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NC-140
Peach, Apple and Cherry Rootstock Trials Update

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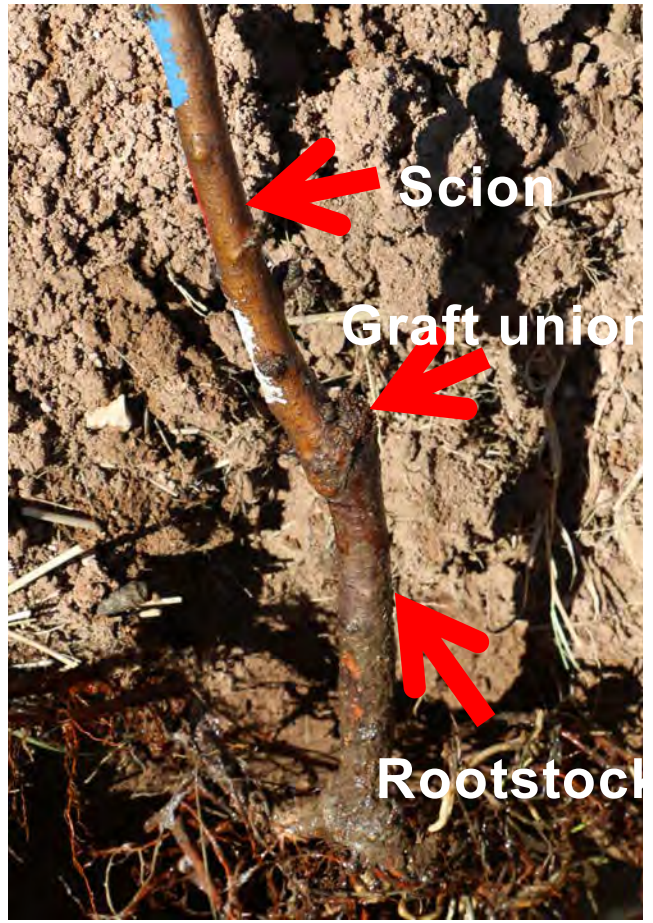
COLORADO STATE UNIVERSITY

Selecting rootstocks for orchard systems

- **Rootstock choice is one of the key decisions in establishing an orchard**
- Rootstocks are carefully bred and used for a variety of known desirable qualities, such as:

1. tree size/vigor control
2. adaptation to soils or climate
3. disease and pest tolerance (eg. nematodes, replant disease)
4. productivity
5. most rootstocks are clonally produced but some are still produced as seedlings



Size controlling rootstocks

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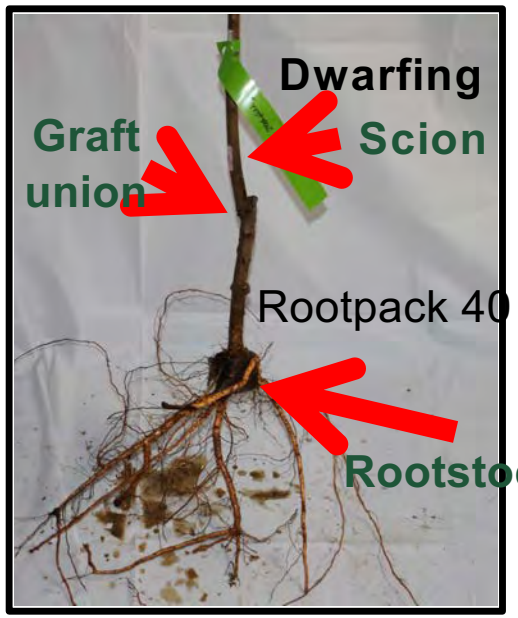
- Can affect size, precocity, and reproductive capacity of the scion cultivar
- Final tree size depends not only on the rootstock but also the scion variety
- Soil type/conditions and environment will also affect tree size
- Ability for high density plantings to maximize productivity and efficiency (less pruning/mechanization)
- East Malling & Malling Merton first produced apple rootstocks for wide range of tree sizes
- NC-140 multi-state project that evaluates rootstock performance across USA

'Cresthaven' peach budded on size controlling rootstocks



CO-2017 State Report

CO-2017 State Report NC-140

(click to open)

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State: Colorado

Principal Investigator:
Ioannis S. Minas, Assistant Professor of Pomology, Dept. of Horticulture and Landscape Architecture located at Western Colorado Research Center-Orchard Mesa, Colorado State University, 3168 B ½ Rd. Grand Junction, CO 81503

Collaborators/Technical Assistance:
Davis Sterle, Emily Dowdy, Bryan Brady, Research Associates, Western Colorado Research Center-Orchard Mesa, Colorado State University, 3168 B ½ Rd. Grand Junction, CO 81503

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Peach size controlling and replant tolerant rootstocks trial

NC-140

9 years study on Red Haven peaches grafted in dwarfing and semi-dwarfing rootstocks-Open Vase

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2009 NC-140 Red Haven Peach Rootstock Trial

NC-140

Coordinator: Greg Reighard (Clemson University, SC)

Sites: AL, CA, CO, GA, IL, KY, MA, MO, MX, NC, NY-Geneva, NY-Hudson Valley, PA, SC, UT-Kaysville, UT-South Shore

Scion Cultivar: Red Haven

17 Rootstocks: Viking, Atlas, BH-5 (Brights Hybrid-5), Mirobac, Guardian®, Lovell, KV 010123, KV 010127, Krymsk®86 (Kuban86), Empyrean®2 (Penta), Imperial California, Controller 8 (HBOK 10), Controller 7 (HBOK 32), Prunus americana, ~~Fortuna~~, Krymsk®1 (VVA-1), Controller 5 (K146-43)

Year planted: 2009

Training system: Open-Vase

Spacing: 13 x 16.5 feet (4 x 5 m)

Trees/acre: 206

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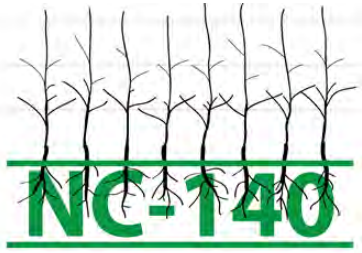
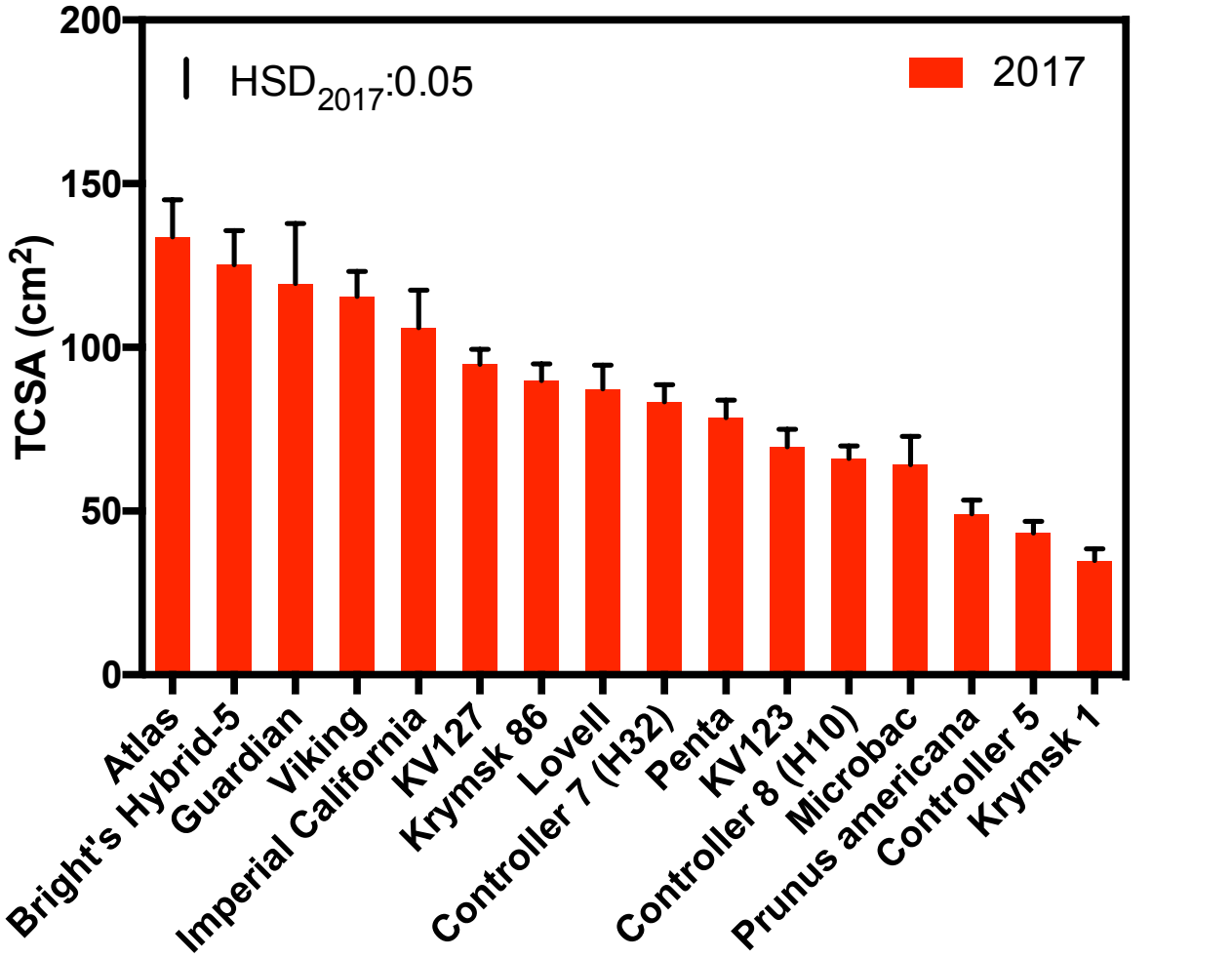
2009 NC-140 Peach rootstocks trial



Rootstock Cultivar	Country of origin	Species	Tree vigor (% of Lovell)
Lovell	U.S.A.	*Prunus persica*	100
Guardian®	U.S.A.	*Prunus persica*	110
KV 10123	U.S.A.	*Prunus persica*	100
KV 10127	U.S.A.	*Prunus persica*	100
HBOK 10 (Controller™ 8)	U.S.A.	*Prunus persica*	90
HBOK 32 (Controller™ 7)	U.S.A.	*Prunus persica*	80
BH-5 (Bright's Hybrid #5)	U.S.A.	*P. dulcis* × *P. persica*	110
Empyrean® 2 (Penta)	Italy	*P. domestica*	80
Empyrean® 3 (Tetra)	Italy	*P. domestica*	70
Imperial California	Italy	*P. domestica*	70
Mirobac (Replantpac)	Spain	*P. domestica*	110
Fortuna	Russia	*P. cerasifera* × *P. persica*	70
Krymsk® 86	Russia	*P. cerasifera* × *P. persica*	110
Krymsk® 1	Russia	*P. tomentosa* × *P. cerasifera*	50
Controller™ 5	U.S.A.	*P. salicina* × *P. persica*	60
Viking	U.S.A.	unknown interspecific cross	110
Atlas	U.S.A.	unknown interspecific cross	120
P. americana	U.S.A.	*Prunus americana*	60

Effect of rootstock on Red Haven tree size 2017



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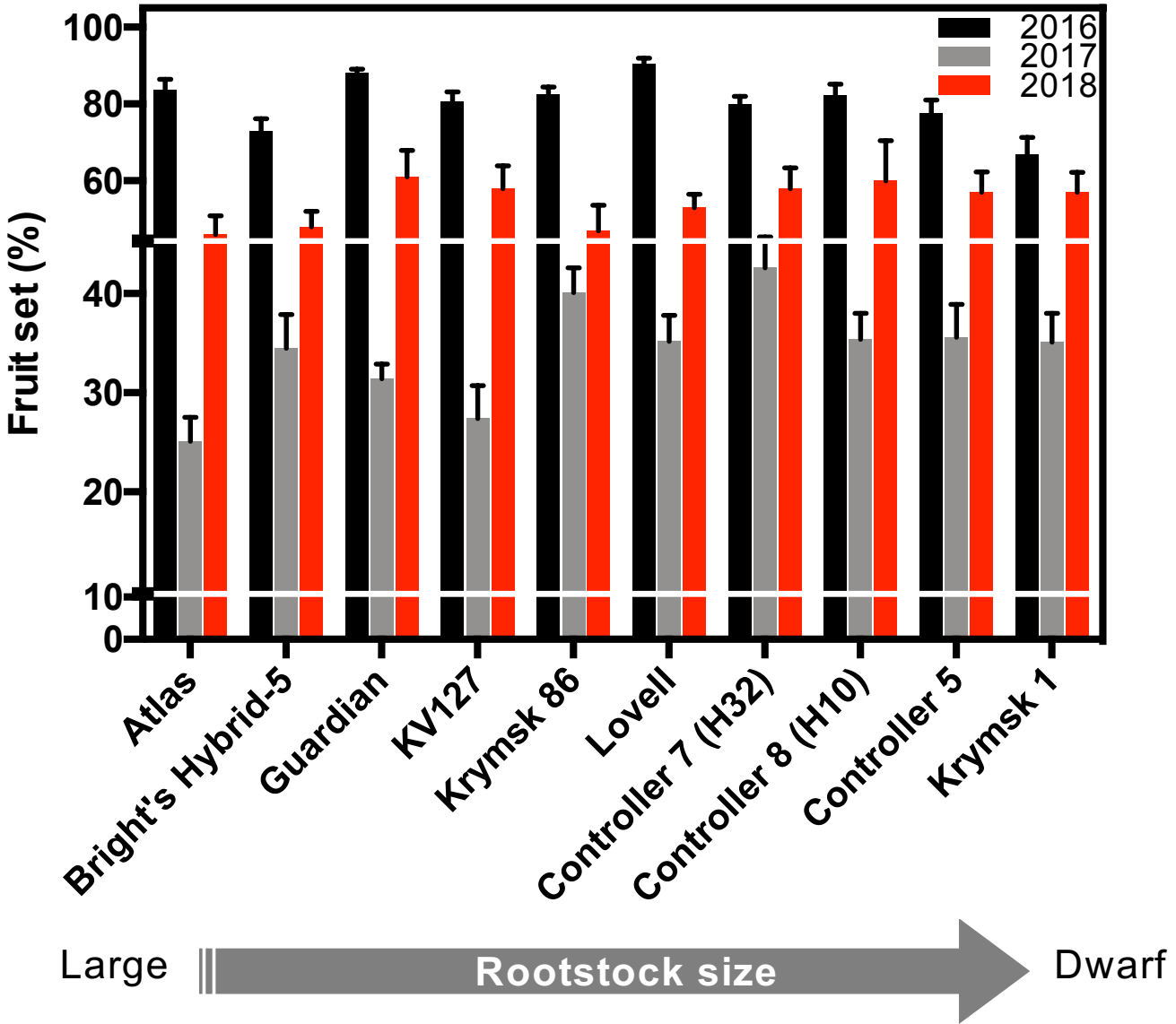
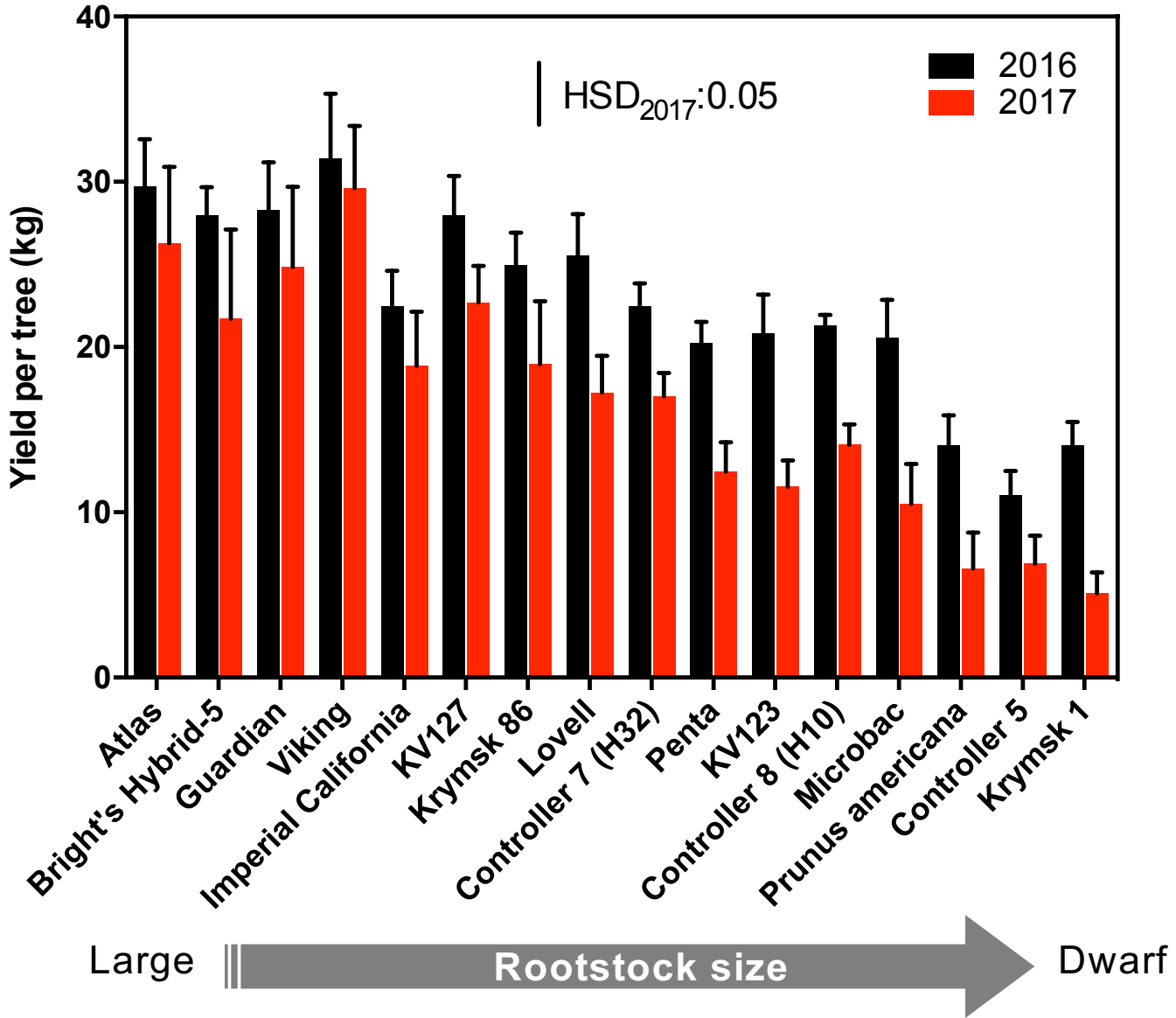
Effect of rootstock on Red Haven peach fruit set 2016, 2017 & 2018



Effect of rootstock on Red Haven yield per tree 2016 & 2017



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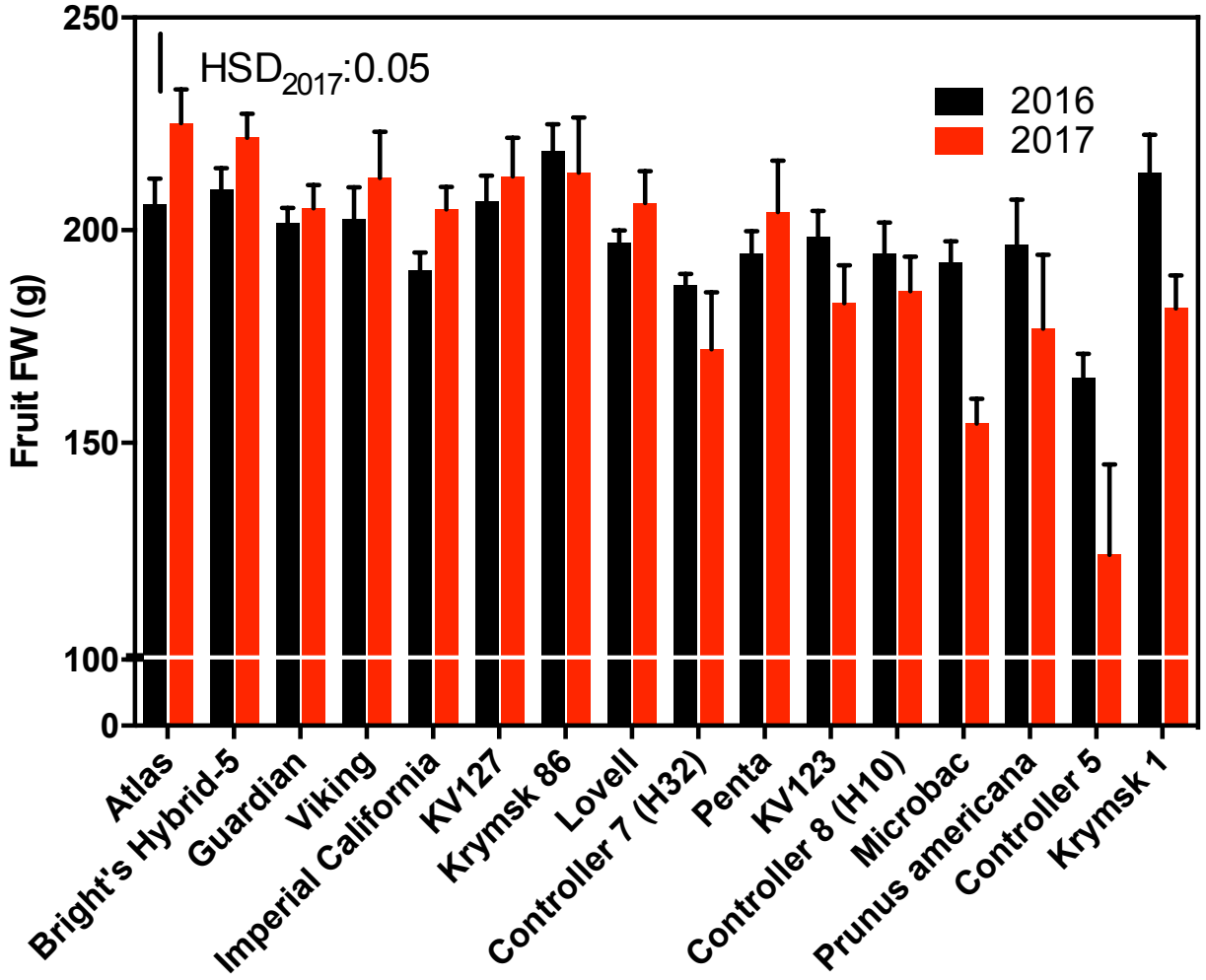
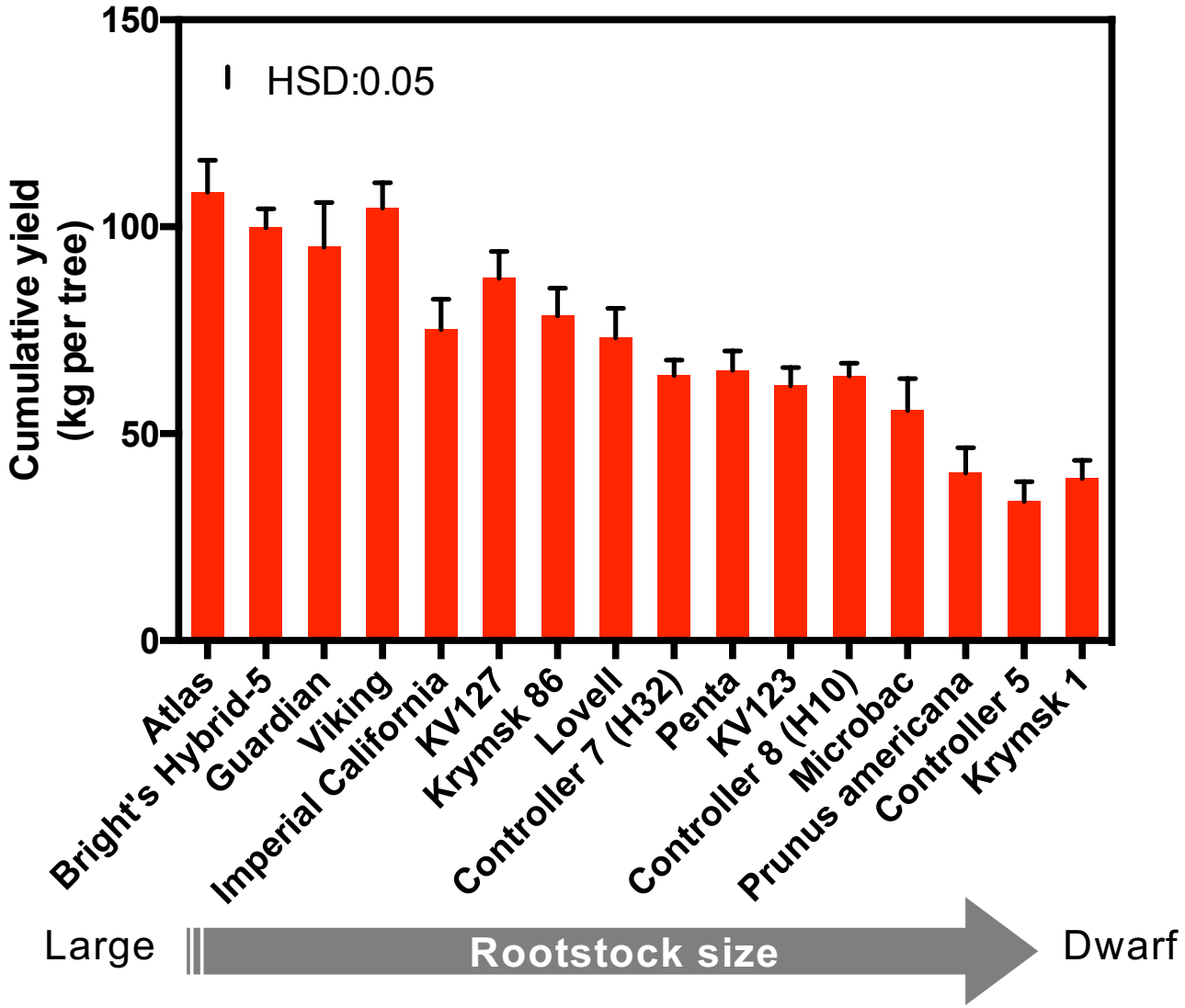
Effect of rootstock on Red Haven fruit fresh weight 2016 & 2017



Effect of rootstock on Red Haven cumulative yield per tree (2009-2017)



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Development of non-destructive technologies to estimate internal fruit quality

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Handheld non-destructive sensors to estimate internal fruit quality and maturity in the field

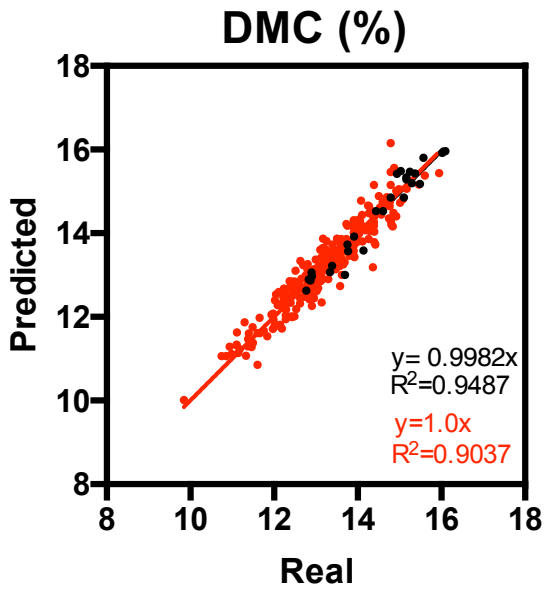
F-750 Produce Quality Meter
Near-Infrared Spectroscopy (NIR)

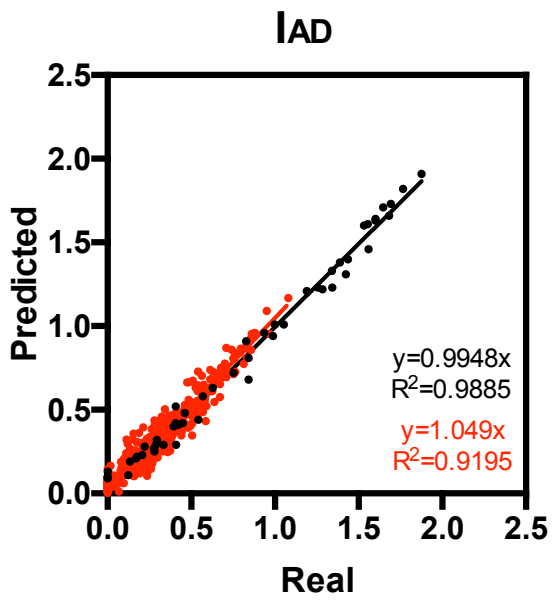
- "Open" type instrument
- On-site calibration and optimization for local cultivars and production practices
- Three online measurements at the same time (2 displayed)
- **DMC, SSC at 729-935 nm**

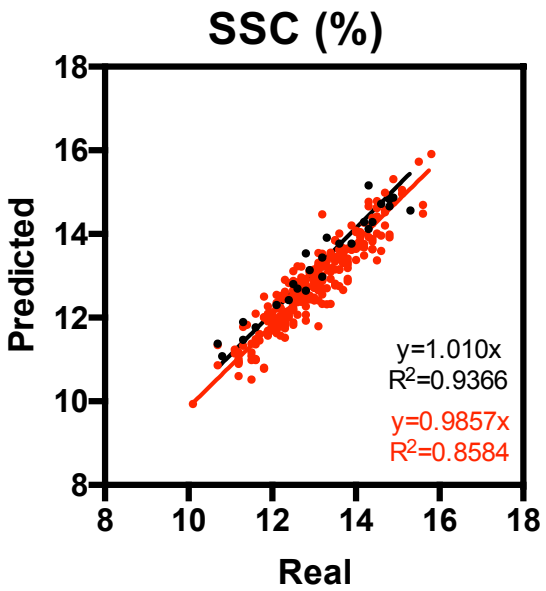
DA-meter
Vis/NIR

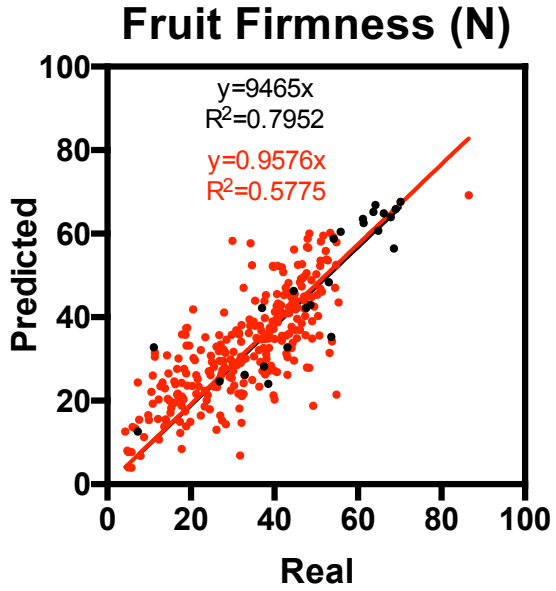
- **Costa et al., 2009**
- "Closed" type instrument
- Calibrated at the factory
- **Index of Absorbance Difference (I_{AD})**
- **$I_{AD}=A_{670nm}-A_{720nm}$**
- **Chlorophyll's Content**
- **Fruit Physiological Maturity**

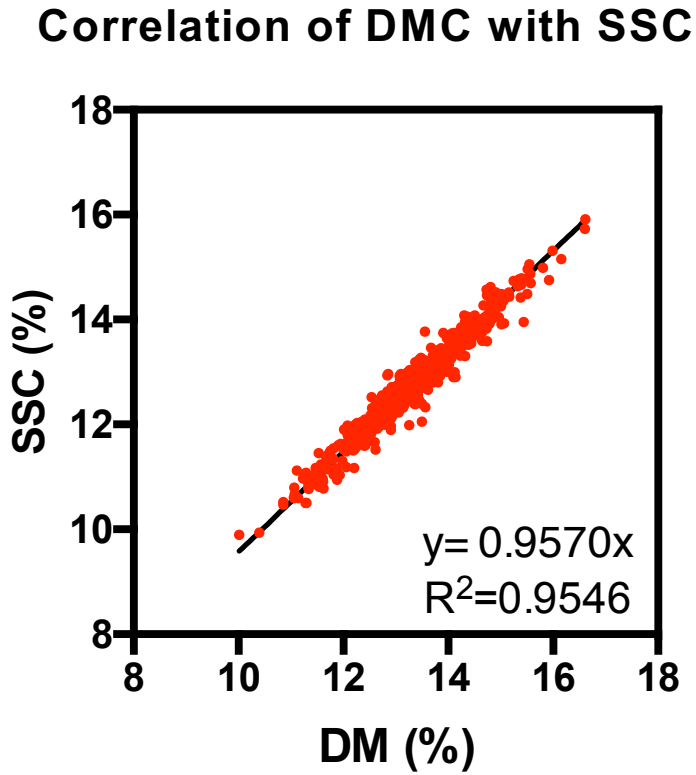
Red Haven DM, SSC and I_{AD} models validations











Influence of rootstocks on peach fruit internal quality

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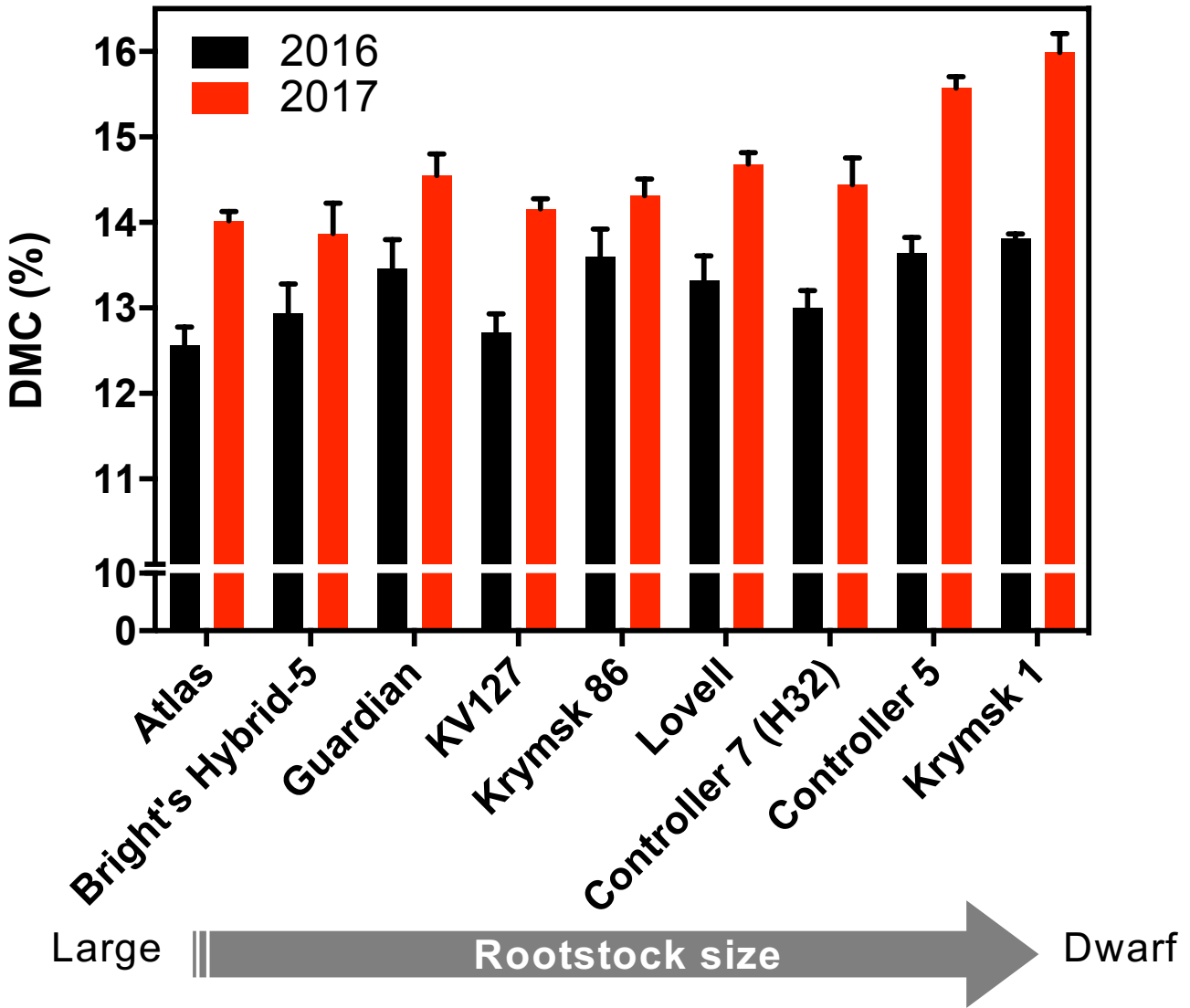
Rootstock influence on Red Haven peach dry matter content (DMC) in 2016 & 2017



Mitigating cold damage in Colorado tree-fruit

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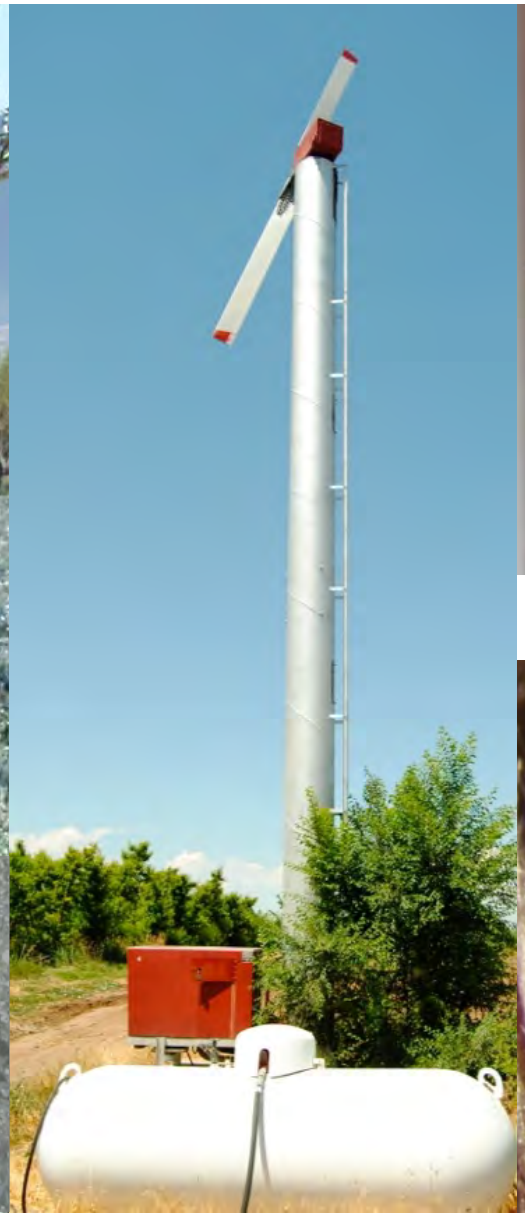
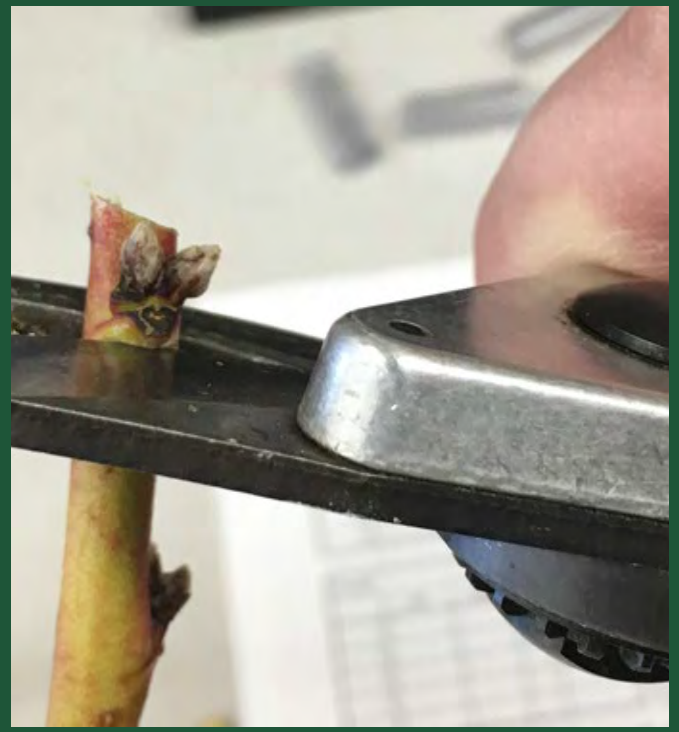
Winter low temperatures and spring frosts are the major limiting factors of CO tree fruit production



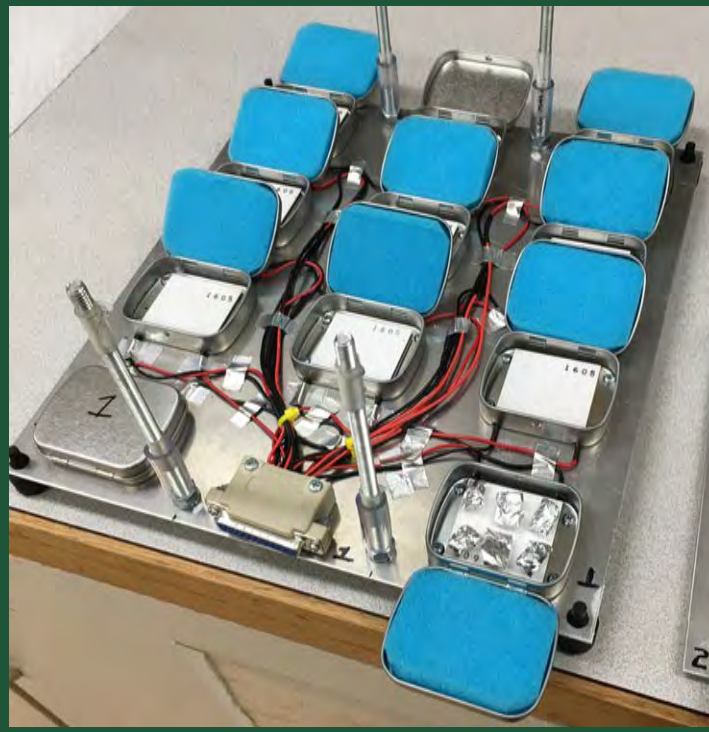
Peach dormant floral buds

Differential Thermal Analysis (DTA)

- Monitors difference in temperature between sample and a reference thermocouple
- Thermoelectric modules (TEMs) detect temperature gradients generated by the exotherms (methodology described by Mills et al. (2006) AJEV)



10-12 peach buds per TEM



10 replicated TEMs plus one reference

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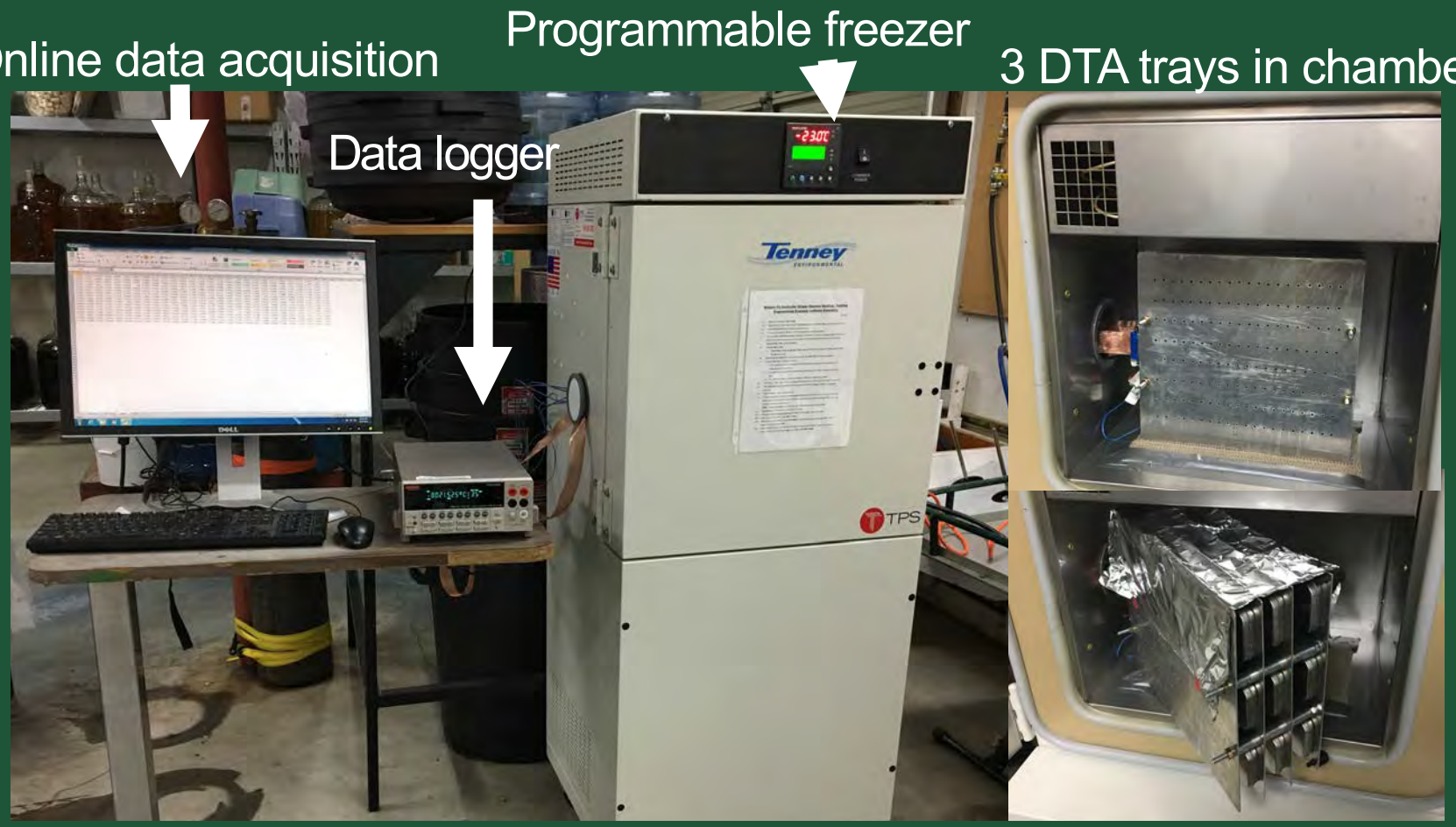
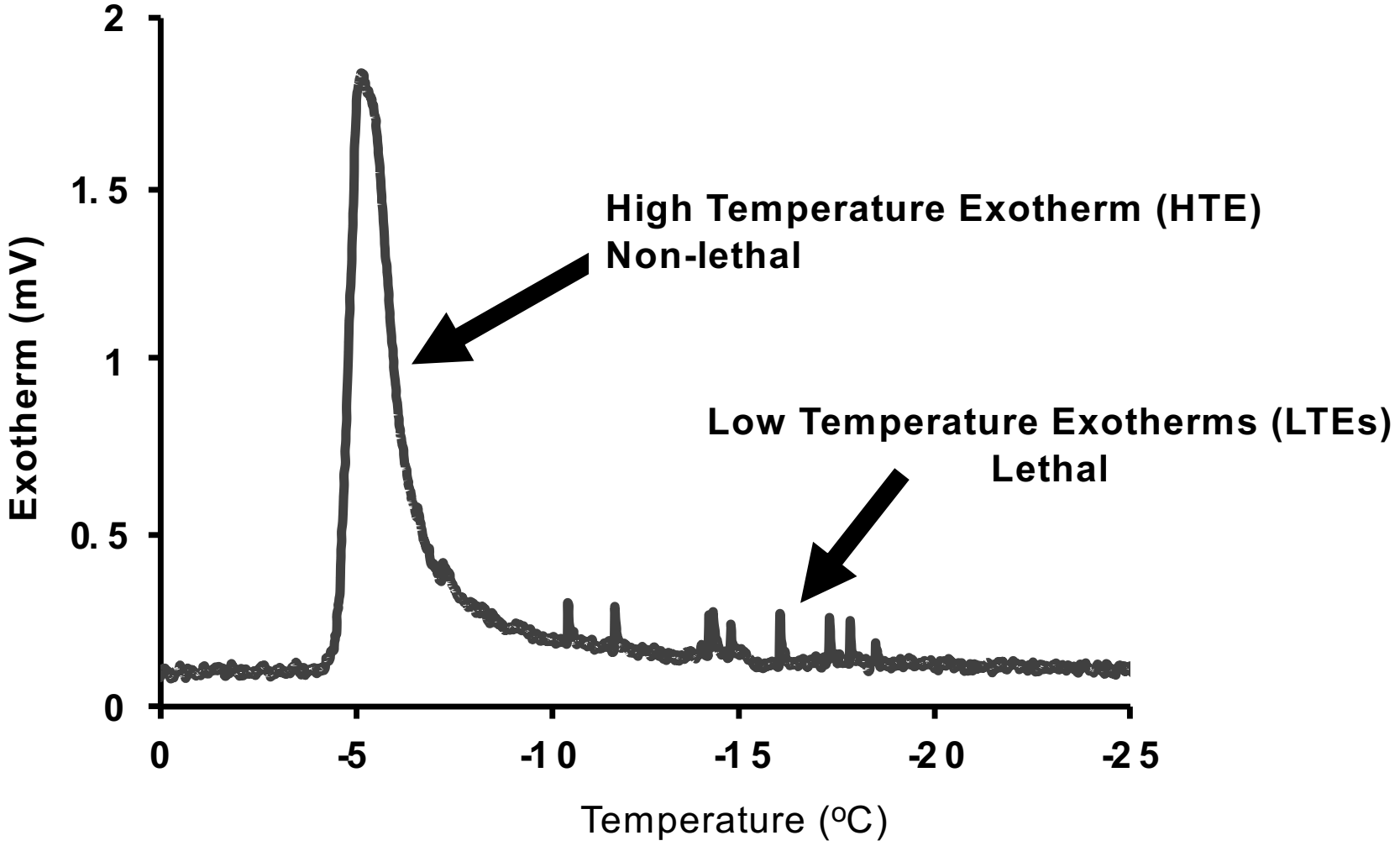
Differential Thermal Analysis (DTA)

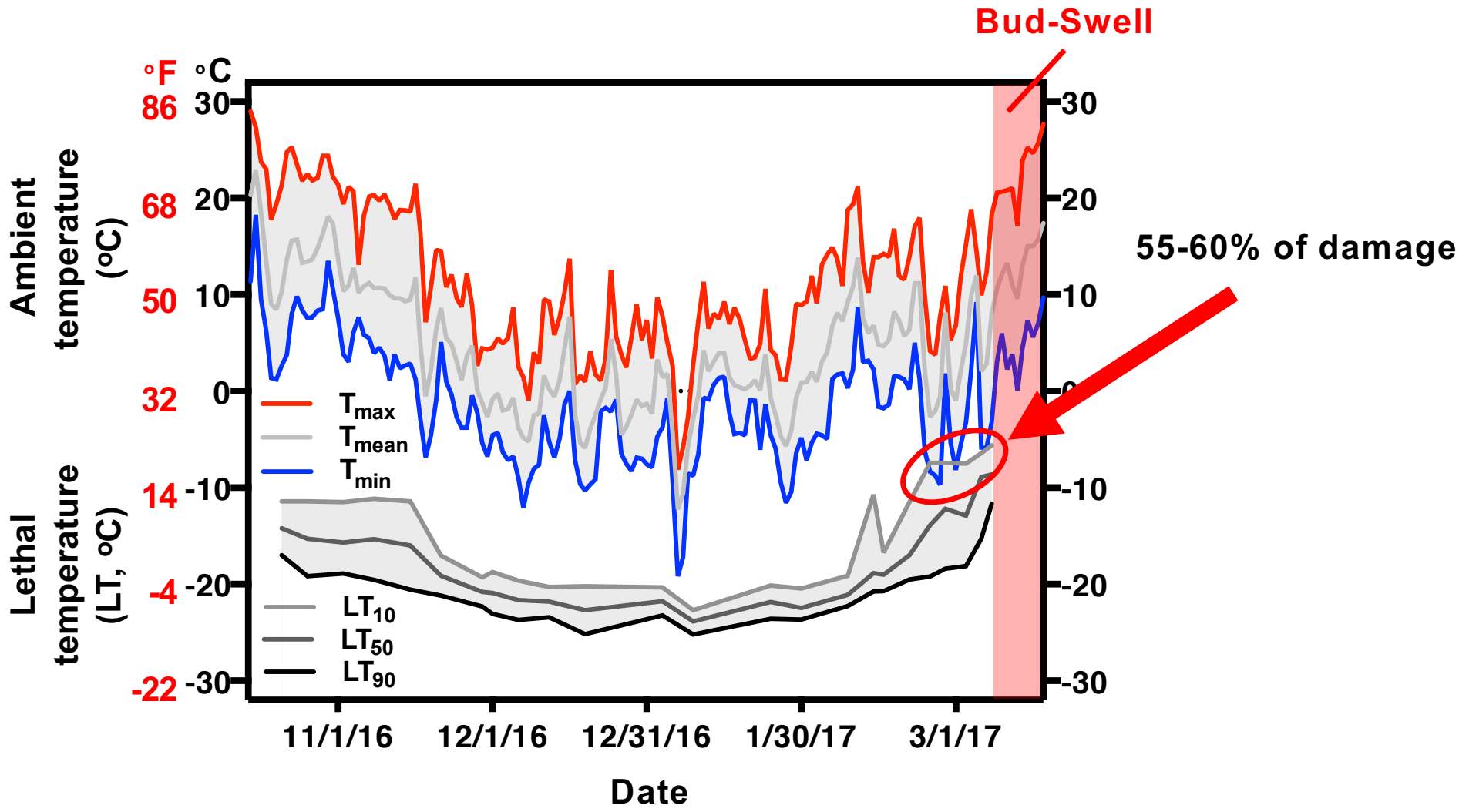


- Programmable freezer (Tenney Jr Test Chamber, Thermal Product Solutions)
- For each TEM a voltage signal that corresponds to the temperature at which super cooled water in the bud tissue freezes was sent to an output directly to an Excel spreadsheet through a data logger

Differential thermal analysis on Red Haven peach floral buds



Red Haven peach floral buds cold hardiness (Lovell)



Seasonal patterns of temperature and cold hardiness (expressed as lethal temperature, LT) for Red Haven peach floral buds from trees grafted on 'Lovell' rootstock

Peach bud cold hardiness monitoring updates

http://minas.agsci.colostate.edu/tree-fruit-information/cold-hardiness/

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Effect of Rootstock on Red Haven peach floral buds acclimation, max hardiness & deacclimation (2017-18)

	Atlas	Bright's Hybrid-5	Guardian®	KV 010127	Krymsk®86	Lovell	Controller 7	Controller 8	Controller 5	Krymsk®1	Date
LT_{10}	-14.9	-14.9	-14.4	-14.6	-13.8	-15.4	-14.4	-13.6	-16.2	-15.4	**11/6/17**
	-16.6	-16.7	-17.8	-15.8	-15.4	-14.9	-16.4	-17.4	-17.0	-17.0	**11/17/17**
	-18.4	-16.7	-17.8	-16.9	-18.6	-18.7	-15.8	-18.1	-18.7	-17.9	**11/28/17**
	-18.3	-19.0	-16.9	-20.0	-15.3	-19.2	-19.5	-17.9	-17.4	-18.1	**12/14/17**
	-19.3	-18.2	-17.5	-20.8	-21.0	-16.8	-15.0	-20.4	-18.7	-18.3	**1/4/18**
	-13.8	-15.0	-12.7	-9.6	-18.4	-15.3	-7.6	-11.1	-19.3	-8.2	**1/24/18**
	-6.2	-7.0	-6.5	-6.4	-6.5	-6.4	-6.5	-6.4	-7.1	-6.4	**2/14/18**
LT_{50}	-18.1	-17.1	-18.2	-17.2	-18.2	-17.2	-18.1	-17.9	-18.5	-17.8	**11/6/17**
	-19.3	-19.0	-19.5	-18.8	-19.4	-18.6	-19.3	-19.2	-19.4	-19.0	**11/17/17**
	-19.8	-19.6	-19.6	-19.2	-19.9	-20.0	-19.9	-19.9	-20.4	-19.9	**11/28/17**
	-20.4	-21.1	-21.3	-21.3	-21.5	-21.0	-21.2	-20.8	-21.1	-20.2	**12/14/17**
	-22.6	-22.3	-22.5	-23.1	-22.9	-21.5	-22.3	-22.4	-22.5	-21.9	**1/4/18**
	-20.5	-22.2	-22.7	-22.1	-22.6	-22.6	-22.4	-22.7	-22.3	-21.0	**1/24/18**
	-17.8	-19.0	-18.2	-19.3	-18.9	-19.4	-19.0	-17.9	-19.3	-18.2	**2/14/18**
LT_{90}	-19.1	-18.8	-20.1	-19.7	-19.8	-19.5	-20.0	-19.8	-19.9	-19.4	**11/6/17**
	-20.1	-20.8	-20.2	-20.5	-20.8	-20.4	-20.4	-21.0	-21.2	-20.0	**11/17/17**
	-20.9	-21.2	-21.4	-20.7	-20.6	-21.1	-20.8	-21.5	-21.8	-20.9	**11/28/17**
	-22.1	-22.0	-22.5	-22.3	-22.1	-22.4	-22.6	-22.2	-22.3	-21.8	**12/14/17**
	-23.5	-23.7	-24.1	-23.9	-23.9	-23.8	-23.4	-23.6	-23.8	-21.9	**1/4/18**
	-23.0	-23.8	-23.7	-23.7	-23.6	-23.6	-23.7	-23.9	-23.8	-23.3	**1/24/18**
	-20.9	-21.4	-20.9	-20.7	-21.3	-20.9	-21.2	-21.0	-21.0	-21.0	**2/14/18**

Least hardy: Atlas and Krymsk 1
Most hardy: Guardian, Krymsk 86, KV127, Controller 8

Early acclimation: Lovell, Guardian, Controller 5
Late deacclimation: Krymsk 86, Controller 5

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Apple size controlling and replant tolerant rootstocks trial

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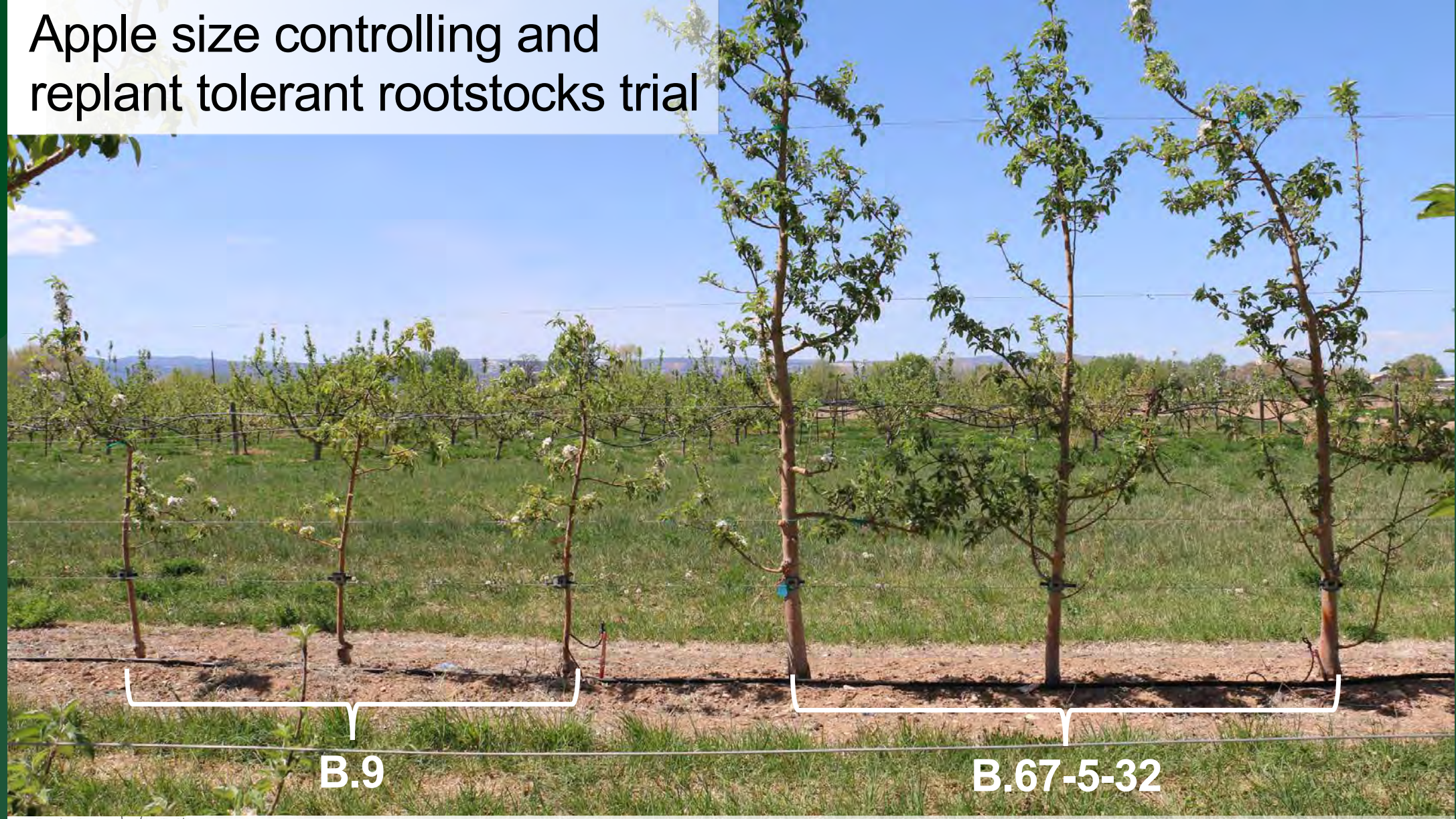

NC-140

8 years old Honey crisp apples grafted in dwarfing and semi-dwarfing rootstocks-Tall Spindle Axe

2010 NC-140 Honeycrisp Apple Rootstock Trial

Sites: BC, CH, CO, IA, IL, MA, MN, MI, NS, NY, OH, WI

Coordinator: Wesley Autio (University of Massachusetts Amherst, MA)

Scion Cultivar: Honeycrisp

30 Rootstocks: B.9, B.10, B.7-3-150, B.7-20-21, B.64-194, B.67-5-32, B.70-7-8, B.71-7-22, G.11, G.41 N, G.41 TC, G.202 N, G.202 TC, G.935 TC, G.5202, CG.2034, CG.3001, CG.4003, CG.4004, CG.4013, CG.4814, CG.5087, CG.5222, Supp. 3, PiAu 9-90, PiAu 51-11, M.9 NAKBT337, M.9 Pajam 2, M.26 EMLA

Year planted: 2010

Training system: TSA

Spacing: 4 x 12 feet (1.2 x 3.6 m)

Trees/acre: 908

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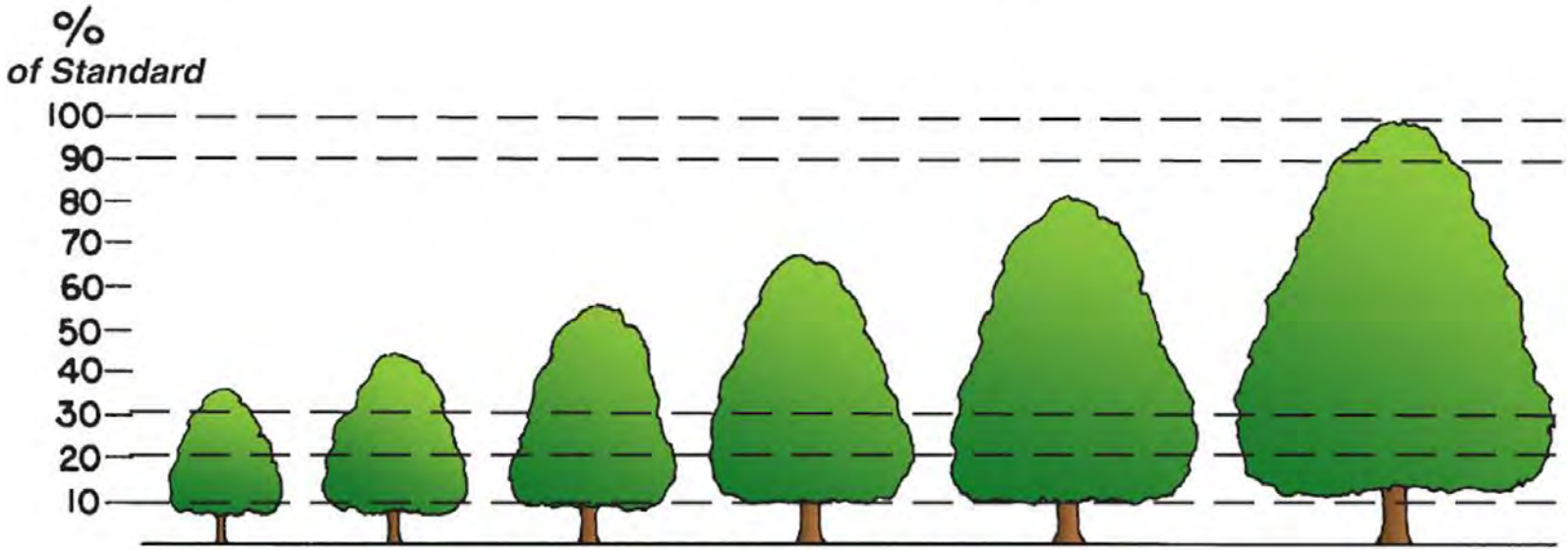
Apple Size Controlling Rootstocks



15-30% size of seedling	30-35% size of seedling	40-50% size of seedling	40-50% size of seedling	50-75% size of seedling	Over 75% size of seedling
Mark	M9 T337	M9 Pajam2	M.26	M.7	Seedling
B.9	G.11	G.935	G.30	MM 106	B.118
M.27	G.41	G.222	G.969	MM 111	M.13
P.22	G.16	G.202	G.210	P.2	M.25
B.491	G.213	G.214	G.890	P.18	MAC 24
	B.10	G.814	MAC 46	MAC 1	
			MAC 39	B.490	
			CG.44	M.2	
				M.4	

Geneva Rootstocks tested in NC-140

Fire blight resistant: G11, G16, G202, G222, G.969
Replant tolerant: G.30, G.41, G.210, G.214, G.890, G.935
Wooly apple aphid resistant: G.41, G.210, G.214, G.890

2010 NC-140 Honeycrisp Apple rootstocks performance by vigor

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Vigor Category	Rootstock	TCSA (2017, cm^2)	Yield per tree (2017, kg)	Fruit weight (2017, g)	Cumulative yield per tree (2011-2017, kg)*
Large semi-dwarf (200+% of M.9 size)	B.7-20-21	46.9	7.9	275.7	20.9
	B.64-194	60.6	8.0	267.7	17.5
	B.70-6-8	44.5	6.9	244.7	16.8
	B.67-5-32	51.1	9.1	264.5	15.9
	B.7-3-150	**43.2**	**8.6**	**243.3**	**24.1**
Moderate semi-dwarf (150-200% of M.9 size)	CG.3001	31.7	5.4	265.2	14.4
Small semi-dwarf (130-150% of M.9 size)	PiAu 51-11	30.5	6.0	225.5	18.8
	PiAu 9-90	28.4	4.8	215.6	13.4
	CG.4004	30.0	6.0	269.6	21.2
Large dwarf (110-130% of M.9 size)	**CG.5222**	**27.2**	**13.6**	**213.9**	**26.5**
	M.9 Pajam 2	**24.4**	**7.9**	**269.4**	**28.5**
	CG.4814	**23.8**	**2.8**	**258.2**	**21.4**
	G.41 N	26.4	0.8	250.0	18.0
	CG.3041	**25.5**	**5.1**	**262.8**	**22.3**
	G.935 TC	24.7	1.5	269.3	15.9
	M.26 EMLA	23.7	7.0	229.5	19.8
	Supp.3	24.6	4.9	256.6	11.4
	G.202 N	23.1	1.3	224.4	13.7
	CG.5087	23.6	8.0	365.8	18.3
Moderate dwarf (80-110% of M.9 size)	**M.9 NAKBT337**	**21.0**	**4.8**	**286.2**	**25.6**
	CG.4214	**17.7**	**6.0**	**254.4**	**26.0**
	G.11	19.7	4.5	322.3	17.9
	G.41 TC	**22.4**	**5.0**	**240.0**	**26.4**
	G.202 TC	**19.4**	**8.6**	**182.5**	**20.9**
	B.10	18.9	5.8	233.0	17.2
Small dwarf (40-80% of M.9 size)	B.9	9.2	4.5	200.7	12.4
	CG.4003	15.1	8.7	287.3	15.1
	CG.2034	13.6	1.0	219.9	7.1
Sub-dwarf (0-40% of M.9 size)	B.71-7.22	4.6	1.2	164.4	2.9
	Estimated HSD	4.8**	2.2	43.2	

**2015 data not included.*

***Mean separation in columns by Tuckey's HSD (P=0.05). HSD was calculated based on the number of observations per mean.*

2015 NC-140 Modi Organic Apple Rootstock Trial

Sites: CA, CO, IA, ID, MA, MI, NM, NS, NY-Ithaca, NY-Geneva, VT, WI

Coordinator: Wesley Autio (University of Massachusetts Amherst, MA)

Scion Cultivar: Modi

30 Rootstocks: G.11, G.16, G.30, G.41, G.202, G.214, G.222, G.890, G.935, G.969, M.9 NAKBT337 (Pollinizer: Liberty/G.935)

Year planted: 2015

Training system: TSA

Spacing: 3.5 x 11.5 feet (1 x 3.5 m)

Trees/acre: 1114

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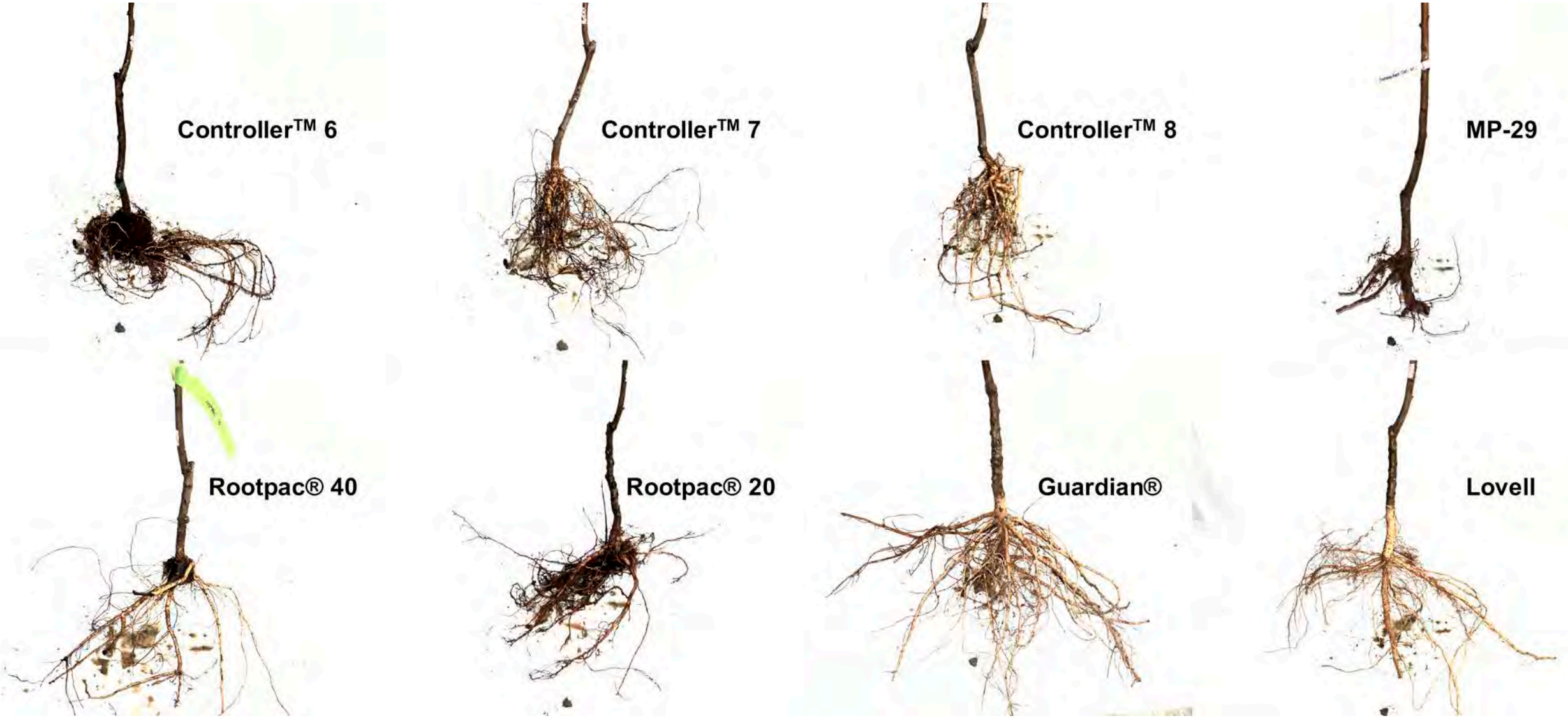
2015 NC-140 Modi Organic Apple rootstocks performance

Rootstock	TCSA (2017, cm^2)	Fruit no (2017)	Yield per tree (2017, kg)
G.11	4.0	1.2	0.1
G.16	1.7	0.2	0.0
G.202	5.3	0.8	0.1
G.214	2.1	0.1	0.0
G.222	1.8	0.0	0.0
G.30	4.0	1.3	0.2
G.41	3.8	0.9	0.5
G.890	5.8	1.3	0.2
G.935	4.0	1.8	0.2
G.969	3.5	2.8	0.3
Liberty	3.4	4.8	0.5
M9T337	4.5	1.7	0.2
Estimated HSD	0.6*	0.3	1.4

***Mean separation in columns by Tuckey's HSD (P=0.05). HSD was calculated based on the number of observations per mean.*

The 2017 NC-140 Cresthaven Semi-Dwarf Peach Rootstock Trial



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Good Fruit Grower, February 1st, 2018

2017 NC-140 Cresthaven Semi-Dwarf Peach Rootstock Trial

Sites: AL, CO, GA, MI, NC, NY, ONT, PA, SC, UT
Coordinator: Ioannis Minas (Colorado State University)

Cultivar: Cresthaven
Training system: KAC-V

Spacing: 6 x 15 feet (1.8 x 4.5 m)
Trees/acre: 484

Rootstock	Breeder, Country	Genetic origin
Controller™ 6 (HBOK 27)	UC Davis,USA	peach x peach hybrid (P. persica x P. persica)
Controller™ 7 (HBOK 32)	UC Davis, USA	peach x peach hybrid (P. persica x P. persica)
Controller™ 8 (HBOK 10)	UC Davis, USA	peach x peach hybrid (P. persica x P. persica)
MP-29	USDA-Georgia, USA	plum x peach interspecific hyb. (Prunus umbellata x P. persica)
Rootpac® 40 (Nanopac)	Agromillora Iberia, Spain	almond x peach interspecific hyb. [(P. dulcis x P. persica) x (P. dulcis x P. persica)]
Rootpac® 20 (Densipac)	Agromillora Iberia, Spain	plum x peach interspecific hybrid (P. besseyi x P. persica)
Guardian®	Clemson/USDA, USA	peach seedling (P. persica)
Lovell	G.W. Thissell, USA	peach seedling (P. persica)

2017 NC-140 Semi-Dwarf Cresthaven Peach Rootstocks Performance

1st leaf

Rootstock	Survival (%)	% Size of Lovell	TCSA (cm^2) at planting	TCSA (cm^2) at fall	% increase of TCSA	% of chlorotic trees*
Controller™ 6	90	52.2	0.4	1.1	173.0	16.7
Controller™ 7	95	60.0	0.6	1.3	41.5	100.0
Controller™ 8	95	76.7	1.1	1.7	51.4	52.6
MP-29	83	123.2	2.2	2.7	18.3	6.7
Rootpack® 20	100	124.7	0.8	2.7	223.0	31.6
Rootpack® 40	73	73.5	0.5	1.6	216.0	0.0
Guardian®	95	154.4	2.2	3.3	49.5	70.0
Lovell	80	100	1.5	2.2	43.3	31.2
Estimated HSD			0.4**	0.6		

**Spring 2018*

***Mean separation in columns by Tuckey's HSD (P=0.05). HSD was calculated based on the number of observations per mean.*

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Iron chlorosis symptoms on the 2017 NC-140 Semi-Dwarf Cresthaven Peach Rootstocks

Controller™ 6

Controller™ 7

Controller™ 8

Lovell

Controller™ 6

Rootpack® 20

Rootpack® 40

Guardian®

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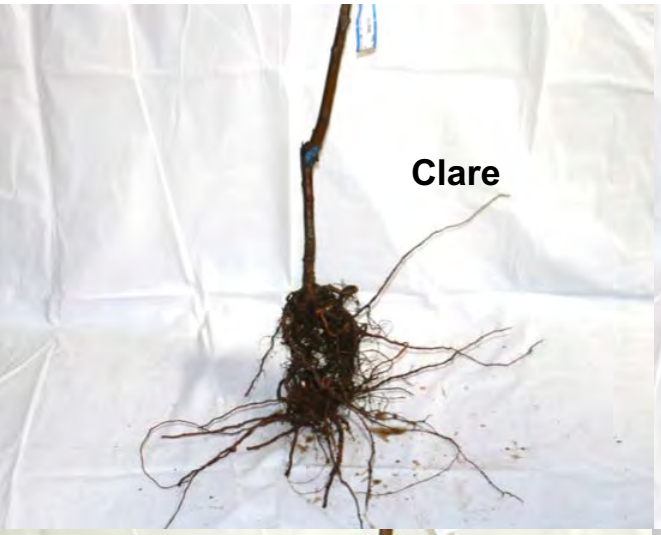
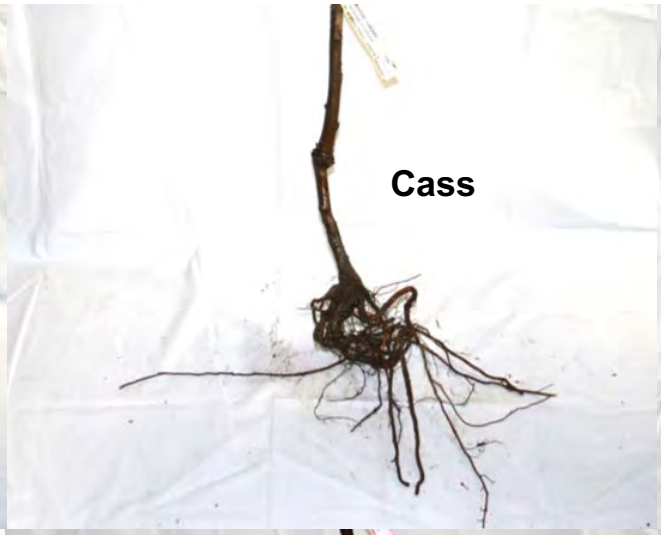
2017 NC-140 ‘Benton’ Sweet Cherry Rootstock x Training Systems Trial





3 Training systems:

- Tall spindle axe (TSA)
- Bi-cordon Upright Fruiting Offshoots (Bi-UFO)
- Kym green bush (KGB)

2017 NC-140 ‘Benton’ Sweet Cherry Rootstock x Training Systems Trial

Cultivar: Benton

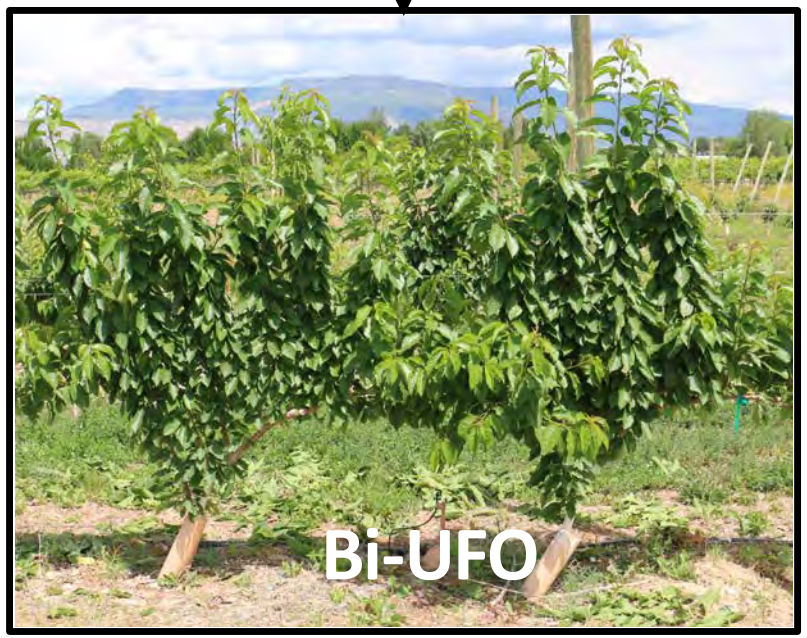
Coordinator: Greg Lang (Michigan State University, MSU)

Sites: CO, ID, MI-1, MI-2, NY, WA

Rootstocks: Cass (Cornell), Clare, Clinton and Lake (MSU), Gisela 3 (Gi3), Gisela 5 (Gi5), Gisela 12 (Gi12), Control: MxM14

Spacing: 6 x 15 feet (1.8 x 4.5 m); **Trees/acre:** 484

Training systems:



2017 NC-140 'Benton' Sweet Cherry Rootstocks Performance on TSA

1st leaf

Rootstock	Survival (%)	% Size of MxM14	TCSA (cm^2) at planting	Tree height (cm) at planting	TCSA (cm^2) at fall	New growth (cm)	Lateral shoots (no.)	Length of lateral shoots (cm)
Cass	83	40.7	1.2	87.3	1.9	24.0	3.5	9.0
Clare	100	45.5	1.0	82.4	1.6	34.3	3.5	19.0
Clinton	83	69.4	0.9	71.4	2.5	76.1	2.9	33.3
Lake	92	61.5	1.5	101.0	2.2	33.0	3.1	18.6
MxM14	33	100	2.9	130.1	3.6	51.5	3.3	20.8
Gi3	83	57.9	1.0	93.7	2.1	31.1	4.0	14.4
Gi5	83	79.8	1.4	108.0	2.8	41.9	3.6	26.8
Gi12	80	69.1	0.8	75.8	2.5	44.5	4.5	26.5
Estimated HSD			0.3*	11.0	0.8	31.5	1.6	12.1

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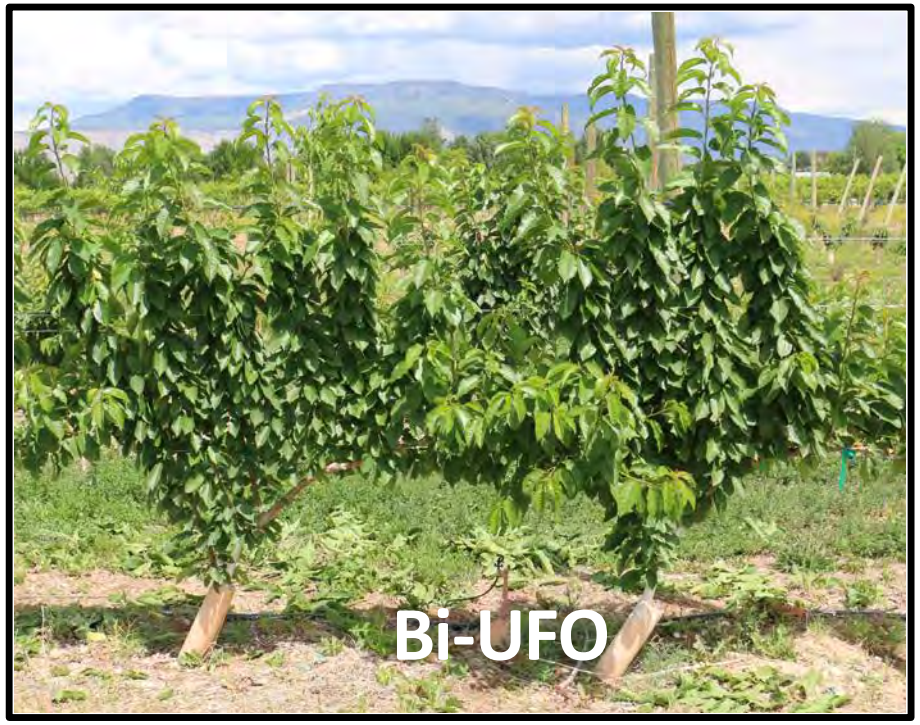
2017 NC-140 ‘Benton’ Sweet Cherry Rootstocks Performance on Bi-UFO

1st leaf



Rootstock	Survival (%)	% Size of MxM14	TCSA (cm^2) at planting	Tree height (cm) at planting	TCSA (cm^2) at fall
Cass	100	36.5	1.2	87.7	1.9
Clare	100	34.6	0.9	86.5	1.8
Clinton	92	47.8	0.9	70.1	2.5
Lake	92	43.1	1.2	92.9	2.2
MxM14	42	100.0	3.3	137.9	5.2
Gi3	75	43.5	0.9	84.3	2.2
Gi5	100	49.5	1.2	101.7	2.6
Gi12	90	59.6	1.4	102.0	3.1
Estimated HSD			0.3	14.0	0.6

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2017 NC-140 ‘Benton’ Sweet Cherry Rootstocks Performance on KGB

1st leaf

Rootstock	Survival (%)	% Size of MxM14	TCSA (cm^2) at planting	Tree height (cm) at planting	TCSA (cm^2) at fall
Cass	100	40.8	1.1	83.0	1.7
Clare	100	44.6	0.9	83.1	1.9
Clinton	100	50.2	1.0	74.1	2.1
Lake	92	60.1	1.2	89.7	2.6
MxM14	67	100.0	3.2	137.5	4.2
Gi3	100	51.7	0.8	84.9	2.2
Gi5	100	79.0	1.2	96.3	3.4
Gi12	89	71.9	1.2	83.1	3.1
Estimated HSD			0.6	13.2	0.9

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NC-140

The impact of training system on Benton sweet cherry tree survival and TCSA

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Rootstock	Survival (%)	TCSA (cm^2) at planting	TCSA (cm^2) at fall
TSA	79.8	1.33	2.26
Bi-UFO	86.1	1.38	2.46
KGB	93.5	1.32	2.55
Estimated HSD		ns	0.25

Conclusions

- DTA valuable tool for comparative studies on cultural management practices, rootstocks and cultivars evaluation
- *Prunus* sp. hybrid rootstocks acclimate later in fall compared to peach rootstocks, however, Krymsk86 seems to deacclimate later in spring also
- Excessive growth might interfere with fruit quality
- *Prunus* sp. hybrids: good for replant sites and high pH soils: Atlas, Viking, Bright's Hybrid-5 the largest and more productive trees
- In non-replant soils: *Prunus* sp. hybrids: excessive growth and heavy pruning – *Cytospora* risk - early acclimation?
- G.41TC good potential as replacement of M9T337
- New trials: Controller 6 and Rootpack 20 and 40 show promise
- Large trees do not show good survival in the first year after planting especially in cherry
- Training system affects tree vigor

Up coming workshop!

Pruning & Training: Peaches & Cherries under different training systems

Monday 21th, 2019
WCRC-OM

Principles of Tree-Fruit Production: beginner growers' edition
(Monday 15th, 2018 at WCRC-OM, 33 attendants)

Questions?

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