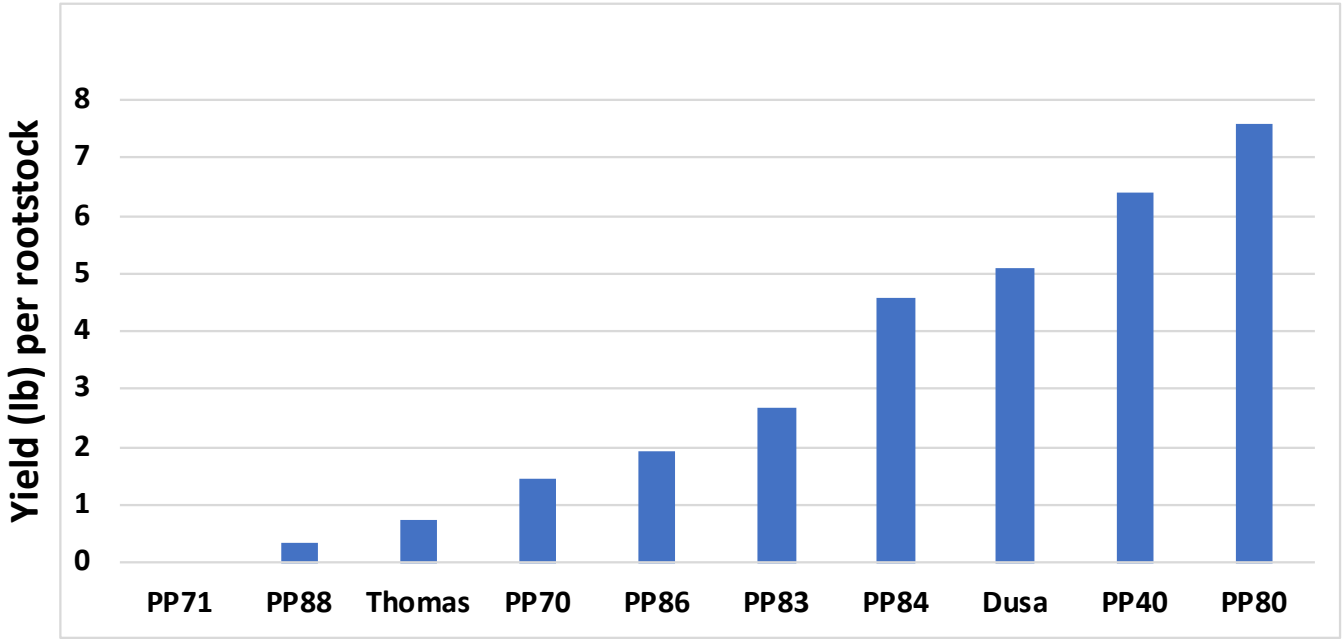
* = Significantly different than Dusa

Overall tree health (0 best – 5).
Leaf necrosis (salinity), heat damage (0 best – 5)



Field Evaluation of PP40,PP35, PP42, PP45, PP80 (old plots)

Jim Brown 2 (2018)



PP40: Good resistance to PRR and tolerant to salinity

Pictures: Peggy Mauk, AgOPs UCR

Ventura 2019

RO.05 (South African Selection) and PP35 exhibited similar levels of salinity tolerance. PP35 is smaller than RO.05.

RO.05 PP35

Pictures: Peggy Mauk, AgOPs UCR

2019: Santa Paula (Ventura) under PRR, high pH, and high alkalinity as $CaCO_3$ conditions

Dusa

PP45

2019: Santa Paula (Ventura) under PRR, high pH, and high alkalinity as $CaCO_3$ conditions

Dusa

PP42

PP80: PRR resistant, salinity and heat tolerant

2019: Temecula plot under PRR, high salinity, high pH and high alkalinity as $CaCO_3$ conditions

Dusa

PP80

Semi-commercial trials with 5 most advanced UCR rootstocks (UCR and CAC)

100 trees/rootstock
Hass grafted

Grower	County	Year	Rootstocks	Conditions
Leo McGuire	Riverside	2019	PP35, PP40	PRR and high chloride levels
John Lamb	Ventura	2019	PP35, PP40	PRR, high chloride and pH
Massod Sohaili (Rick and CJ Shade)	Ventura	2020	PP35, PP40, PP45, PP42 (28), PP80 (39)	High PRR (replanting)
Andrew Gabryszak	Riverside	2020	PP35, PP40, PP45	PRR and high chloride levels
Pete Miller	Santa Barbara	2020	PP35, PP40, PP45, PP42 (28), PP80 (39)	High PRR, high chloride, high EC, clay soils.
Chris Sayer	Ventura	2020	PP35, PP40, PP45	High salinity (EC) and high alkalinity
Dr. Lauren Garner (Cal Poly State University, SLO)	San Luis Obispo	2020	PP35, PP40, PP45	Pending water analyses and PRR analyses

Field trials with 5 most advanced UCR rootstocks in other countries

https://news.ucr.edu/articles/2020/06/09/uc-riverside-and-eurosemillas-partner-bring-next-generation-avocados-market

UC Riverside and Eurosemillas partner to bring the next generation of avocados to market

Eurosemillas will test some of UCR's avocado scion and advanced rootstock selections on other continents

AUTHOR:
HOLLY OBER

June 9, 2020

UC Riverside has entered into a $2.25 million partnership with Spain-based Eurosemillas S.A., a global leader in the commercialization of agriculture innovations, to help the university bring to market the most promising and advanced avocado scions and rootstocks in its collection.

If successful, these varieties would meet diverse regional growing requirements, exhibit better post-harvest characteristics, increase yields, provide resistance against disease, and expand consumer market diversity.

"Eurosemillas has successfully commercialized citrus varieties developed at UC Riverside in the past. They have the global network and expertise to do the same with the next generation of avocados," said Brian Suh, director of technology commercialization in the Office of Technology Partnerships at UC Riverside, who worked with a team on this initiative for the past four years.

Scion yield by rootstocks

Trees planted 12 x 15 feet

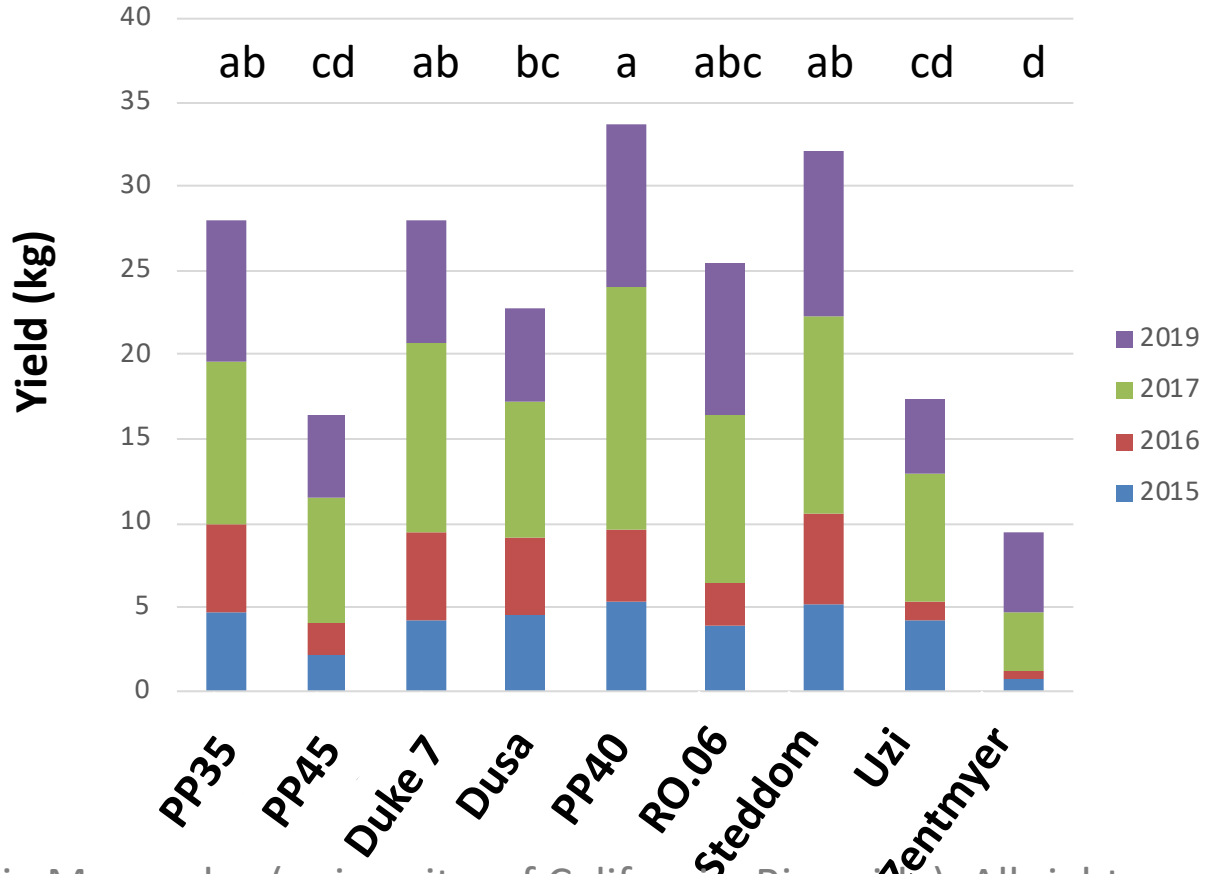
Randomized Complete Block Design

Trees planted June 2012

Zentmyer, Steddom, Uzi, PP35, PP40, and PP45 grafted to

Hass, Carmen, GEM, Lamb, and Reed scions.

There is no variety x rootstock interaction for tree size currently



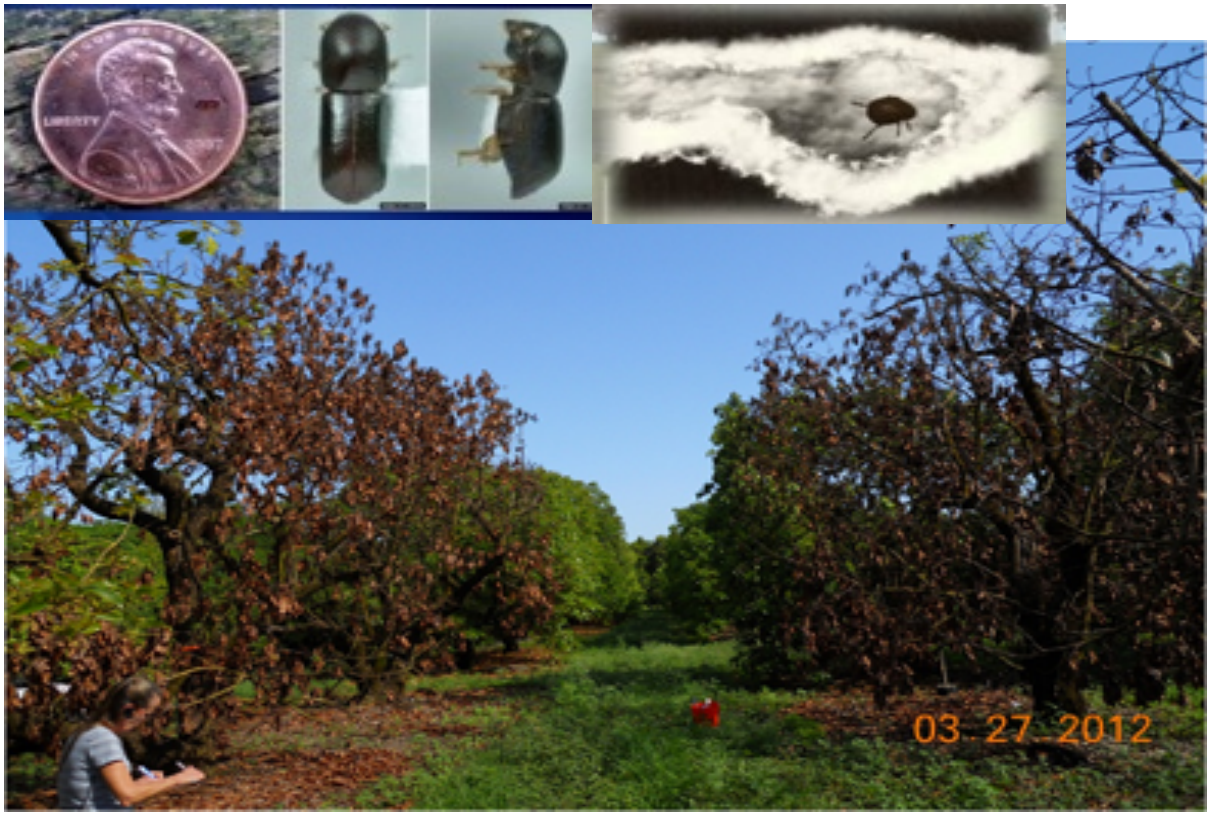
Mary Lu Arpaia

AVOCADOS IN DANGER!!

Laurel Wilt Disease

Ambrosia beetle-*Raffaelea lauricola*

60% avocado crop lost in FL



http://www.freshfromflorida.com/Divisions-Offices/Plant-Industry/Agriculture-Industry/Pests-Diseases/Laurel-Wilt-Disease

DUSA IS SUSCEPTIBLE TO WHITE ROOT ROT

Martínez-Ferri *et al. BMC Plant Biology* (2019) 19:458
https://doi.org/10.1186/s12870-019-2016-3

BMC Plant Biology

RESEARCH ARTICLE Open Access

Mild water stress-induced priming enhance tolerance to *Rosellinia necatrix* in susceptible avocado rootstocks

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RESEARCH ARTICLE

Rosellinia necatrix infection induces differential gene expression between tolerant and susceptible avocado rootstocks

Adela Zumaquero[1], Elsa Martínez-Ferri[2], Antonio J. Matas[3], Bianca Reeksting[4,5], Nicholas A. Olivier[5,6], Fernando Pliego-Alfaro[3], Araceli Barceló[1], Nöelani van den Berg[4,5], Clara Pliego[1*]

"WE NEED MORE VARIETIES, ROOTSTOCKS, AND SCION X ROOTSTOCK COMBINATIONS FOR A COMPETITIVE AND SUSTAINABLE AVOCADO INDUSTRY"

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Noelani Van den Berg – University of Pretoria (SA)

Pest and beneficial

USDA NIFA

California Avocado Society (CAS)
Our grower cooperators
Brokaw Nursery

UC MEXUS-CONACYT

UCR cdfa CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

Eurosemillas

CALIFORNIA AVOCADO COMMISSION

UCR CNAS Delfino funds