CRDF Directed Research – Efficacy of OTC Injection Treatments on Mature Trees

Overview

This project is a simple side-by-side evaluation of OTC injection treatments on citrus trees greater than 20 years old. The study contained two sites, one Hamlin and one Valencia. Data were collected on factors relevant to citrus growers in making decisions on injecting OTC for improved fruit yield, fruit quality, and tree health.

Hamlin Site – Frostproof

A Hamlin/Swingle block was selected for the early variety cultivar. The block is 30-years old and planted in traditional central Ridge fashion. The spacing is 12’ x 25’ with a planting density of 145 trees per acre.

All treatments were conducted on March 30, 2023. The starting time for injection was 9:00 am and all injection devices were empty by 10:00 am. The soil within the drip line of the tree was moist but the soil outside the wetted zone of the microjet emitters was dry. The air temperature was 74°F and the soil temperature at 6 inches deep was 71°F. The sky was clear with a 3-4 mile per hour wind. Relative humidity was 55%.

The OTC product label called for the maximum dosage according to trunk diameter. The volume needed per injector was 150 mL and the OTC concentration was 11,000 ppm.

Three treatments were evaluated, to wit:

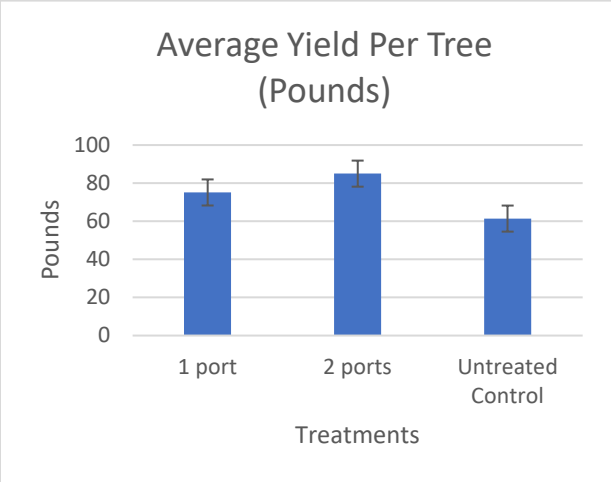
1. Untreated control
2. Single port injection: Injection of 150 mL of an 11,000 ppm OTC solution with a single injection port on the east side of the tree
3. Two port injection: Injection with 2 injection devices. Each injection device had a volume of 75 mL of an 11,000 ppm OTC solution. One injection device was inserted on the east side of the tree and the second was inserted on the west side of the tree.

The trial design was comprised of 5 replicated plots per treatment with each plot containing 5 trees. At the start of the trial, trees were selected according to DI ratings to reduce tree-to-tree variability. Data were collected on yield, fruit drop, DI ratings, and fruit quality.

Data were analyzed using ANOVA and Tukey HSD. Significant differences are at a p value less than 0.05.

Yield

Yield data was collected on January 8, 2024, approximately 9 months after injection. Each tree was harvested separately, and a single weighed value was recorded for each tree in the trial.

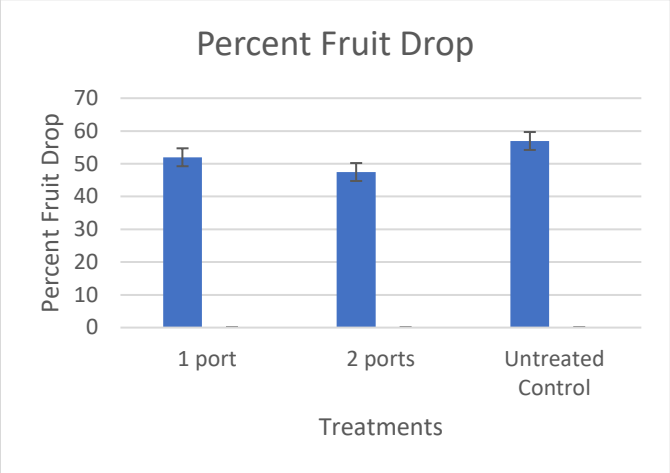


Treatment	Yield Per Tree (Pounds)	
1 port	75.12	A
2 ports	85	A
Untreated Control	61.4	A
Model p>F	0.139	

While there was a difference in yield between the treatments, the difference was not significant. The 2-port injection treatment was numerically higher than the 1 port treatment and untreated control treatment.

Percent Drop

Fruit drop counts were conducted at six points in time leading up to harvest. Fruit drop counts began in October 2023 and continued through January 2024. Fruit drop was assessed on a per tree basis.

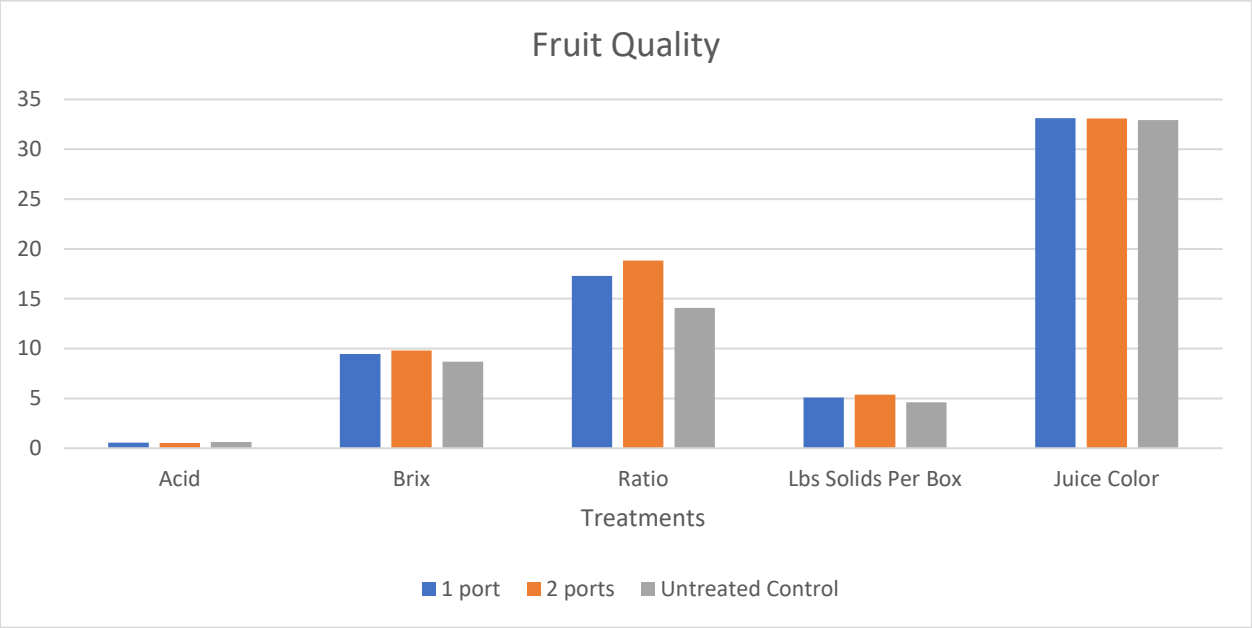


Treatment	Percent Fruit Drop	
1 port	51.97	A
2 ports	47.47	A
Untreated Control	56.94	A
Model p>F	0.106	

There was no significant difference found in the analysis of fruit drop. The untreated control had the highest percent of fruit drop at 56.9%. The 2-port treatment had the lowest amount at 47.4%.

Fruit Quality

Fruit quality analysis was performed at the CREC Pilot Plant on January 9, 2024. A single fruit quality sample was collected from each plot in the trial.



	Acid		Brix		Ratio		Pound Solids Per Box		Juice Color	
1 Site	0.548	AB	9.458	A	17.29	A	5.0873	A	33.114	A
2 Site	0.522	B	9.824	A	18.84	A	5.36864	A	33.104	A
Untreated Control	0.624	A	8.682	B	14.1	B	4.605	B	32.924	A
Model p>F	0.027		0.002		0		0.002		0.56	

Analysis of titratable acid showed a significant difference between the untreated control at 0.624 and the 2-port treatment at 0.522. The 1-port treatment was not significantly different from either the untreated control or the 2-port treatment.

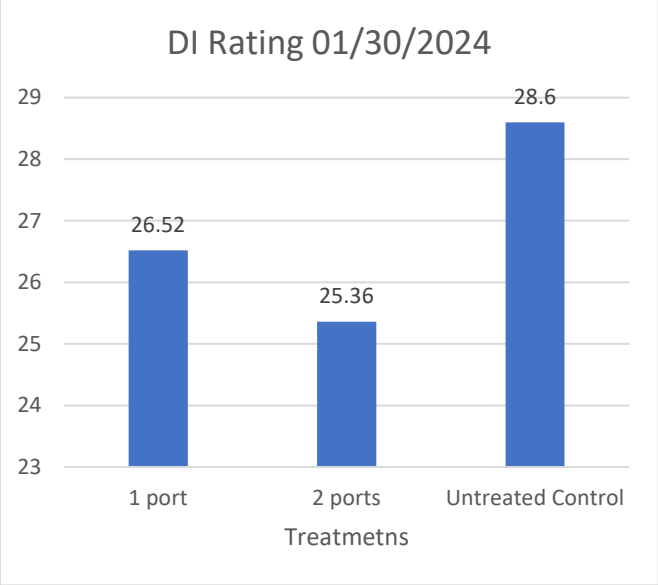
Brix content and Brix/Acid Ratio was significantly different for both OTC treatments compared to the untreated control. The 1-port and 2port treatments were not significantly different from each other.

Pound solids per box values for both OTC treatments were higher than the recent historical performance for Hamlin. The 2-port treatment provided the highest pound solids per box at 5.36 and the 1 port treatment produced 5.08-pound solids per box. Both the 1-port and 2-port treatments were significantly different (higher) than the untreated control.

There was no significant difference between any of the treatments for juice color.

DI Ratings

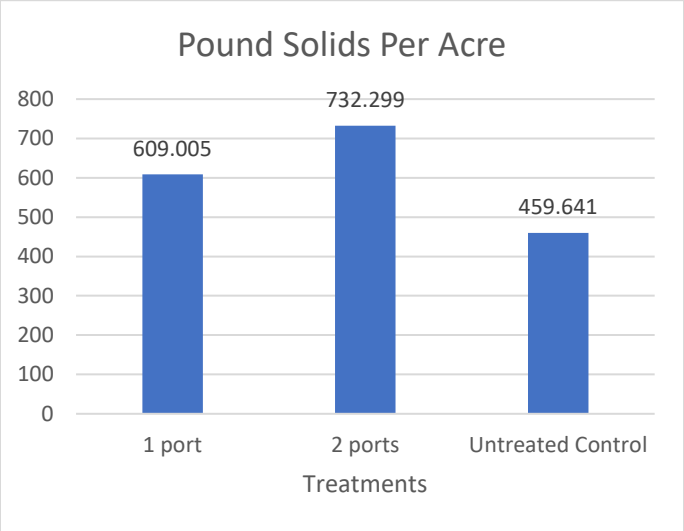
DI Ratings were determined at the start of the trial and after harvest. The DI ratings were first taken on March 30, 2023. The crop consultant used his best judgement to select trees that were of similar visual appearance. The crop consultant was able to select trees which all had a combined DI rating of 32, indicating this block is uniformly declined with HLB. The DI rating scale for mature trees is 0 – 40. The higher the score the more pronounced the HLB disease expression and tree decline. A DI rating of 32 is high but not unheard of for a commercial block. The second DI rating was taken on January 30, 2024. DI ratings improved across the block for all treatments. The average improvement for the treatments showed that the untreated control decreased (improved) by an average of 3.4 points, the 1-port treatment decreased by an average of 5.5 points, and the 2-port treatment decreased by an average of 6.6 points.



Treatments	DI_March_30_2023	DI_Jan_30_2024
1 port	32	26.52
2 ports	32	25.36
Untreated Control	32	28.6

Economic Analysis

By using yield values and planting density, a calculation of boxes per acre can be estimated. Additional calculations using fruit quality data and the estimated yield per acre values can provide a close estimation of pound solids per acre to aid in determining revenue per acre.



Treatment	Pound Solids Per Acre	
1 port	609.005	AB
2 ports	732.299	A
Untreated Control	459.641	B
Model p>F	0.0373	

The analysis showed a significant difference between the 2-port treatment and the untreated control. There was no significant difference between the untreated control and the 1 port treatment.

Year 2 The same sites and trees used in the first year of the study were used in the second year. The Hamlin/Swingle trees are now 31 years old, and the Valencia/Swingle trees are 21 years old. An additional treatment was added to the protocol for year two. The treatments employed in the second year were:

1. Untreated Control
2. Single port injection (1 port): Injection of 150 mL of an 11,000 ppm OTC solution with a single injection port on the west side of the tree
3. Two port injection (2 port): Injection with 2 injection devices. Each injection device had a volume of 75 mL of an 11,000 ppm OTC solution. One injection device was inserted on the south side of the tree and the second was inserted on the north side of the tree.
4. Two port injection full rate (2 port X 2): Injection with 2 devices. Each injection device had a volume of 150 mL of an 11,000 ppm OTC solution. The injectors were placed into opposite sides of the tree trunk, 180 degrees apart from each other.

The trial design stayed the same as in year one (5 replicated plots per treatment with each plot containing 5 trees). The trees used for treatment 4 (2-port X 2) had never been injected with OTC or any other agrochemical. Data were collected on yield, fruit drop, DI ratings, and fruit quality.

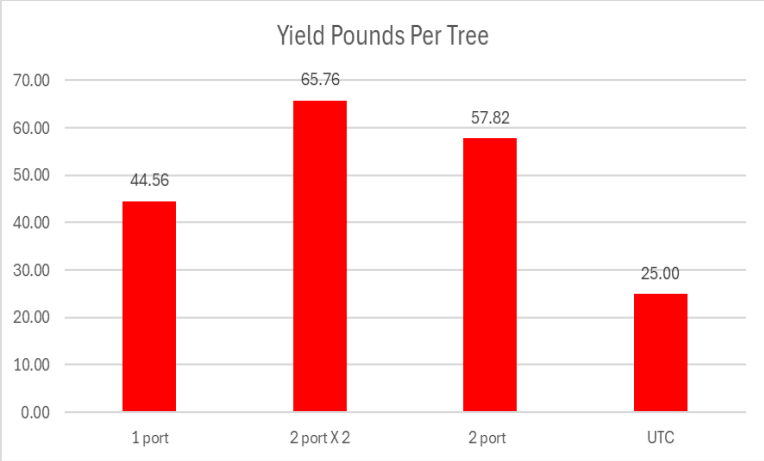
Data were analyzed using ANOVA and Tukey HSD. Significant differences are so at a p value less than 0.05.

Hamlin Site Year 2

Injections were made on May 16, 2024. The injection work began at 7:00 am and concluded at 9:30 am. The air temperature was 83 degrees with relative humidity of 66%. There was no wind and cloud cover was 90%. The soil temperature at 6 inches of depth was 80 degrees. The soil was moist within the wetted zone of the micro irrigation emitter.

Yield

Yield data was collected on December 31, 2024. Each tree was harvested separately, and a single weighed value was recorded for each tree in the trial. The yield values presented are an average for each treatment.

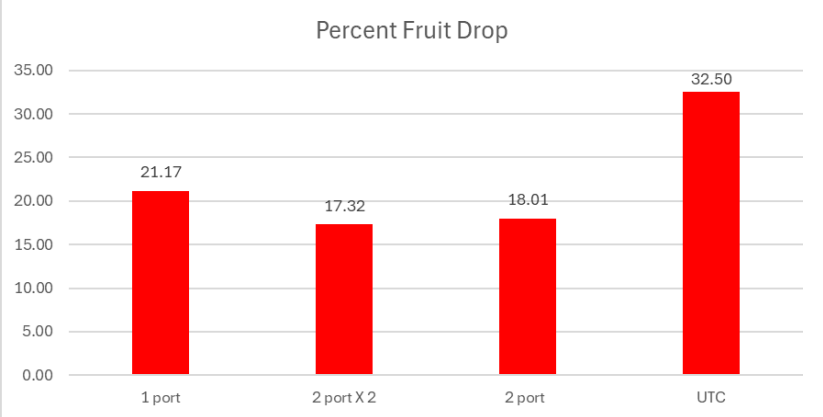


Treatment	Yield Pounds	
1 port	44.56	B
2 port X 2	65.76	A
2 port	57.82	AB
UTC	25.00	C
Model	<.0001	

The UTC treatment was significantly lower for yield compared to the 3 OTC treatments. The 2 port X 2 treatment provided the highest yield which was significantly different compared to the 1 port treatment and UTC.

Percent Drop

Fruit drop evaluation was performed from October 2024 through December 2024, but Hurricane Milton significantly impacted this trial. Due to the storm's impact on fruit drop, there is no way to determine whether the observed fruit drop was due to HLB or the immediate and/or long-term aftereffects of the hurricane. However, the data was collected and analyzed but there is little confidence in the fruit drop data due to the storm.

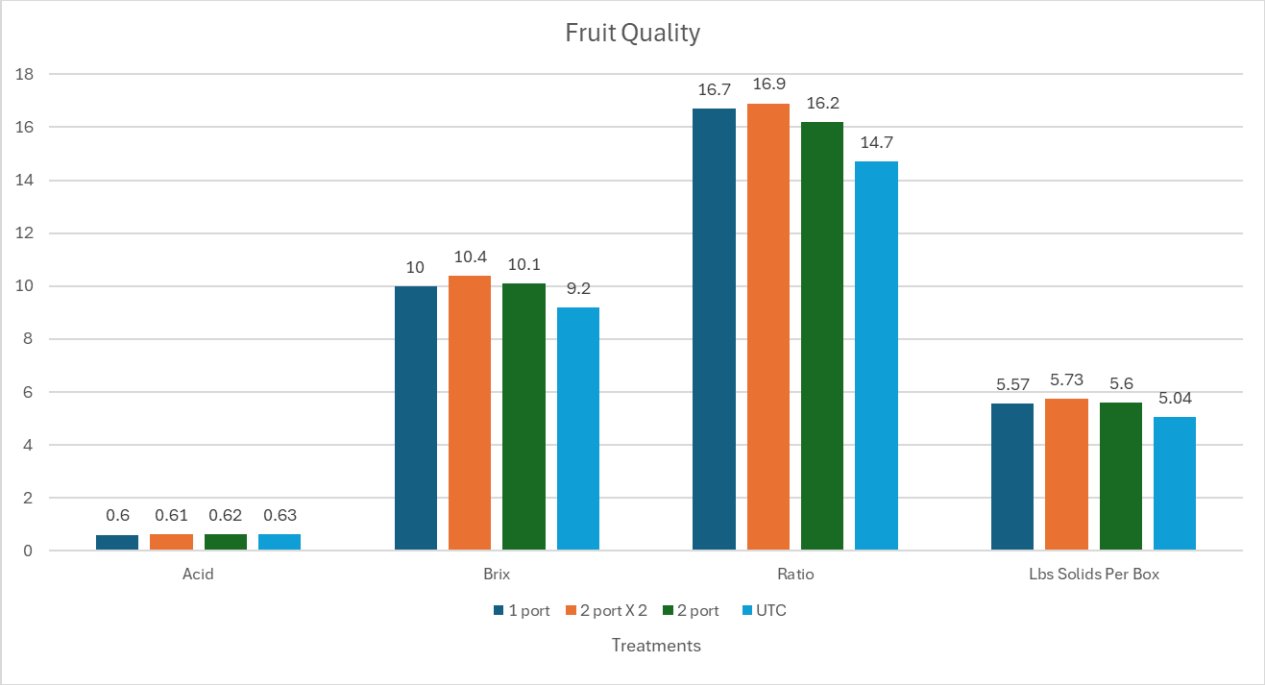


Treatment	Percent Drop	
1 port	21.17	B
2 port X 2	17.32	B
2 port	18.01	B
UTC	32.50	A
Model	<.0001	

The UTC treatment suffered significantly higher fruit drop compared to the 3 OTC injection treatments.

Fruit Quality

Fruit quality analysis was performed at the CREC Pilot Plant on January 2, 2025. A single fruit quality sample was collected from each plot in the trial and the data below is the average of each treatment.



Treatment	Acid		Brix		Ratio		Pound Solids Per Box	
1 port	0.6	A	10	B	16.7	A	5.57	A
2 port X 2	0.61	A	10.4	A	16.9	A	5.73	A
2 port	0.62	A	10.1	B	16.2	A	5.6	A
UTC	0.63	A	9.2	C	14.7	B	5.04	B
Model	0.0908		<.0001		<.0001		<.0001	

Analysis of titratable acid shows no significant difference between any of the treatments.

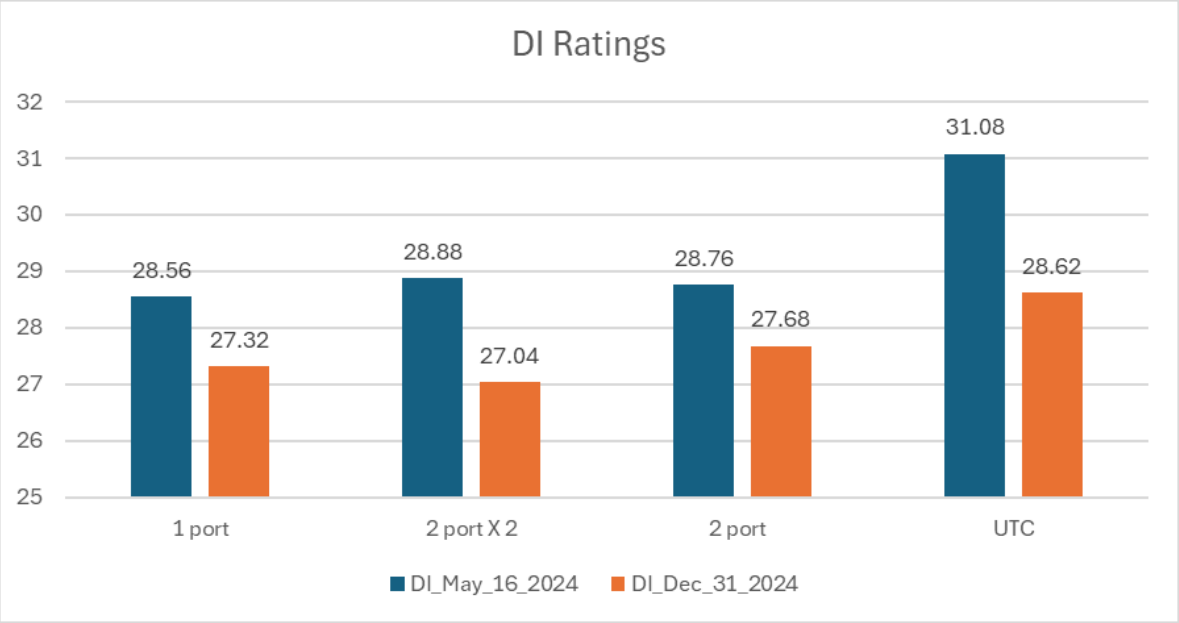
Brix content was highest in the 2-port X 2 treatment at 10.4-degree brix. The 2-port X 2 treatment was significantly different (higher) than all other treatments. The 1-port treatment and the 2-port treatment were not significantly different from each other but were higher than the UTC treatment. The UTC treatment had the lowest Brix content and was significantly lower than all other treatments.

Brix/Acid Ratio was significantly higher for all OTC treatments compared to the UTC treatment.

Pound solids per box values for all OTC treatments were significantly different (higher) than the UTC treatment. The 2-port X 2 treatment provided the highest pound solids per box value at 5.73. There was no significant difference between any of the OTC treatments. The UTC treatment produced 5.04-pound solids per box. The UTC treatment was significantly lower than all OTC treatments.

DI Ratings

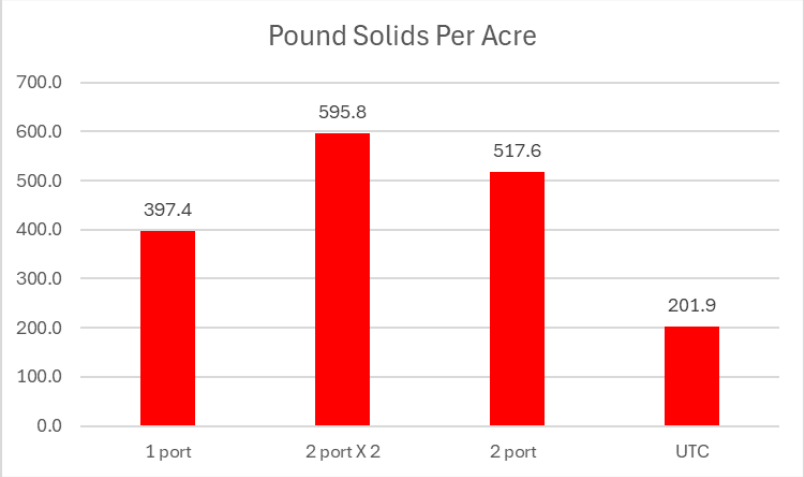
DI Ratings were taken in May 2024 and at harvest in December 2024. The DI rating scale for mature trees is 0 – 40. The higher the score the more pronounced the HLB disease expression and tree decline. DI ratings improved for all treatments in the second year of the trial. The amount of improvement was minimal and does not indicate a remarkable recovery of visually assessed tree health. The separation of DI ratings between treatments was shown to be significant by statistical analysis but the reality of these differences does not translate into meaningful differences in commercial citrus production.



Treatment	DI_May_16_2024		DI_Dec_31_2024	
1 port	28.56	B	27.32	AB
2 port X 2	28.88	B	27.04	B
2 port	28.76	B	27.68	AB
UTC	31.08	A	28.62	A
Model	<.0001		0.0175	

Economic Analysis

By using collected yield data and planting density, a calculation of boxes per acre can be performed. Additional calculations using fruit quality data and estimated yield per acre values can provide a close estimation of pound solids per acre to aid in determining revenue per acre.



Treatment	Pound Solids Per Acre	
1 port	397.4	B
2 port X 2	595.8	A
2 port	517.6	AB
UTC	201.9	C
Model	<.0001	

Pound solids per acre was highest in the 2-port X 2 treatment and was significantly different than the 1 port and UTC treatments. The UTC treatment produced the lowest value and was significantly lower than all OTC treatments.

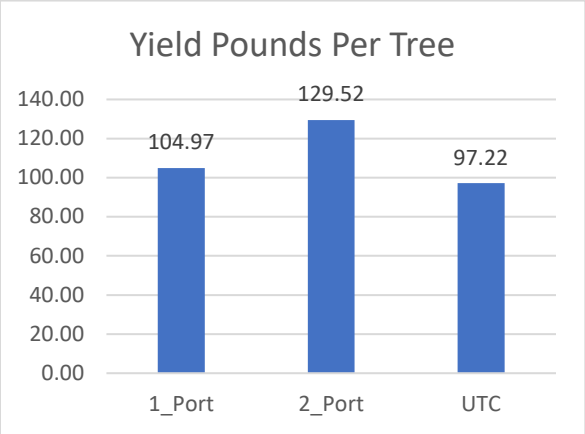
Valencia Site – Avon Park

A Valencia/Swingle block was selected for the late variety cultivar. The block is 21-years old and planted in traditional central Ridge fashion. The planting density is 200 trees per acre.

All treatments were conducted on May 2, 2023. The starting time for injection was 10:45 am and all injection devices were empty by noon. The soil within the drip line of the tree was moist but the soil outside the wetted zone of the microjet emitters was dry. The air temperature was 86°F and the soil temperature at 6 inches deep was 75°F. The sky was clear with a 5 mile per hour wind out of the northwest. Relative humidity was 46%.

Yield

Yield data was collected on April 15, 2024. Each tree was harvested separately, and a single-weighed value was reported for each tree in the trial.

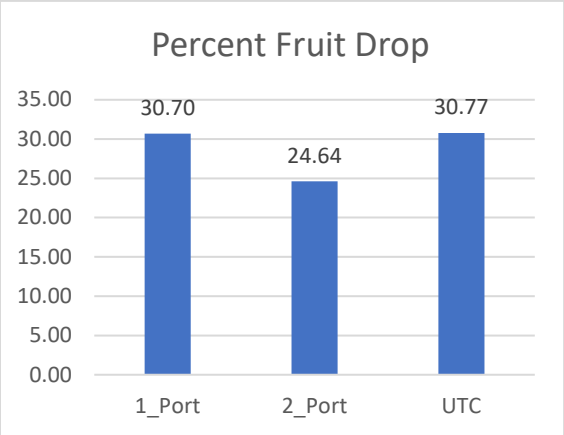


Treatment	Yield Per Tree Pounds	
1_Port	104.97	B
2_Port	129.52	A
UTC	97.22	B
Model p>F	0.0002	

The analysis of yield shows significant differences between the treatments. The 2-port treatment yielded 129 pounds of fruit per tree and that value was significantly different from the 1-port and UTC yield.

Percent Fruit Drop

Fruit drop counts were collected four times prior to harvest approximated on a monthly basis. Fruit drop counts began in January 2024 and continued through April 2024. Fruit drop was assessed on a per tree basis**.**

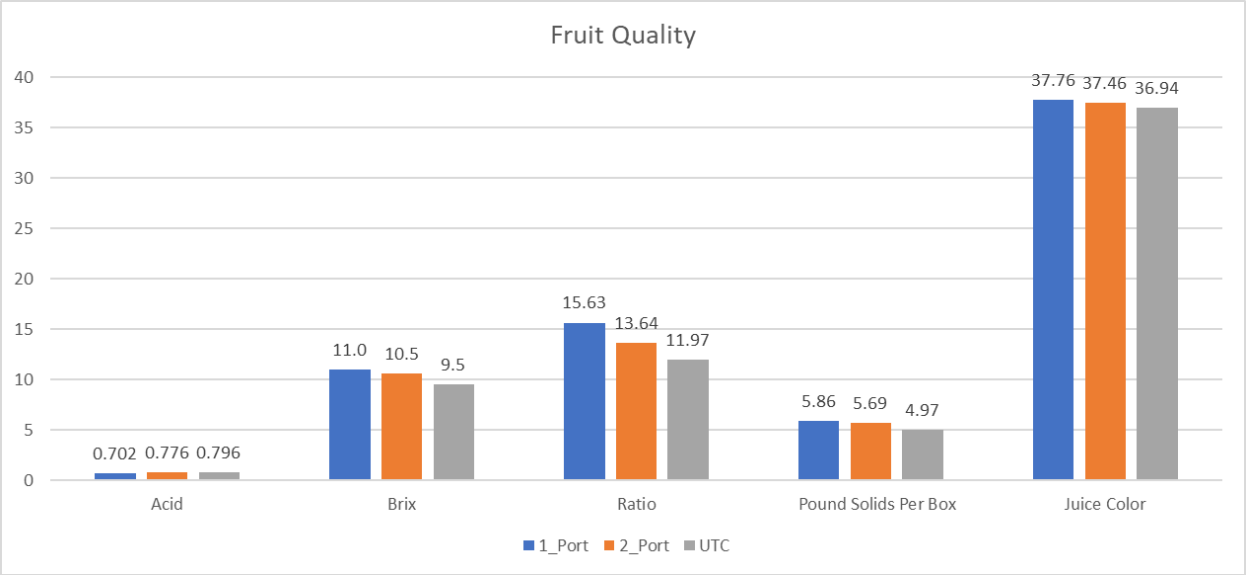


Treatment	Percent Fruit Drop	
1_Port	30.6997391	A
2_Port	24.6362371	B
UTC	30.7743872	A
Model p>F	0.0005	

The percentage of dropped fruit was significantly less in the treatment that used 2-ports compared to the 1-port treatment and UTC. There was no difference in the values for the 1-port treatment and the UTC.

Fruit Quality

Fruit quality analysis was performed at the CREC Pilot Plant on April 18, 2024. A single fruit quality sample was collected from each plot in the trial for a total of 15 samples and the average from the combined treatments are reported below.



Treatment	Acid		Brix		Ratio		Pound Solids Per Box		Juice Color	
1_Port	0.702	B	10.97	A	15.626	A	5.86074	A	37.758	A
2_Port	0.776	A	10.548	A	13.644	B	5.6918	A	37.464	A
UTC	0.796	A	9.504	B	11.972	C	4.97348	B	36.936	B
Model p>F	0.01		<.0001		<.0001		<.0001		0.0005	

Several significant differences were found in the fruit quality analysis.

Titratable acid lowest in the 1-port treatment and significantly different from the values for the 2-port treatment the UTC

Brix levels between the 1-port and 2-port treatment were not significantly different from each other. The UTC was significantly lower than both OTC treatments.

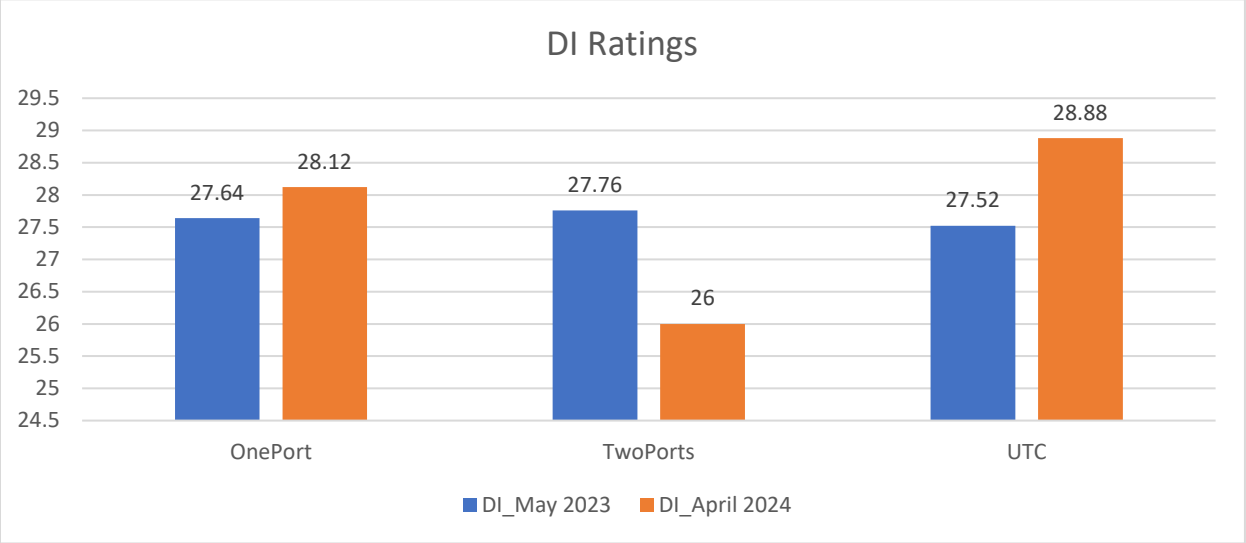
Brix/Acid Ratio was highest in the 1-port treatment at 15.6. The 2-port treatment had a ratio of 13.6. The lowest ratio was seen the UTC at 11.9. Each treatment was significantly different.

Pound Solids per Box was lowest in the UTC at 4.9. The UTC was significantly lower than the both the 1-port and 2-port treatments. There was no significant difference between the 2 OTC treatments.

Juice Color was best in the 1-port treatment at 37.75. There was no significant difference between the 1-port treatment and the 2-port treatment. The UTC was significantly lower than both OTC treatments at 36.93.

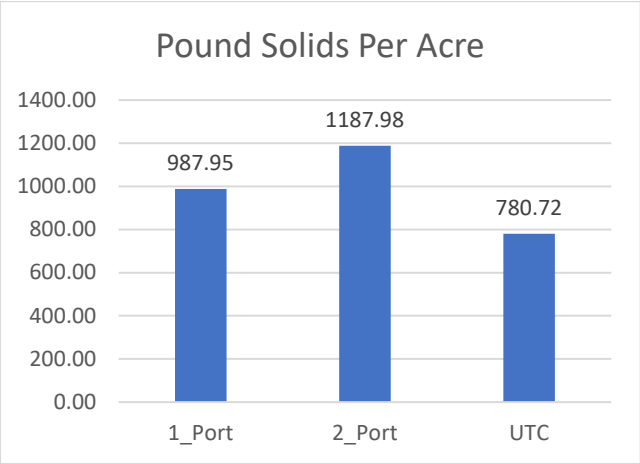
DI Ratings

DI Ratings were determined at the start of the trial and after harvest. The DI ratings were first taken on May 2, 2023. The crop consultant used his best judgement to select trees that were of similar visual appearance. The crop consultant was able to select trees which all had a combined DI rating of 27, indicating the trees selected for this trial were uniformly declined with HLB. The DI rating scale for mature trees is 0 – 40. The higher the score the more pronounced the HLB disease expression and tree decline. A DI rating of 27 is common for trees in a maintained commercial block. The second DI rating was taken on April 15, 2024. DI ratings did not vary much from the first rating in 2023 to the second rating in 2024. The 2-port treatment improved the visual health of the treated trees, but only slightly. The improvement in tree health for the 2-port treatment is inverse of the trend seen in the UTC and 1-port treatment, both of which increased slightly over the course of the year long trial. The DI ratings indicate that none of the treatments had any significant impact on visual tree health.



Economic Analysis

By using collected yield values and planting density, a calculation of boxes per acre can be performed. Additional calculations using fruit quality data and the estimated yield per acre values can provide a close estimation of pound solids per acre to aid in determining revenue per acre.



Treatments	Pound Solids Per Acre	
1_Port	987.95	AB
2_Port	1187.98	A
UTC	780.72	B
Model p>F	0.0016	

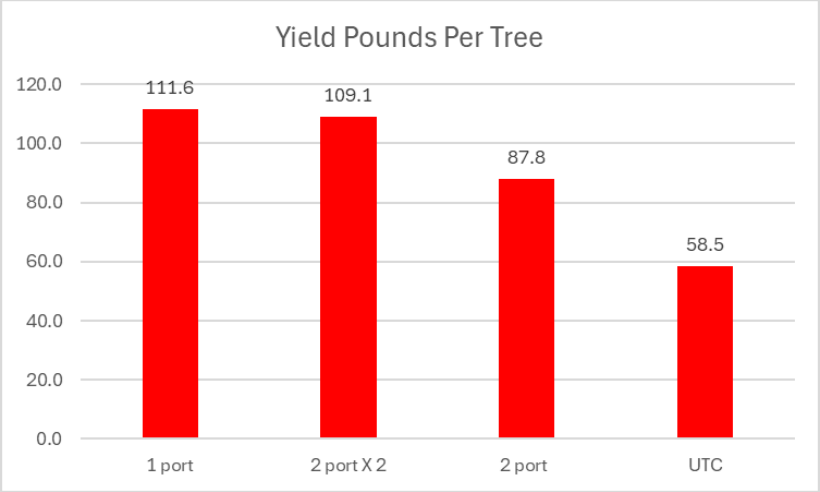
Pound Solids Per Acre was highest in the 2-port treatment and was significantly different than the UTC. The UTC produced the lowest value at 780-pound solids per acre. The 1-port treatment and the UTC are not significantly different from each other.

Valencia Site Year 2

Injections were made on May 17, 2024. The injection work began at 7:30 am and concluded at 9:30 am. The air temperature was 85 degrees with relative humidity of 71%. There was no wind and cloud cover was 10%. The soil temperature at a depth of 6 inches was 78 degrees. The soil was moist within the wetted zone of the micro irrigation emitter.

Yield

Yield data was collected on March 15, 2025. Each tree was harvested separately, and a single weight value was reported for each tree in the trial. The yield values presented are an average for each treatment.

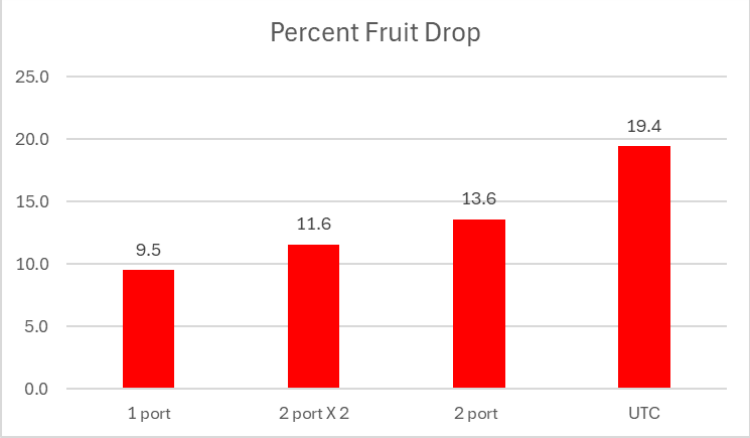


Treatment	Yield Pounds	
1 port	111.6	A
2 port X 2	109.1	A
2 port	87.8	B
UTC	58.5	C
Model P>F	<.0001	

The 1-port and 2-port X 2 treatments produced the highest yield and was significantly different than the 2-port and UTC treatments.

Percent Fruit Drop

Fruit drop counts were conducted in the 3 months leading up to harvest. Fruit drop was assessed on a per tree basis**.** Hurricane Milton impacted this site and caused significant fruit drop. As was the case at the Hamlin site, there is no way to differentiate fruit drop associated with HLB or hurricane impact. Because of that, the fruit drop data presented should not be viewed with a high level of confidence.



Treatment	Percent Fruit Drop	
1 port	9.5	B
2 port X 2	11.6	B
2 port	13.6	AB
UTC	19.4	A
Model P>F	0.0002	

The percentage of fruit drop was highest in the UTC treatment and is significantly different from all other treatments except the 2-port treatment.

Fruit Quality

Fruit quality analysis was performed at the CREC Pilot Plant on March 18, 2025. A single fruit quality sample was collected from each plot in the trial for a total of 20 samples. The data in the table below is the average of each treatment.

Treatment	Acid		Brix		Ratio		Pound Solids Per Box	
1 port	0.83	A	9.41	B	11.40	C	5.10	B
2 port X 2	0.78	B	10.28	A	13.22	A	5.46	A
2 port	0.79	B	9.48	B	11.98	B	5.07	B
UTC	0.79	B	8.53	C	10.81	D	4.56	C
Model P>F	<.0001		<.0001		<.0001		<.0001	

Analysis of titratable acid shows the 1-port treatment had a significantly higher acid content than all other treatments.

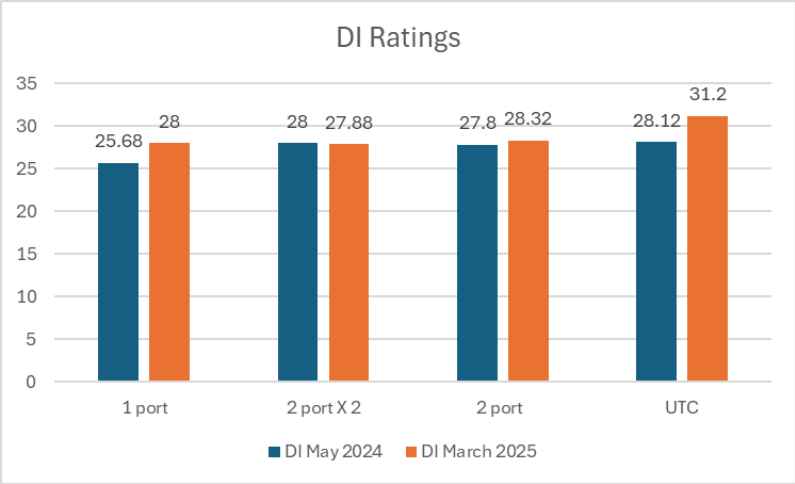
Brix content was highest in the 2-port X 2 treatment at 10.28-degree brix. The 2-side X 2 treatment is significantly different from all other treatments. The 1-port treatment and the 2-port treatment are not significantly different from each other. The UTC treatment has the lowest Brix content and is significantly lower than all other treatments.

Brix/Acid Ratio was significantly higher in the 2-port X 2 treatment at 13.22. The 2-port X 2 treatment is significantly different (higher) than all other treatments. Every treatment resulted in a significant difference for this evaluation.

Pound solids per box values for all OTC treatments were significantly different (higher) than the UTC treatment. The 2-port X 2 treatment provided the highest pound solids per box value at 5.46. The 1-port and 2-port treatments were not significantly different from each other. The UTC treatment produced 4.56-pound solids per box. The UTC treatment was significantly lower than all OTC treatments.

DI Ratings

DI ratings were first determined in May 2024. The rating scale for mature trees is 0 – 40. The higher the score the more pronounced the HLB disease expression and tree decline. The second DI rating was determined in March 2025. DI ratings did not vary much from the first rating in 2024 to the second rating in 2025. The DI ratings indicate that none of the treatments had any obvious and noticeable impact on visual tree health.



Treatment	DI May 2024		DI March 2025	
1 port	25.68	B	28	B
2 port X 2	28	A	27.88	B
2 port	27.8	A	28.32	B
UTC	28.12	A	31.2	A
Model P>F	<.0001		<.0001	

Economic Analysis

By using estimated yield values and planting density, a calculation of boxes per acre can be performed. Additional calculations using fruit quality data and the yield per acre values can provide an estimation of pound solids per acre to aid in determining revenue per acre.

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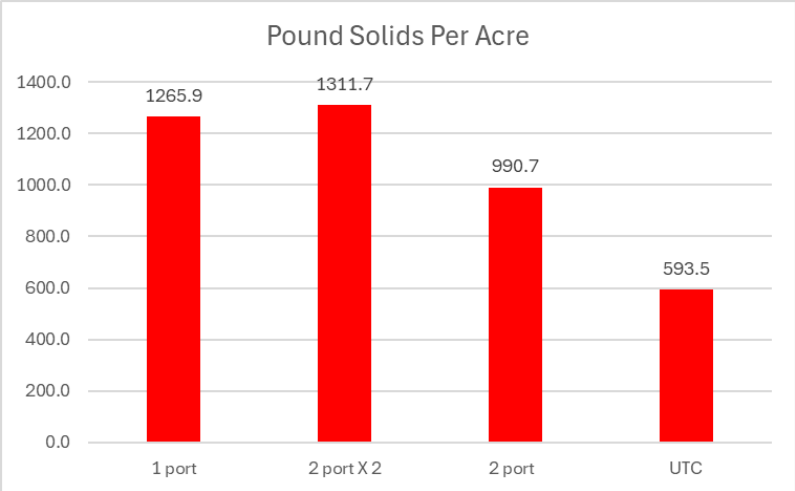

Treatment	Pound Solids Per Acre	
1 port	1265.9	A
2 port X 2	1311.7	A
2 port	990.7	B
UTC	593.5	C
Model P>F	<.0001	

The 2-port X 2 and 1-port treatments resulted in significantly higher calculated pound solids per acre compared to the 2-port treatment and the UTC treatment.

Summary of Findings in Year 1

This trial began as an evaluation of mature trees (defined as older than 20 years) and what type of response could be elicited with OTC trunk injections. The crop consultant saw an opportunity to improve the study by adding a third treatment which used 2 injection ports to deliver the same amount of active ingredient that was scheduled for use in the original 1-port injection treatment.

The trial suggests that OTC injection in mature citrus trees can improve Brix, Ratio, Pound Solids Per Box, and Yield as compared to an untreated control.

The analysis of yield and percent fruit drop was not remarkable at the Hamlin site but did show a trend of improvement over the untreated control. At the Valencia site the 2-port treatment produced a significant impact on yield and percent fruit drop compared to the untreated control.

DI ratings at the Hamlin site improved for all treatments between March 2023 and January 2024. The 2-port treatment had the best improvement of all the treatments, but the untreated control DI ratings improved as well, but not as much as the OTC treatments. The Valencia site did not improve in visual health as the Hamlin site did. The DI ratings show the Valencia trees visually remained almost the same over the course of the trial.

Using calculations to extrapolate the data to a per acre basis, the data indicates that pound solids per acre can be positively impacted by OTC injections. The 2-port treatment significantly improved pound solids per acre compared to the untreated control at both sites. The 1-port treatment was numerically higher than the untreated control, but the values were not significantly different.

The second year of this trial was funded. Injections were made in May 2024. The practice of using multiple injection ports/locations as compared to a single port injection needs to be better understood. Previous work on the subject supports the findings of this project. It is likely using multiple injection ports/locations during a single injection event will distribute the active ingredients more thoroughly through the tree than a single injection and enhance the treatment response. The long-term implications of twice as many injection ports compared to single port injection is unknown.

Summary of Findings in Year 2

The second year of the trial encountered a major obstacle in Hurricane Milton. Both trial sites were impacted by the storm and significantly affected the evaluation of fruit drop. An additional treatment was added for the second year of the project. This new treatment used 2 injection devices per tree with each injector delivering 150 ml of an 11,000 ppm OTC solution. The trees subjected to the new treatment had never been treated with any type of injection prior to the study. This higher rate of OTC is higher than the current label allows.

The project continues to illustrate the impact OTC injection can have on HLB declined mature citrus. Significant differences were identified for Yield, Fruit Quality, and Pound Solids per Acre at both sites.

By and large, the 2-port X 2 treatment produced the best results at both sites. This supports industry observations obtained through private trials that higher volumes and higher rates of OTC result in better

performance. More work needs to be done to better understand the relationship between injection volumes and OTC rates regarding HLB suppression.

The OTC injections, regardless of method and rate, significantly outperformed the UTC treatments for nearly all evaluations conducted in the second year of the project. Yield evaluation at the Hamlin site was nearly doubled for all OTC treatments compared to the UTC treatments. The yield evaluation at the Valencia site resulted in slightly lower but similar trends. This data set, along with other research, supports the practices of OTC injection for HLB mitigation.

Fruit quality improvements at both sites were significant for Brix, Ratio, and Pound Solids per Box. The OTC treatments consistently resulted in significant improvements for fruit quality metrics.

DI ratings for the second year did not see any meaningful separation between treatments. Hurricane Milton likely negated any possible improvements which OTC treatment might have provided. Previous studies have indicated that improvements in observable tree health are not always associated with OTC treatments. It is possible no improvement in DI ratings would have been realized if Hurricane Milton had not impacted the trial sites.

The data generated throughout this project has not cast doubt on the efficacy of OTC injections as a therapy for HLB infected citrus. The data trends have been consistent for nearly all the factors of interest. Yield has improved along with fruit quality. The amount of fruit drop has been positively impacted. The projected value of the harvested fruit is significantly more than if the trees had been left untreated with OTC. It is fair to conclude that mature trees suffering from HLB infection can benefit from OTC injection.