University of Florida, Institute of Food and Agricultural Sciences

Planting Density and Nutritional Trials at the Indian River Research and Education Center

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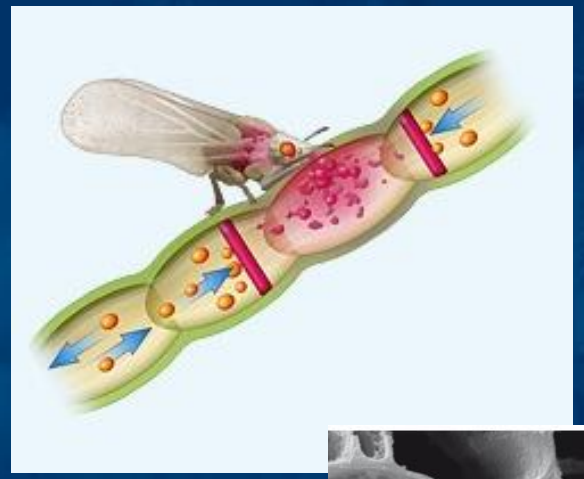
UF UNIVERSITY of FLORIDA
INDIAN RIVER
Research and Education Center

Host

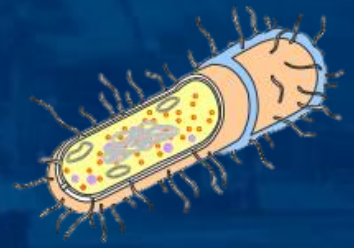
Vector

Asian citrus psyllid
(Diaphorina citri)

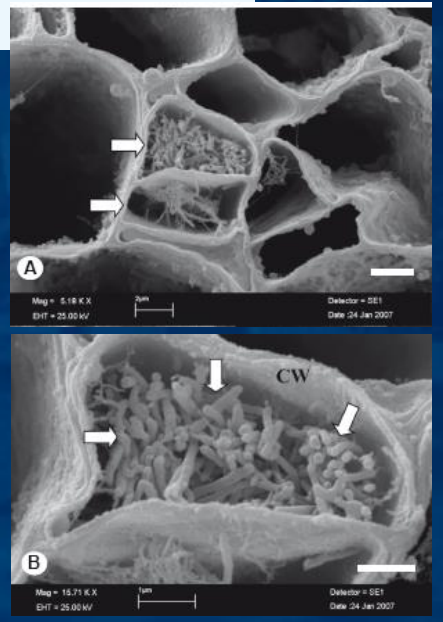
Bacteria



Phloem infection



Candidatus
Liberibacter asiaticus



Host

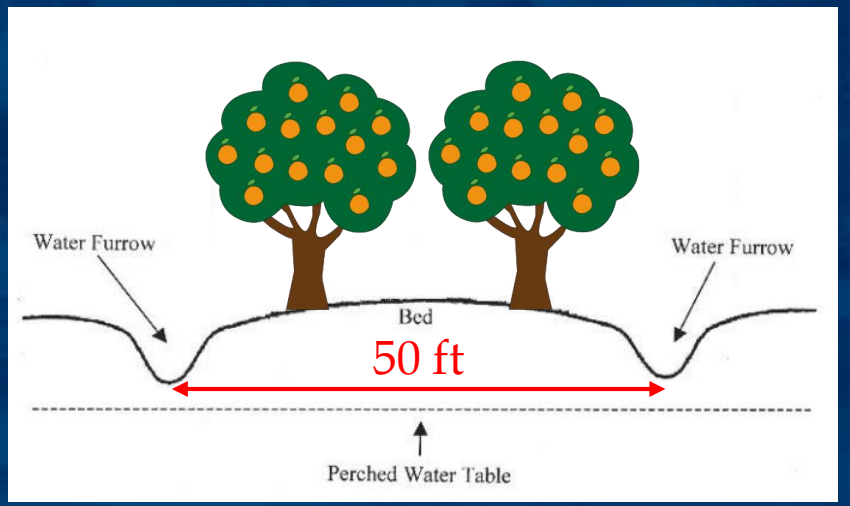
Tree density, macro and micronutrient application on grapefruit affected by HLB

By Dinesh Phuyal, Tom James, Hernan Soto, Davie Kadyampakeni, Kelly Morgan and Rhuanito Ferrarezi

Funding: UF/IFAS Citrus Initiative and USDA-APHIS HLB MAC

TREE DENSITY (Yield per tree vs Yield per area)

- HLB disease increases production costs, reduces fruit yield (Farnsworth et al., 2014), and decreases canopy volume (Bowman et al., 2016)
- With the increase in production cost, new plantings with higher tree density anticipate return of investment (Dalal et al., 2013)
- In the River, we have to optimize the use of 50-ft bed space since trees do grow slow in the first 5-6 years and have been growing even slower due to the negative effects of HLB in plant physiology.



NUTRITIONAL THERAPY: SOIL

- HLB-affected trees show severe leaf nutrient deficiencies such as P, Ca, Mg, Fe, Mn and Zn (Morgan et al., 2017)
- Florida sandy soils have poor water and nutrient holding capacity (Obreza & Morgan, 2008)
- Vashisth & Grosser, 2018: small doses and frequent application (spoon feeding) of control release fertilizer (CRF) result in higher yield in sweet orange

Trial 1

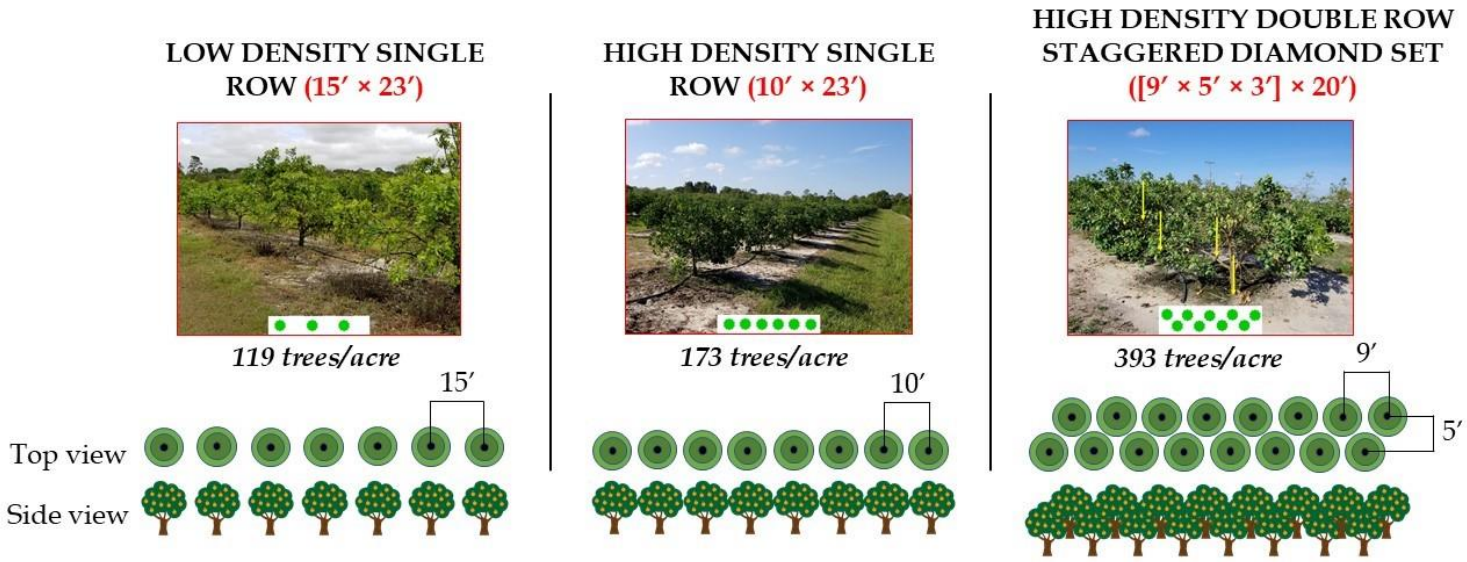
OBJECTIVES

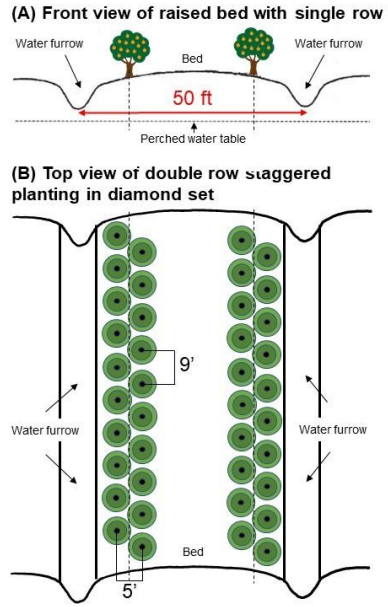
1. To study the responses of soil application of two different CRFs on tree growth, fruit yield and fruit quality

- 16-3-20 CRF with 81% N and 50% K as CRF and micros as sulfates (1× IFAS)
- 12-3-9 CRF with 100% N, 100% P and 95% K as CRF and all other micros as S-coated (2× IFAS)

applied Feb, Jun and Oct

2. To assess the best tree planting spacing for higher tree growth and yield





	Ct value of Clas DNA (unitless)	
Treatments	**2017**	**2018**
Controlled-release fertilizer, CRF		
12-3-9 + micros 2x IFAS as sulfur-coated	26.0 ± 1.6	24.7 ± 0.4
16-3-20 + micros 1x IFAS as sulfates	25.4 ± 1.0	25.4 ± 0.4
Plant density, PD (trees/acre)		
119	27.7 ± 2.2	25.1 ± 0.5
173	23.9 ± 0.5	25.3 ± 0.6
393	25.6 ± 1.5	24.8 ± 0.4
	Probability value (P < 0.05)	
CRF	0.7930	0.1148
PD	0.2534	0.5445
CRF*PD	0.2146	**0.0013***

Tree infected when Ct value < 32

Trial 1

	Trunk diameter (mm)		Canopy volume (m^3)	
Treatments	**2017**	**2018**	**2017**	**2018**
Controlled-release fertilizer, CRF				
12-3-9	75.61 ± 0.82	82.50 ± 0.49	6.7 ± 0.2 A	8.3 ± 0.1 A
16-3-20	75.45 ± 0.71	81.50 ± 0.48	6.1 ± 0.2 B	7.5 ± 0.1 B
Plant density, PD (trees/acre)				
119	81.45 ± 0.77 A	88.85 ± 0.51 A	7.2 ± 0.2 A	9.2 ± 0.2 A
173	78.50 ± 0.65 A	84.87 ± 0.46 B	7.0 ± 0.2 A	8.6 ± 0.1 B
393	66.63 ± 0.80 B	73.33 ± 0.50 C	5.1 ± 0.2 B	6.1 ± 0.1 C
	Probability value (P < 0.05)			
CRF	0.8535	0.0815	**0.0026***	**<0.0001***
PD	**<0.0001***	**<0.0001***	**<0.0001***	**<0.0001***
CRF*PD	0.0982	0.5726	0.1261	0.4100

2017: Hurricane Irma

Trial 1

	Fruit yield per tree (lb)		Fruit yield (boxes/acre)		Total # fruit (No.)	
Treatments	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
Controlled-release fertilizer, CRF						
12-3-9	24.1 ± 1.4 B	21.6 ± 2.0	58.6 ± 3.8 B	52.2 ± 5.4	25.4 ± 1.6 B	27.7 ± 2.5
16-3-20	30.4 ± 1.6 A	16.9 ± 1.6	77.3 ± 5.5 A	43.0 ± 5.3	34.2 ± 1.8 A	23.0 ± 2.1
Plant density, PD (trees/acre)						
119	29.0 ± 1.8 AB	20.3 ± 2.3	39.7 ± 2.4 C	27.8 ± 3.2 B	34.0 ± 2.3 A	27.8 ± 3.1
173	29.7 ± 2.3 A	21.4 ± 2.5	59.4 ± 4.5 B	42.7 ± 4.9 AB	29.6 ± 2.4 AB	27.8 ± 2.9
393	23.2 ± 1.6 B	16.0 ± 1.8	104.7 ± 6.7 A	72.3 ± 8.1 A	26.0 ± 1.7 B	20.4 ± 2.3
	Probability value ($P < 0.05$)					
CRF	**0.0026***	0.0759	**0.0006***	0.1718	**0.0004***	0.1484
PD	**0.0214****	0.1965	**<0.0001***	**<0.0001***	**0.0322****	0.1074
CRF*PD	0.5317	0.6685	0.0570	0.8929	0.6181	0.4392

2017: Hurricane Irma

Trial 1

	Soluble Solids (%)	
Treats	**2017**	**2018**
Controlled-release fertilizer, CRF		
12-3-9	7.6 ± 0.1 B	8.1 ± 0.1
16-3-20	8.0 ± 0.1 A	8.0 ± 0.1
Plant density, PD (trees/acre)		
119	7.7 ± 0.1 B	7.6 ± 0.1
173	7.8 ± 0.1 AB	8.0 ± 0.1
393	8.1 ± 0.1 A	8.6 ± 0.2
	Probability value ($P < 0.05$)	
CRF	**0.0038***	0.9361
PD	**0.0177****	0.0610
CRF*PD	0.4239	0.9978

2017: Hurricane Irma

Trial 1

Trial 2

TREE DENSITY (Yield per tree vs Yield per area)

NUTRITIONAL THERAPY: SOIL

NUTRITIONAL THERAPY: FOLIAR

- Foliar nutrition is vital for perennial crops when nutrient demand is high and soil supply not enough to match uptake (Mengel, 2002)
- HLB causes loss of fibrous root and reduces micronutrient absortion from soil (Pustika et al., 2008)
- Morgan et al., 2016: Foliar application of B, Mn and Zn increases leaf nutrient concentration in sweet orange
- Shen et al., 2013: Long-term foliar application of B, Mn and Zn on HLB-affected sweet orange increased the Cycle threshold (Ct) value

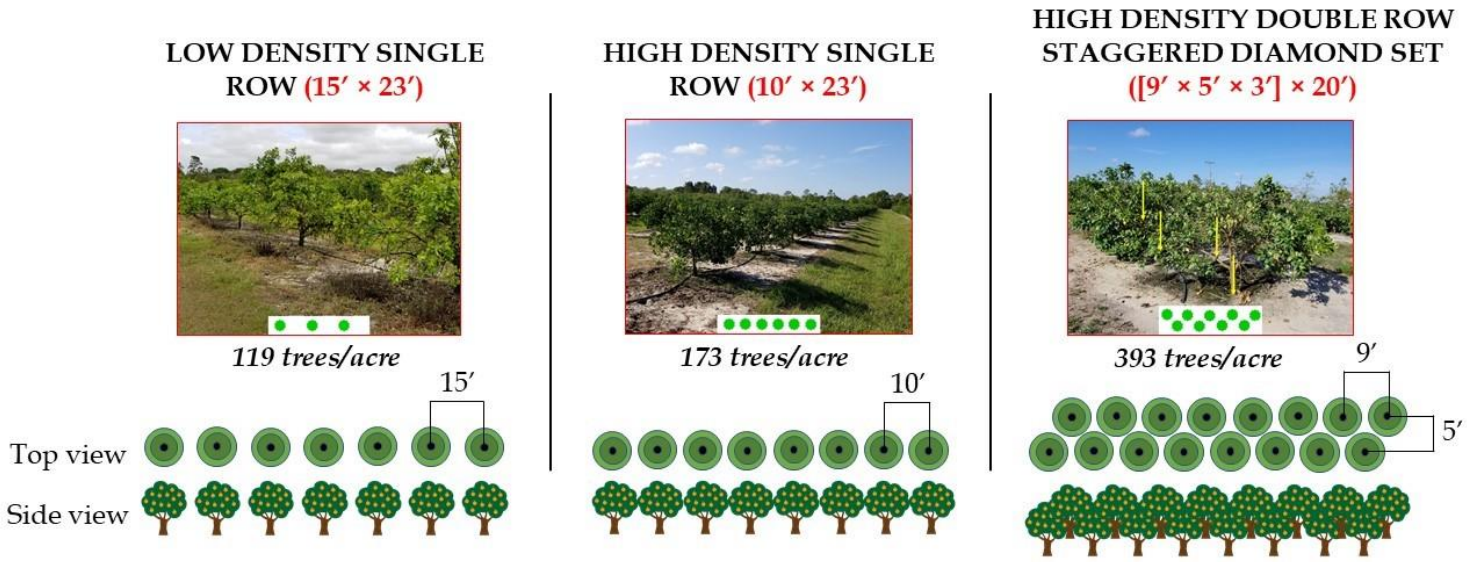
OBJECTIVES

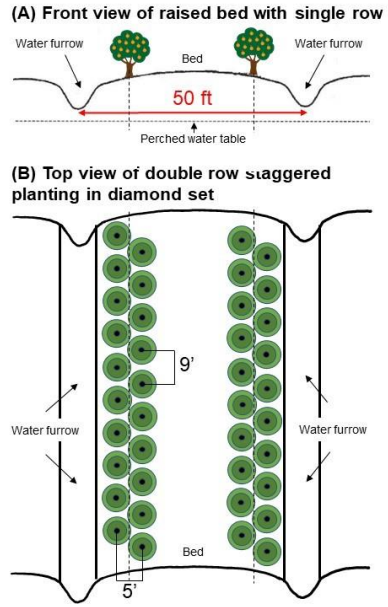
1. To study the responses of soil application of two different CRFs on tree growth, fruit yield and fruit quality

- 16-3-20 CRF with 81% N and 50% K as CRF and micros as sulfates (1× IFAS)
- 12-3-9 CRF with 100% N, 100% P and 95% K as CRF and all other micros as S-coated (2× IFAS)

applied Feb, Jun and Oct

2. To assess the best tree planting spacing for higher tree growth and yield





OBJECTIVES

3. To study the effect of foliar application of four different rates of B, Mn, and Zn as a blend at 0x, 1.5x, 3x and 6x IFAS recommendation on tree growth, fruit yield and fruit quality

Total per year	lb/acre/year					
	B (borax)	B	$MnSO_4$	Mn	$ZnSO_4$	Zn
0x	0	0	0	0	0	0
IFAS recommendation (1x)	1.19	**0.25**	12.5	**4**	13.89	**5**
1.5x	1.79	0.375	18.75	6	20.83	7.5
3x	3.57	0.75	37.5	12	41.67	15
6x	7.14	1.5	75	24	83.33	30

Applied March, May and September

	Ct value of Clas DNA	
Treatments	**2018**	**2019**
Controlled-release fertilizer, CRF		
12-3-9 + micros 2x IFAS as sulfur-coated	24.70 ± 0.38	24.95 ± 0.24
16-3-20 + micros 1x IFAS as sulfates	25.45 ± 0.41	24.94 ± 0.26
Plant density, PD (trees/acre)		
119	25.10 ± 0.49	25.12 ± 0.39
173	25.34 ± 0.61	24.91 ± 0.27
393	24.79 ± 0.42	24.82 ± 0.28
Foliar Applied Micronutrient, FAM		
0x	N/A	25.07 ± 0.34
1.5x	N/A	25.13 ± 0.41
3x	N/A	24.64 ± 0.34
6x	N/A	24.96 ± 0.34
	Probability value (P < 0.05)	
CRF	0.1148	0.8074
PD	0.5445	0.7750
CRF*PD	**0.0013***	**0.0274****
FAM	N/A	0.5642
CRF*FAM	N/A	**0.0266****
PD*FAM	N/A	0.7381
CRF*PD*FAM	N/A	0.2790

Tree infected when Ct value < 32

	Trunk diameter (mm)		Canopy volume (m^3)	
Treatments	**2018**	**2019**	**2018**	**2019**
Controlled-release fertilizer, CRF				
12-3-9	82.82 ± 1.16	87.69 ± 1.25	8.33 ± 0.28 A	8.63 ± 0.3 A
16-3-20	81.86 ± 1.08	86.49 ± 1.33	7.59 ± 0.25 B	7.98 ± 0.32 B
Plant density, PD (trees/acre)				
119	88.81 ± 0.79 A	93.26 ± 1.22 A	9.18 ± 0.28 A	9.83 ± 0.32 A
173	84.88 ± 0.68 B	90.26 ± 0.95 A	8.56 ± 0.23 A	8.93 ± 0.26 B
393	73.33 ± 0.65 C	77.75 ± 0.92 B	6.13 ± 0.2 B	6.14 ± 0.19 C
Foliar Applied Micronutrient, FAM				
0x	82.31 ± 1.69	87.63 ± 1.99	8.01 ± 0.44	8.59 ± 0.58
1.5x	81.42 ± 1.48	85.6 ± 2	7.75 ± 0.35	7.85 ± 0.41
3x	82.64 ± 1.69	88.17 ± 1.56	7.95 ± 0.36	8.31 ± 0.32
6x	83.01 ± 1.53	86.96 ± 1.77	8.12 ± 0.39	8.45 ± 0.43
	Probability value ($P < 0.05$)			
CRF	0.2471	0.3328	**0.0045***	**0.0264****
PD	**<0.0001***	**<0.0001***	**<0.0001***	**<0.0001***
CRF*PD	0.7509	0.6151	0.6832	0.7307
FAM	0.5725	0.4834	0.7417	0.2963
CRF*FAM	0.1234	0.2496	**0.0082***	0.5397
PD*FAM	0.7020	0.4442	0.2670	0.1042
CRF*PD*FAM	0.7031	0.8255	0.3854	0.1446

	Fruit yield per tree (lb)		Fruit yield (boxes/acre)		Total # fruit (No.)	
Treatments	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Controlled-release fertilizer, CRF						
12-3-9	17.1 ± 0.9	38.2 ± 2.0	44.0 ± 2.8	90.6 ± 4.9	21.9 ± 1.1	38.7 ± 2.3 B
16-3-20	16.7 ± 0.7	41.7 ± 1.6	41.9 ± 2.2	102.1 ± 4.8	22.3 ± 0.9	48.1 ± 1.9 A
Plant density, PD (trees/acre)						
119	17.4 ± 1.1	42.1 ± 2.1 A	23.8 ± 1.5 C	57.5 ± 2.9 C	22.5 ± 1.3	47.2 ± 2.6 A
173	18.0 ± 1.0	47.7 ± 2.4 A	36.1 ± 2 B	95.3 ± 4.8 B	23.9 ± 1.3	51.4 ± 2.9 A
393	15.3 ± 0.8	30.1 ± 1.6 B	69.0 ± 3.8 A	136.2 ± 7.1 A	19.9 ± 1.1	31.6 ± 1.9 B
Foliar Applied Micronutrient, FAM						
0x	19.2 ± 1.3 A	49.4 ± 3.2 A	47.6 ± 3.8 A	115.5 ± 8.0 A	25.3 ± 1.7 A	54.2 ± 3.9 A
1.5x	17.5 ± 1.1 AB	39.1 ± 2.4 B	44.6 ± 3.6 AB	94.4 ± 6.4 AB	22.8 ± 1.3 AB	42.7 ± 2.9 B
3x	17.1 ± 1.1 AB	39 ± 2.2B	43.9 ± 3.9 AB	95.9 ± 6.7 AB	22.6 ± 1.5 AB	42.0 ± 2.6 B
6x	13.7 ± 0.9 B	32.2 ± 1.7B	35.7 ± 3.0 B	79.6 ± 5.7 B	17.8 ± 1.2 B	34.5 ± 2.0 B
	Probability value ($P < 0.05$)					
CRF	0.6988	0.1276	0.5025	0.0549	0.8034	**0.0009***
PD	0.1111	**<0.0001**	**<0.0001***	**<0.0001***	0.0740	**<0.0001***
CRF*PD	0.8330	0.6611	0.6594	0.2566	0.7927	0.1611
FAM	**0.0068***	**<0.0001**	**0.0410****	**0.0004***	**0.0028***	**<0.0001***
CRF*FAM	0.1659	0.1750	0.5540	0.4185	0.1893	0.3871
PD*FAM	0.8485	0.3745	0.9640	0.9825	0.6544	0.3759
CRF*PD*FAM	0.7375	0.2790	0.8839	0.7656	0.5917	0.1505

	Soluble Solids (%)	
Treatments	**2018**	**2019**
Controlled-release fertilizer, CRF		
12-3-9	7.9 ± 0.1	8.31 ± 0.11 A
16-3-20	7.7 ± 0.1	7.52 ± 0.14 B
Plant density, PD (trees/acre)		
119	7.7 ± 0.1 B	7.63 ± 0.17 B
173	7.8 ± 0.1 AB	7.9 ± 0.16 AB
393	8.1 ± 0.2 A	8.22 ± 0.17 A
Foliar Applied Micronutrient, FAM		
0x	8.1 ± 0.16	7.98 ± 0.22
1.5x	7.8 ± 0.13	8.00 ± 0.20
3x	7.6 ± 0.18	7.80 ± 0.20
6x	7.9 ± 0.15	7.88 ± 0.19
	Probability value (P < 0.05)	
CRF	0.3717	**<0.0001***
PD	**0.0223****	**0.0471****
CRF*PD	0.0518	0.8720
FAM	0.1093	0.8694
CRF*FAM	0.2116	0.9813
PD*FAM	0.1281	0.9532
CRF*PD*FAM	0.3459	0.7158

TAKE HOME MESSAGES

- ✓ There is no effect of enhanced soil and foliar nutrition on *Ct value* of GF yet over a period of 2 years (possible effect overtime stills unknown)
- ✓ Higher tree planting density increases *Fruit yield* and Fruit *Quality*
- ✓ Excessive supplemental foliar micronutrient application is negative to *Fruit yield* and *Total # fruit*

Host

Planting densities, fertilization methods and irrigation systems for sweet orange production in the Indian River District

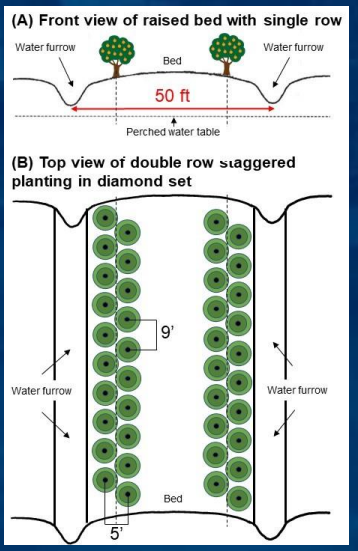
Rhuanito Ferrarezi, Tom James, Clarence King, Don Davis, Randy Burton

(2 single-rows/bed)

- ‘STD_dry_MS: standard tree spacing (12.5’×23.5’ @ 145 trees/acre) + controlled-release fertilizer (CRF) + microsprinkler irrigation (one emitter per tree; microsprinkler 50 green nozzle, 16.7 GPH at 20 psi) (Bowsmith, Exeter, CA)

18N-1.31P-16.6K CRF fertilizer (Harrell’s 18-3-20) applied three times a year at 200 lb/acre

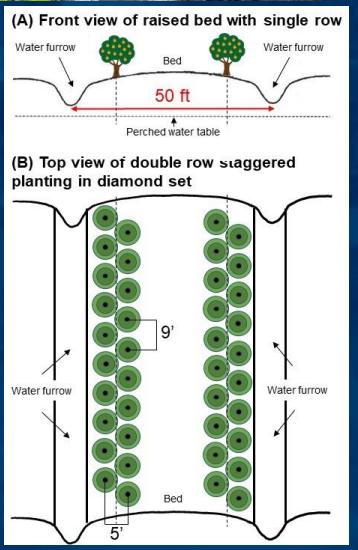
(2 double-rows/bed)



- HDS_fert_MS: high density staggered in diamond set ([9′ × 5′ × 3′] × 20′ @ 386 trees/acre) + fertigation + microsprinkler irrigation (one emitter per two trees; microsprinkler 50 green nozzle, 16.7 GPH at 20 psi) (Bowsmith, Exeter, CA)

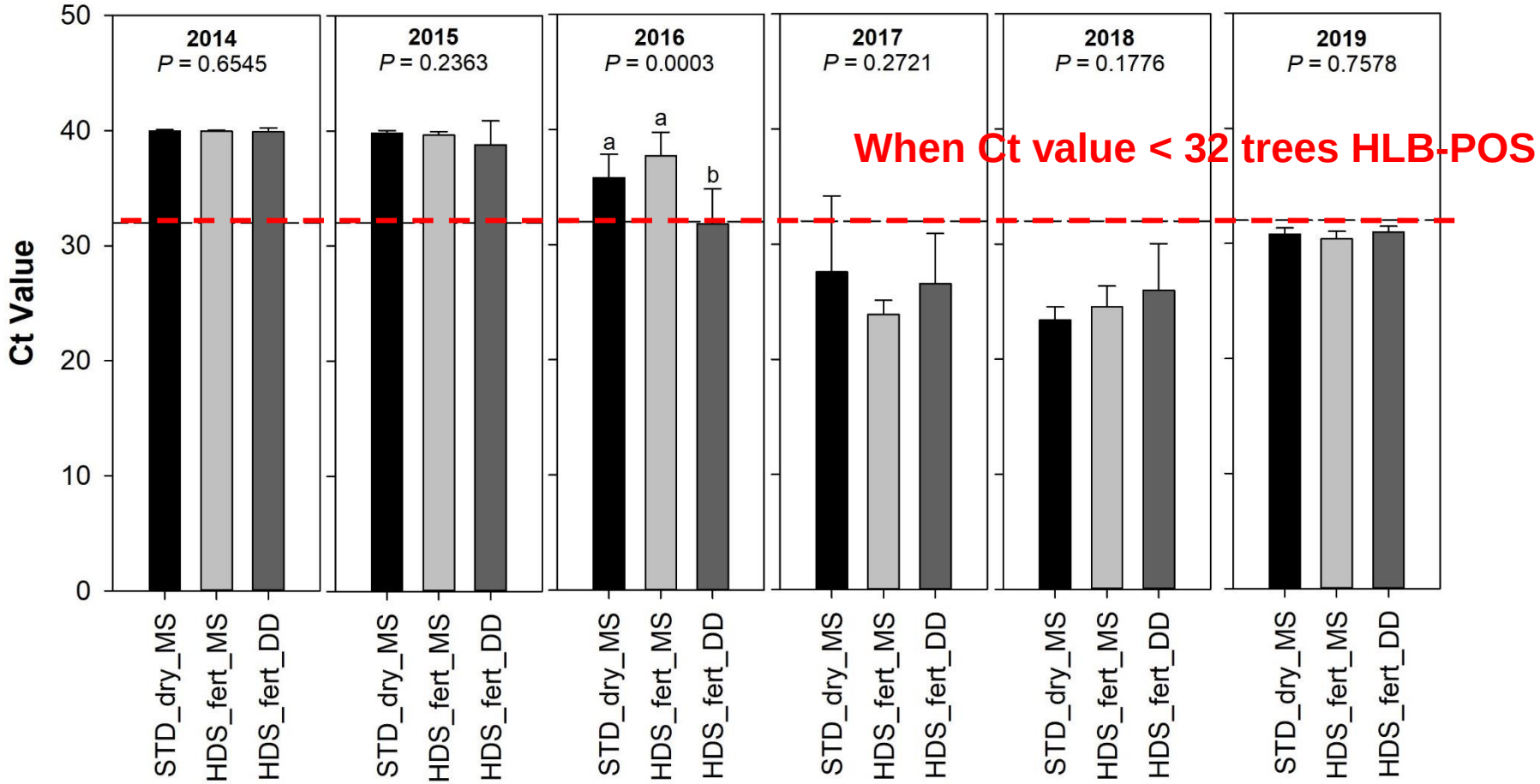
15N-4.81P-25.73K water-soluble fertizer (Agrolution phLow 15-11-31 +0.75Mg, High K with Mg) applied weekly at 200 lb/acre

(2 double-rows/bed)

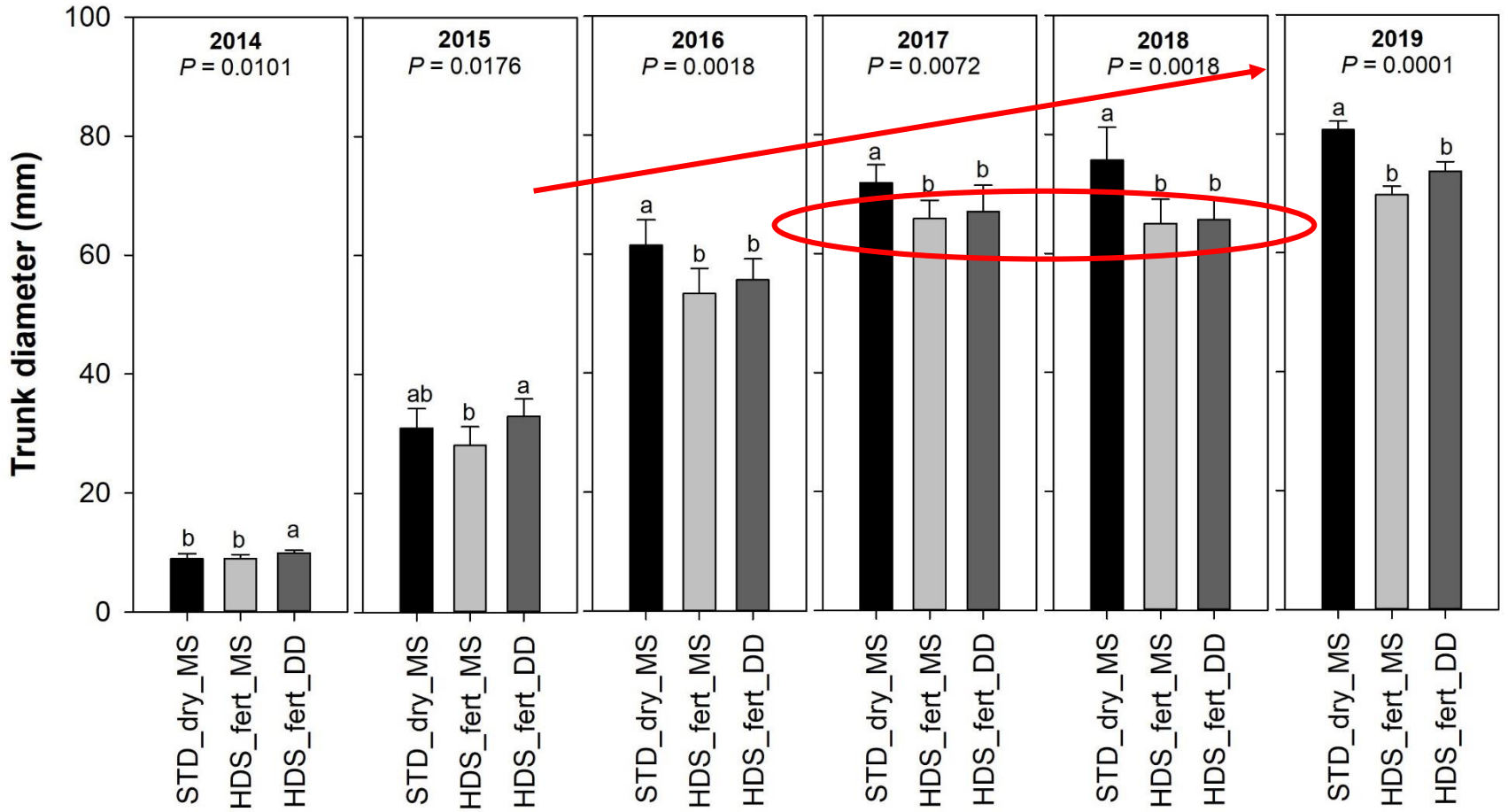


- HDS_fert_DD: high density staggered in diamond set ([9′ × 5′ × 3′] × 20′ @ 386 trees/acre) + fertigation + double-line drip irrigation (two lines per row; Emitterline 0.58 GPH at 10 psi, 12-inch spacing) (Jain Irrigation, Fresno, CA)

15N-4.81P-25.73K water-soluble fertizer (Agrolution phLow 15-11-31 +0.75Mg, High K with Mg) applied weekly at 200 lb/acre



STD_dry_MS: standard tree spacing (12.5’ × 23.5’ @ 145 trees/acre) + CRF fertilizer + microsprinkler (one emitter/tree, 16.7 GPH at 20 psi)
HDS_fert_MS: high density staggered ([9’ × 5’ × 3’] × 20’ @ 386 trees/acre) + fertigation + microsprinkler (one emitter/two trees)
HDS_fert_DD: high density staggered + fertigation + double-line drip irrigation (two lines/row; 0.58 GPH at 10 psi, 12-inch spacing)



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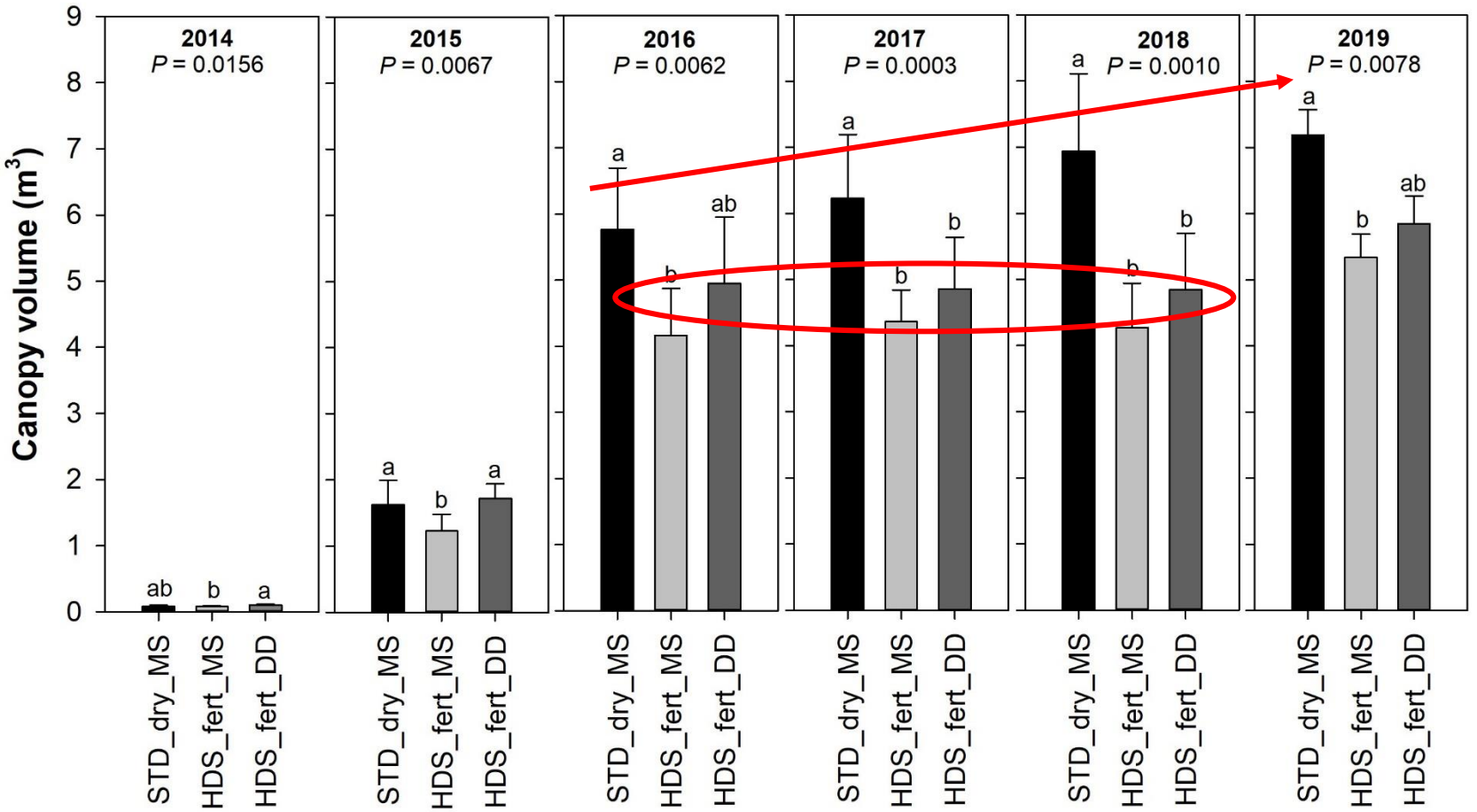

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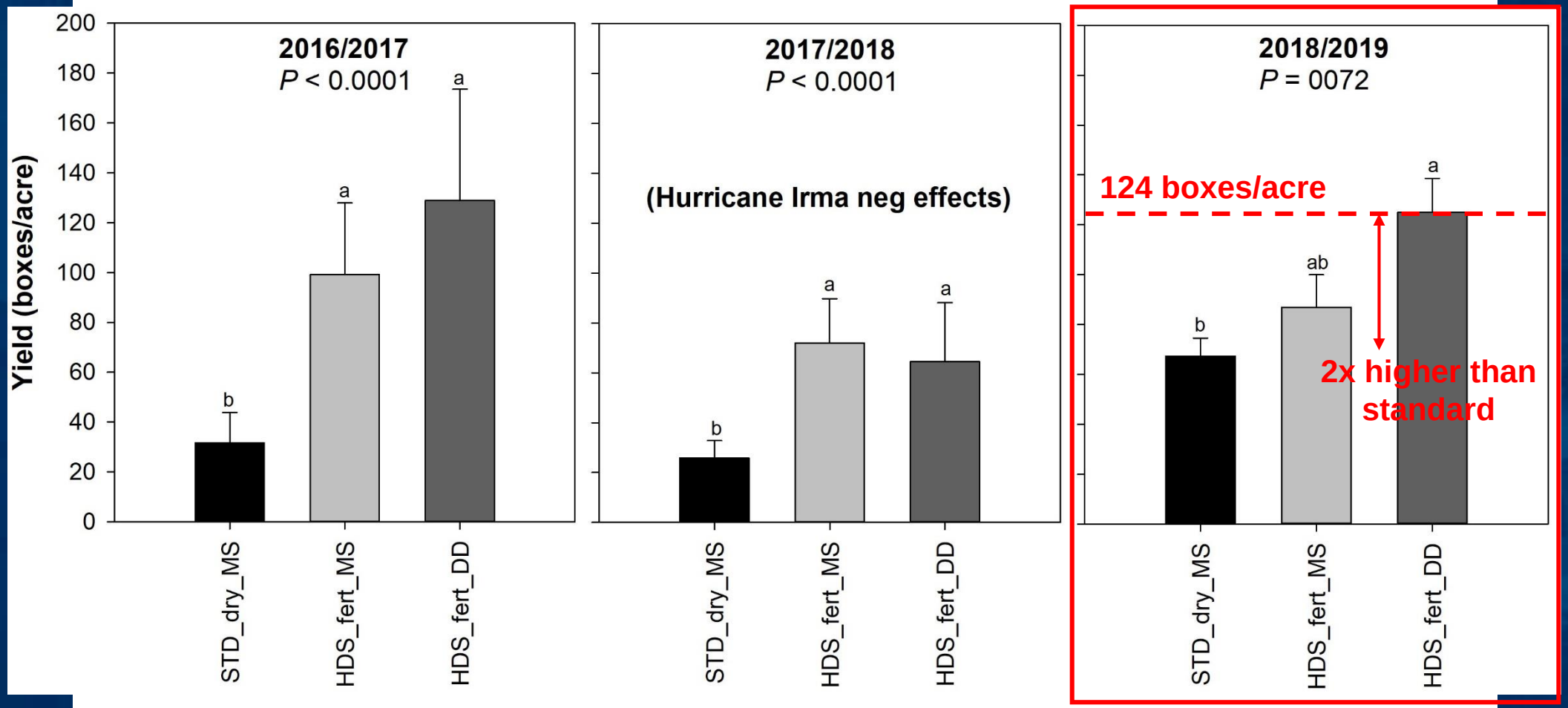

Negative effect of rootstock and extremely high-density planting

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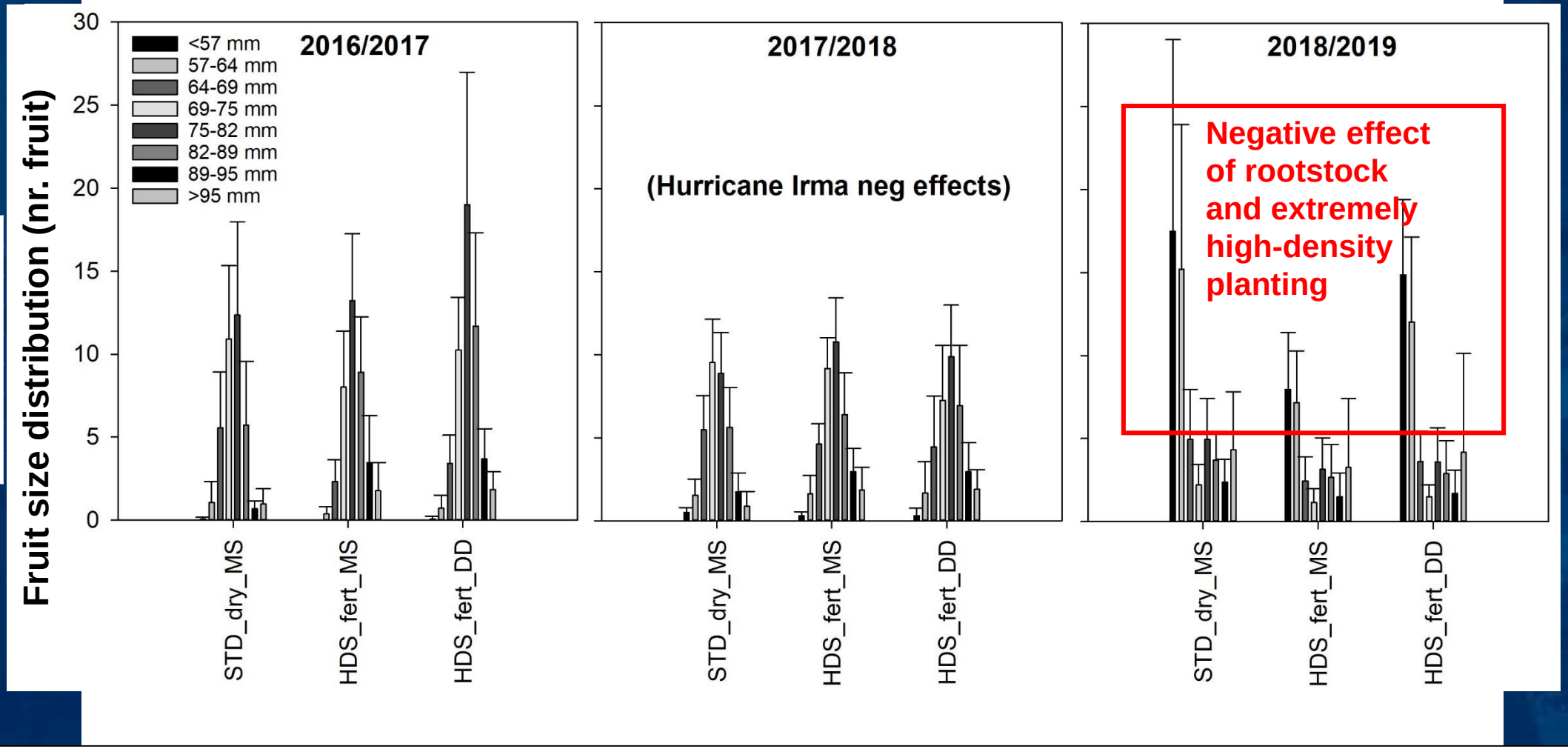
HDS_fert_DD: high density staggered + fertigation + double-line drip irrigation (two lines/row; 0.58 GPH at 10 psi, 12-inch spacing)

(5th year)

fruit (size)
<163 (<57 mm)
163 (57-64 mm)
125 (64-69 mm)
100 (69-75 mm)
80 (75-82 mm)
64 (82-89 mm)
50 (89-95 mm)
>50 (>95 mm)



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HDS_fert_DD: high density staggered + fertigation + double-line drip irrigation (two lines/row; 0.58 GPH at 10 psi, 12-inch spacing)

Graves Brothers groves in Fort Pierce, FL (thanks David Howard!)

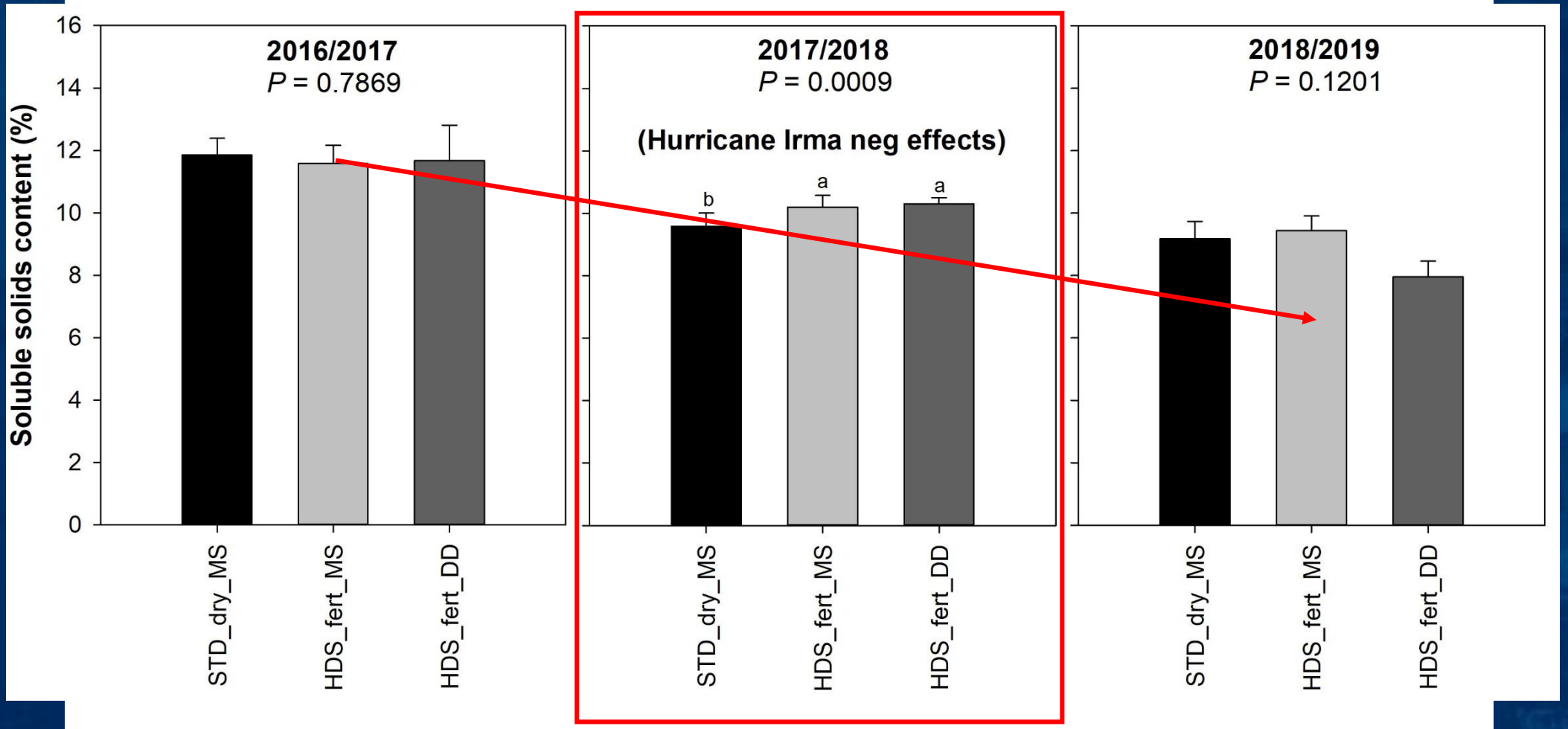
Valencia on **Swingle** staggered @ 290 trees/acre
Planted 2012
1 hedging/topping
6th year 231 boxes/acre

Valencia on **x639** staggered @ 290 trees/acre
Planted 2012
2 hedging/topping
6th year 297 boxes/acre

Valencia on **US-802** staggered @ 290 trees/acre
Planted 2012
2 hedging/topping
6th year 250 boxes/acre

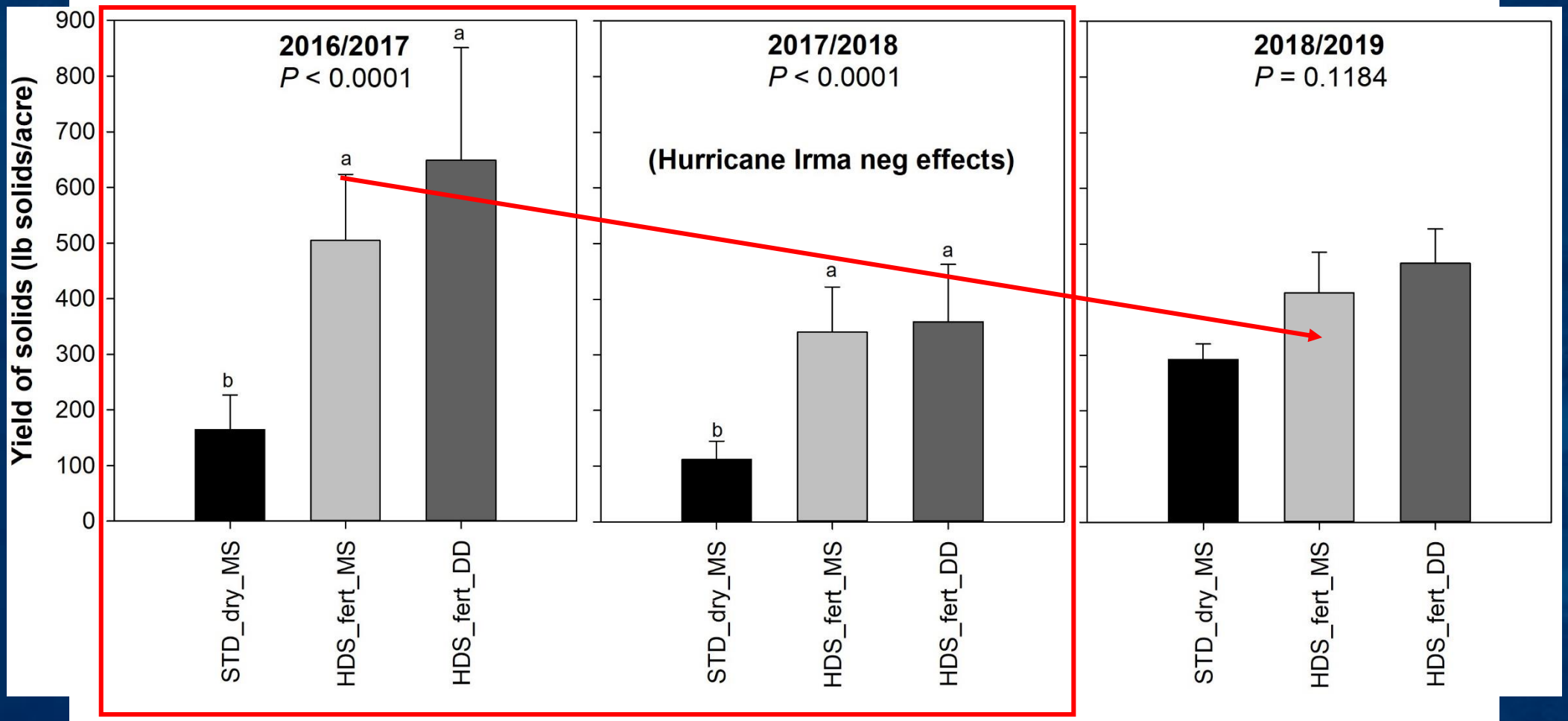
Valencia on **US-802**
single @ 227
trees/acre
Planted 2012
No production record

Valencia on **Kuharske**
staggered @ 386
trees/acre
Planted 2013
6th year 125 boxes/acre



STD_dry_MS: standard tree spacing (12.5' × 23.5' @ 145 trees/acre) + CRF fertilizer + microsprinkler (one emitter/tree, 16.7 GPH at 20 psi)
HDS_fert_MS: high density staggered ([9' × 5' × 3'] × 20' @ 386 trees/acre) + fertigation + microsprinkler (one emitter/two trees)
HDS_fert_DD: high density staggered + fertigation + double-line drip irrigation (two lines/row; 0.58 GPH at 10 psi, 12-inch spacing)

Acidity and ratio data not shown



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Take-home messages

- Staggered, high-density plantings resulted in higher fruit yield and quality, producing more soluble solids per area.

- However, yield is too low as consequence of rootstock performance/choice (Kuharske citrange) and extremely high planting density (386 trees/acre).

- A field trial in a commercial grove (Graves Brothers) indicates that better rootstocks and lower tree densities resulted in economical yield at the Indian River ~ THE SWEET SPOT (Spike, Castle & Stover, 2018).

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Thanks! Questions?

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