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FINAL REPORT
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Development of a Novel Planting Design and Irrigation Strategy for Water Use Efficiency and Conservation in Citrus

Contract #1513581823

A Final Report for the Project Funded by the Texas Water Development Board

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All comments provided by the TWDB were received, red, and addressed within this report.

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I. Executive Summary

The conservation of water in arid, semi-arid, and subtropical regions is of great importance. As agricultural regions are being developed and municipal areas are being prioritized for water, less is being allocated for agricultural consumption. Year-round demand for water in perennial crops like citrus puts additional strain on these already overtaxed resources. Citrus production consumes a large amount of water in the Lower Rio Grande Valley (LRGV). Approximately 70-80% of citrus producers rely on flood irrigation to meet the water requirements of their trees. Flood irrigation is less efficient than conservation or micro-irrigation methods. During flood irrigation, a designated section of a grove is filled with water leaving a large area open to evaporation. This evaporated water is lost to the atmosphere. However, flood irrigation is a less expensive method of irrigation which requires little to no extra equipment, energy, or land. Thus, methods to adapt conservation practices to flood irrigation techniques are necessary in the quest to conserve water.

To address this issue, we proposed to compare different grove floor management techniques to traditional flood irrigation methods currently used in the LRGV. In a newly established grove of Valencia orange trees, we were able to save 2.2% water compared to traditional flood and grove floor management practices using flat beds with a plastic mesh groundcover. This is equivalent to saving approximately 11,000 gallons of water over the course of the experiment. Other grove floor management practices such as raised beds with and without plastic mesh groundcovers, were less effective in saving water but offered other benefits. Raising planting beds increased water infiltration and eased compaction issues in the soil while promoting leaching of salts in the soil profile. This could prove beneficial in areas with perched water tables or other drainage issues. In addition to water savings benefits, trees in treatments with flat beds and groundcovers were larger and had higher yield and water use efficiency. Conversely, treatments with the traditional planting methods had higher salts and lower root growth values compared to the other management treatments.

Overall, new grove floor management treatments show great promise in conserving water compared to traditional methods. In addition to benefits in promoting tree growth and yield, water use efficiency can be improved in young tree establishment. Further research should be conducted to determine if these management practices are maintained or enhanced as trees mature.

II. Introduction

Water resources are being taxed beyond their capacity; increasing municipal demand, recurrent drought and challenges between neighboring countries for the same water supplies have exacerbated this problem. The LRGV is one of the fastest growing areas in the country, leaving water districts struggling to meet the needs of this population. Irrigation districts in the LRGV provide water to both agricultural users and municipalities, effectively making them prioritize water distribution in these areas. Distribution of water will be reallocated from agricultural usage to meet the demands of municipalities, leaving producers to meet crop water requirements with less available water. The traditional flood method of irrigation is inefficient and much of the water applied is lost to evaporation, infiltration, or runoff. Reducing the amount of water applied to a crop, while still providing water for adequate growth and yield is vital in times of water scarcity.

Improving water management and conserving water through application strategies is of great importance for the LRGV water plan (Rio Grande Regional Water Planning Group, 2015, www.twdb.texas.gov). Providing producers with alternative, low cost planting and irrigation systems while simultaneously conserving water resources is vital for the future of LRGV agriculture. The proposed strategies will potentially reduce total water use footprint for irrigated citrus that is starting to increase in acreage in the LRGV from new plantings. And in turn, these methods can prevent excessive evaporation from the soil surface and effectively keeping water in the root zone and available for plant uptake. Current narrow border flood (NBF), drip irrigation (DI), and microsprinkler (MS) water conservation methods have been shown to potentially save between 26,200 to 49,000 acre-feet of water each year for the Texas citrus industry alone (Nelson and Young, 2011; TexasAWE.org). Further water savings through these new methods will allow us to meet the predicted demands of 1.68 million acre-feet by the year 2060. Reducing the irrigation events and amount needed for irrigation, if adopted, could conserve large amounts of water and increase water use efficiency, benefiting producers both financially and environmentally.

III. Objectives

The goal of this project was to develop and promote a new planting design and irrigation strategy to improve water use efficiency in newly planted citrus trees grown in South Texas. The work tasks of this project included: 1) Developing a demonstration field; 2) Assessing the effectiveness of the treatments; and 3) Promotion and dissemination of results.

IV. Summary of Activities

Throughout this study, trees have been monitored, growth has been recorded, and soil moisture data have been collected. Data were analyzed and results were discussed with growers and other audiences at grower demonstration days, regional meetings and events, and national meetings.

1. Materials and Methods

This demonstration site was located in McAllen, TX, on a 15 acre plot of land owned by Mr. Jimmy Pawlik of Southmost Farms/Pawlik Farms (26.13580887,-98.26407595; Figure 1). The experiment location is characterized by predominantly Matamoros silty clays with >50% clay particles. This site was divided into 4 grove floor management treatments: flat beds with no groundcover (traditional; FNC), flat beds with black plastic mesh groundcover (FC), raised beds with no groundcover (RNC), and raised beds with groundcover (RC).

Figure 1. Grower demonstration site at Southmost (Pawlik) Farms in McAllen, TX.

In late 2015 to early 2016 the site was prepared and the beds were raised or laser leveled in accordance with treatment. The raised beds were prepared using a specially adapted bedding apparatus which raised the soil surface to between 18-21 inches (for more information on bedding specifics see Simpson et al., 2019). The groundcover was ordered and installed according to grower needs. The groundcover was a mesh, black plastic was laid on the customized bed and sides were anchored and buried to prevent movement. In April 2016, Valencia orange trees microbudded onto Sour Orange rootstocks were planted at the site in each respective treatment. Tree fertilization and pest management programs were implemented according to grower specifications and each treatment was treated equally throughout the study. After planting, trees were irrigated frequently to combat the high heat and drought conditions seen that year. Irrigation was applied by poly-tubing which flooded rows in each treatment with water at a rate specified by the grower. The water was retained in each treatment by soil berms to create a 'basin' without distributing water to other treatments. The amount of irrigation applied was recorded by Mr. Pawlik and then sent to Dr. Simpson. Soil moisture sensors and dataloggers (Watermark soil moisture sensors, Irrometer Company Inc., Riverside, CA) were installed according to manufacturer's instructions at two locations within each treatment and at two depths per location (6 inches and 18 inches). Sensors were programmed to take soil moisture measurements every two hours each day throughout the study. Sensors would occasionally become inoperable throughout the course of the experiment and would be replaced at our earliest convenience. Data were downloaded at least once per month and recorded. This information was used in conjunction with growers judgement to determine irrigation needs. Growth measurements were taken each month to determine tree height, canopy circumference, and trunk diameter over time. Four rows within each treatment were selected for tree growth measurements. Within each row, the fourth tree was marked and growth measurements were collected on selected trees throughout the experiment for a total of 40 trees per treatment (10 trees per row/ 4 rows per treatment and 160 trees total for all 4 treatments). Tree height was measured with a roll tape measure or incremented measuring pole if they were taller than ~5 feet. Tree canopy circumference was not measured the first year of growth due to tree size and growth habit. After one year, tree canopy circumference was measured at the widest point of the canopy with the rolled tape measure. Trunk diameter was measured with digital calipers at a distance of 10 cm above the bud union. The spot was marked and maintained throughout the experiment for consistent measurements. Tree relative growth rate (RGR) for each measurement factor was calculated from these measurements using the following calculation:

$$RRRRRR = \left(\frac{\ln(tt2) - \ln(tt1)}{ddaaaaaa}\right) * 1000$$

Where:

t1 = time 1

t2 = time 2

Tree RGR was used to determine the rate of growth of trees within each treatment. This was done because to normalize data and provide a more reliable measure of growth in each treatment due to some trees being larger at the time of planting. This calculation was performed for height, tree trunk circumference, and canopy circumference then measurements were averaged for the average relative growth rate shown in the results section.

In addition to the growth measurements collected, the grower provided us with the amount of water applied to each treatment area throughout the seasons. From this we collected and calculated water savings (%) using the following calculation:

$$\% \; WWaattWWWW \; aaaassssssssaa = \left(\frac{wwaattWWWW \; aaaaaallssWWdd \; ssss \; ttWWaaddssttssttssaall \; aallaassttssssss \; ttWWWWaatttttWWsstt - wwaattWWWW \; aaaaaallssWWdd \; ssss \; cctttttaaaaWWssaattss \; ttWWWWaatttttWWsstt}{wwaattWWWW \; aaaaaallssWWdd \; ssss \; ttWWaaddssttssttssaall \; ttWWWWaatttttWWsstt}\right) * 100$$

Estimated yield was calculated in May 2018 to assess if fruit was evenly distributed amongst treatments. Fruit estimates were conducted by counting the number of fruit within a 0.27 m^2 guide on 8 trees within each treatment. Guides were randomly placed within the canopy of each tree, fruit were counted, and recorded. Fruit were then harvested in March 2019. Yield was considered a preliminary harvest because the trees were harvested late in the season and a small portion of the fruit had fallen to the ground prior to harvest. In addition, the first yield of fruit from young citrus trees is not considered to be reflective of future yield. During harvest, trees were stripped of fruit and placed in bins designated for each treatment. Numbers of bins were counted and the weight was estimated from this. Individual rows and trees could not be separated for analysis because of the limitations of technology and crew available for harvest. Water use efficiency (WUE) was then extrapolated for each treatment by dividing the weight of harvested fruit by the amount of water applied.

Fruit quality was conducted by harvesting a subsample of fruit from selected trees within each treatment. Fruit were brought back to the lab for analysis and then weighed and rind thickness, fruit firmness, brix, acidity, and maturity index were assessed.

Statistical differences between treatments were determined using JMP Pro 14.0.0 software (SAS Institute, Cary, NC). When applicable, full factorial analysis were conducted to determine significance to $p \leq 0.05$. Where significant differences at $p \leq 0.05$ were found between treatments, a students t test was used to separate means and were shown by different letters.

2. Results

Over the course of the experiment trees showed significant increases in growth (Figure 2). By the end of the experiment, tree height was significantly different between treatments ($p = 0.0003$, Fig. 3A). Trees grown in flat beds with groundcover were tallest, followed by the raised bed with covers, raised beds with no covers, and flat beds with no covers (Fig. 3A). Trunk diameter was also significantly different amongst treatments. Flat beds with groundcovers and raised beds with no covers had larger trunk diameters, followed by raised beds with covers and flat beds with no covers ($p = 0.0001$, Fig. 3B). Canopy circumference was significantly different amongst treatments as well ($p = 0.0001$; Fig. 3C). Flat bed treatments with covers had the largest canopy circumference, followed by all other treatments.

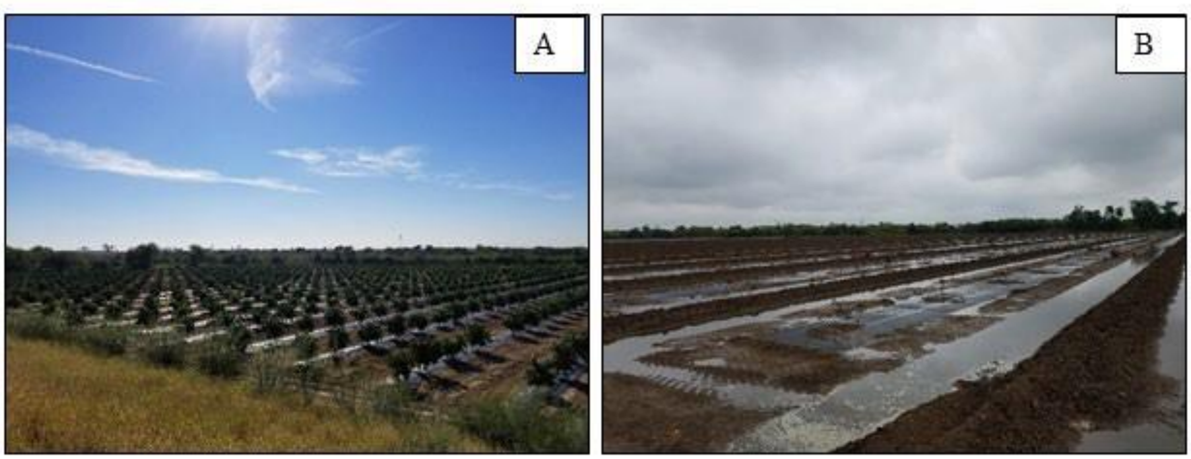

Figure 2. Grower demonstration site A) after three years of growth (2019)and B) soon after planting (2016).

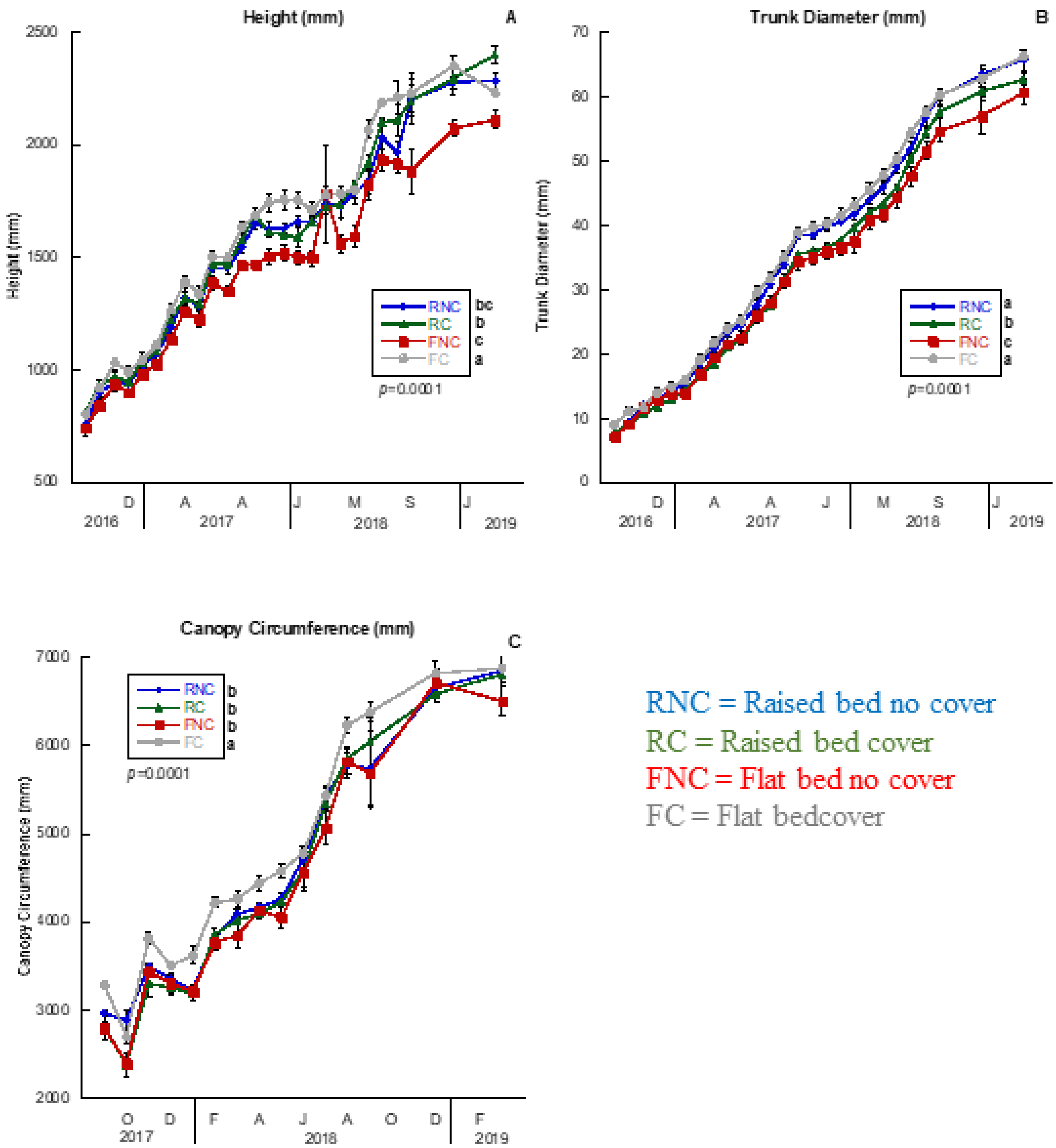

Figure 3. Growth parameters recorded for trees in raised beds, raised beds with groundcover, flat beds, and flat beds with ground cover. A) Increase in tree height over time, B) increase in tree trunk diameter over time, and C) canopy circumference over

Over the experimental period there have been many fluctuations in relative growth rate parameters. However, as the trees have progressed and growth rate has slowed, we have seen fewer differences between treatments. The flat bed treatments with cover grew faster in the beginning and resulted in larger trees more quickly than other treatments. Now, other treatments are catching up with those trees and the growth rate is slowing as they reach maturity. When taking into consideration the entire study period (Aug 2016-2019) we saw no significant difference in tree height relative growth rate ($p = 0.321$; Fig. 4A). However, trunk diameter relative growth rate was significantly different between treatments over the study period; with the flat bed with cover having the smallest diameter relative growth rate and the raised bed with no cover having the greatest trunk diameter relative growth rate ($p = 0.009$; Fig. 4B) by the end of the experiment. However, the actual trunk diameter in the flat bed with cover treatment is larger than the other treatments, and this discrepancy could be due the fact that they are larger trees and are expanding at a slower rate and the trees in the raised bed with no cover treatment are growing faster. Canopy circumference relative growth rate was also significantly different amongst treatments over the entire period, with the flat bed with cover treated trees having the smallest canopy relative growth rate compared to all other treatments ($p = 0.001$; Fig. 4C).

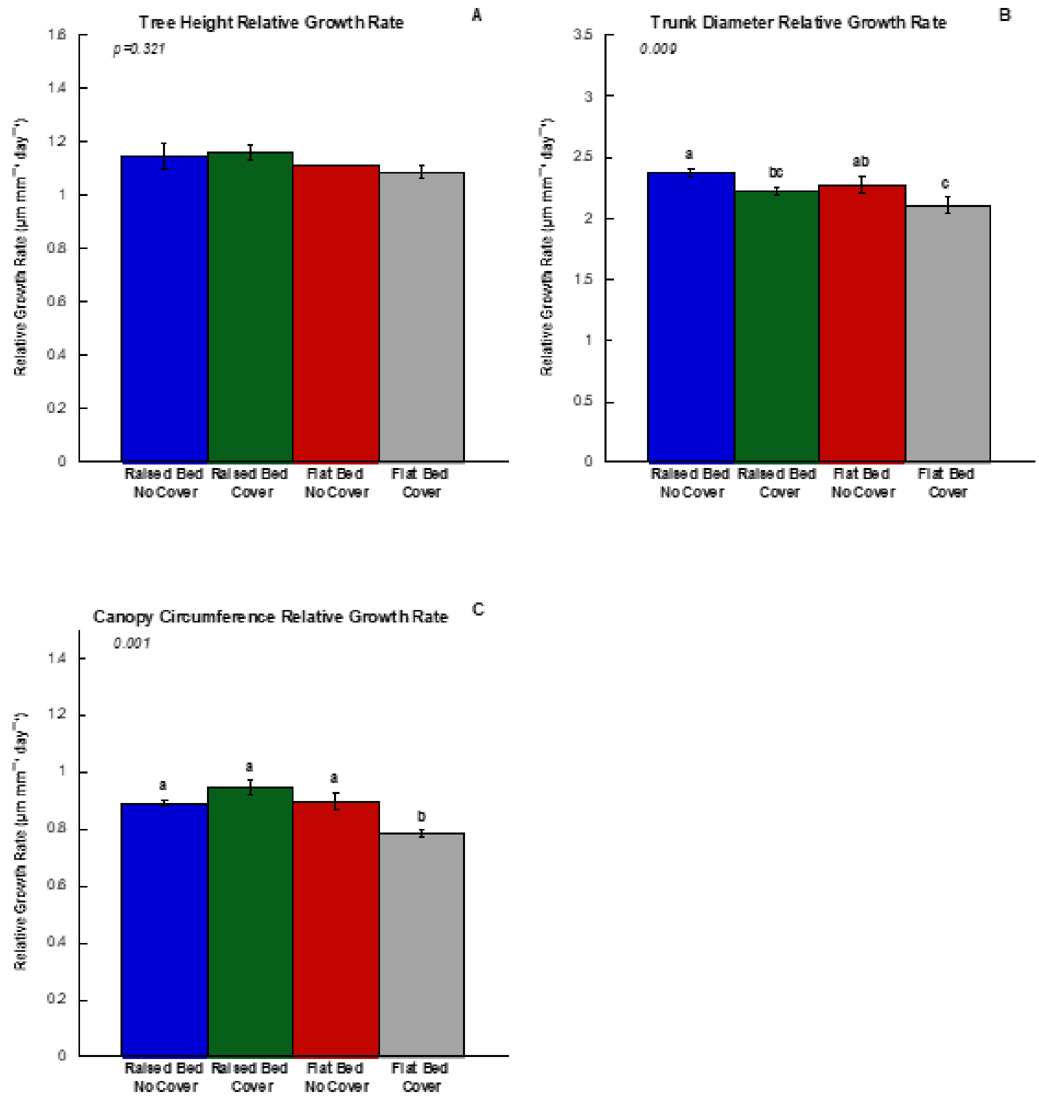

Figure 4. A) Tree height relative growth rate, B) trunk diameter relative growth rate, C) canopy circumference relative growth rate.

Soil moisture was monitored throughout the 3 year experimental period. There were 3 abnormally heavy rain events where the site experienced heavy flooding, in 2015, 2017 and 2018. Otherwise, irrigation supplemented rainfall and was applied according to the growers schedule and plant needs. Sensors occasionally failed and were replaced as needed. Soil sensor data indicate that moisture in the upper 6 inches of the soil profile fluctuated throughout the experiment (Figure 5A). There were significant differences between treatments at 6 inches, with raised bed with groundcover treatment having the highest soil tension values at 6 inches, followed by flat bed with no cover, raised bed with no cover, and flat bed with groundcover (P =

0.0001). This indicates that more moisture (less tension) was in the flat bed treatments with groundcover. At the 18 inch depth, the raised bed with no cover had higher soil tension, followed by the raised bed with cover, flat bed with cover, and flat bed with no cover (p=0.0001; Fig. 5B). Showing that more moisture was in the flat bed treatments at 18 inches. These readings indicate that, in general, the raised bed treatments have less soil moisture deeper in the soil profile while the flat beds with no groundcover have significantly more moisture in the lower depths. The reduced moisture in raised bed treatments is most likely due to increased infiltration rates through more aggregated soil, or due to the distance that water has to travel laterally through the bed (from irrigation site) to reach the sensors. These results show that greater differences occurred in the upper 6 inches of soil, and more moisture remained at lower depths more consistently throughout the season.

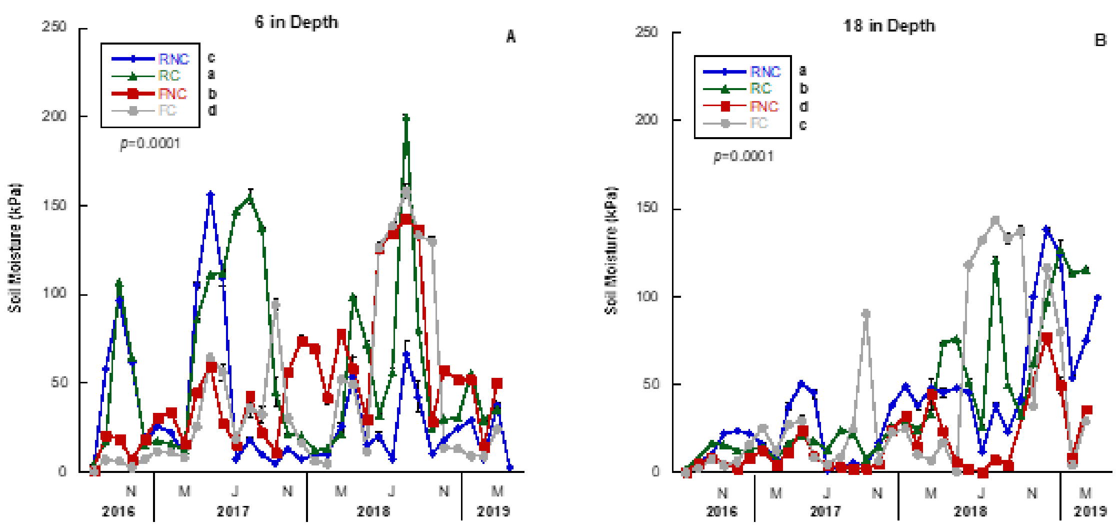

Figure 5. Pawlik Farms soil moisture data for each management treatment. A) Soil moisture (kPa) at 6 inches and B) soil moisture (kPa) at 18 inch depth.

Soil nutritional analysis was taken at the end of the experiment to compare treatments and how management techniques may have affected soil and root development. While there was a difference between treatments for S, this was likely just due to spatial differences rather than an effect of treatment. However, soil electrical conductivity (EC), sodium (Na), and organic carbon (C) were significantly impacted by treatment. Soil EC and Na demonstrate the soil salinity levels, while organic C shows the amount of organic matter within the soil. EC and Na were greater in the flat bed with no groundcover treatment (Table 1). This shows that salts are accumulating in the soil in this treatment at a higher rate than others. This is probably due to the better drainage in treatments with raised beds and groundcovers. There was a slightly lower amount of organic C in the raised bed with groundcover treatment. The higher temperatures and porosity in this treatment could have increased microbial activity leading to a greater decomposition of C.

Root measurements showed that grove floor management treatments did not significantly influence root parameters (Table 2). However, there was a trend of greater root fresh weight in the raised bed with no groundcover treatments. It should also be noted that the lowest values for all root parameters were found in the flat bed with no groundcover (traditional) management treatment. Smaller roots with lower surface area are often a result of poor aeration, waterlogging, and compaction of soil. This could have influenced these observations and when trees are larger, more pronounced differences could be found.

Table 1. Soil nutritional analysis

Treatment	pH	Cond (umhos/cm)	NO3-N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)	Na (ppm)	Sand (%)	Silt (%)	Clay (%)	Organic Carbon (%)
Flat + Cover	8.3	286.5 ab	9.8	53.5	425.6	11933.1	615.8	47.7 b	282.6 b	17.5	23.0	60.0	0.9 a
Flat No cover	8.4	422.75 a	13.3	56.3	458.3	11534.7	629.4	93.8 b	483.3 a	14.0	25.8	60.3	1.0 a
Raised + Cover	8.4	185.75 b	5.0	48.1	395.0	11780.1	611.8	38.9 b	220.5 b	19.8	24.3	56.0	0.8 b
Raised No Cover	8.4	302 ab	2.6	41.2	403.2	12644.7	608.6	52.5 a	281.2 b	14.3	23.8	62.0	0.95 a
P treatment	0.4	0.027	0.47	0.08	0.34	0.492	0.96	0.0009	0.01	0.33	0.2	0.22	0.031

Table 2. Average root and tree growth parameters for each management practice located at Pawlik Farms.

Treatment	Depth (cm)	Fresh weight (g)	Area (cm^2)	Width (cm)	Height (cm)	Length (cm)	Surface area (cm^2)	Diameter (mm)
Raised + Cover	0-45	1.011	346.553	16.391	22.167	165.007	61.394	1.133
Raised No Cover	0-45	2.004	381.259	17.152	22.776	149.484	55.352	1.103
Flat + Cover	0-45	0.312	360.563	16.772	22.186	149.526	51.706	1.028
Flat No cover	0-45	0.179	344.052	16.089	21.502	119.634	24.912	0.647
P treatment		0.089	0.389	0.245	0.431	0.719	0.28	0.076

For all years of the experiment, an average of 0.08 acre feet of water was applied to the traditional flat beds with no groundcovers, 0.08 acre feet applied to flat beds with groundcovers, 0.09 acre feet applied to raised beds with groundcovers, and 0.10 acre feet applied to raised beds with no groundcovers (Table 3). Overall, water savings has fluctuated throughout the experiment, however, water savings seems to be highly dependent on the rainfall and weather during each season (Tables 3-5). This translates to an estimated 2.2 percent water savings in flat beds with groundcovers compared to traditional flat beds with no groundcovers. If the data is further analyzed, water savings in 2016 vs. 2019 has increased, indicating that the weather and establishment period may influence water savings and there may be a period of time to realize the water savings benefits. The greatest amount of water was applied in 2016 and 2017, which reflects the young age of the trees and higher water needs. In general, March–August saw the highest amounts of irrigation water applied, due to high temperatures and high evaporative demands (Table 5).

While a 2.2 percent water savings with flat bed and groundcover treatments may not seem like a large amount of water savings, it amounts to an average savings of 652 gallons of water compared to traditional methods. Total savings over the entire experiment were approximately 11,730 gallons of water in the flat bed with groundcover treatment over 4 years. The trees in this experiment were very young and small when planted and required a large amount of water for establishment as seen in Tables 3-5. In the other comparison treatments the water savings fluctuated and were not as efficient as the flat bed treatment with groundcover. This could be due to the small root systems in young plants, increased water infiltration, and high evapotranspiration of these young trees. As the tree growth equilibrates and is more evenly distributed between treatments, it would be interesting to see if water savings data would change.

Table 3. Water applied to each treatment each year. Treatments were flat bed no groundcover (traditional), flat bed with groundcover (FBGC), raised bed with groundcover (RBGC), and raised bed no groundcover (RBNGC).

		Traditional	FBGC	RBGC	RBNGC
Year	**Ave Water Applied**	0.0846	0.0820	0.0974	0.1087
2016	(acre-feet)	0.0805	0.0837	0.1026	0.1220
2017		0.0860	0.0805	0.0911	0.1037
2018		0.0667	0.0660	0.0785	0.0865
2019		0.0737	0.0729	0.0863	0.1002

Table 4. Water savings for 2016 to 2019. No water applied is indicated by NWA. Treatments were flat bed no groundcover (traditional), flat bed with groundcover (FBGC), raised bed with groundcover (RBGC), and raised bed no groundcover (RBNGC).

		Traditional	FBGC	RBGC	RBNGC
Average over all years	Difference from Traditional		0.002	-0.012	-0.024
	% water savings		2.187	-15.256	-30.733
Total for all years	Difference from Traditional		0.036	-0.249	-0.501
	% water savings		2.187	-15.256	-30.733
2016	Difference from Traditional		-0.003	-0.022	-0.041
	% water savings		-3.932	-27.387	-51.531
2017	Difference from Traditional		0.005	-0.005	-0.018
	% water savings		6.398	-5.972	-20.665
2018	Difference from Traditional		0.001	-0.012	-0.020
	% water savings		0.969	-17.712	-29.703
2019	Difference from Traditional		0.001	-0.013	-0.026
	% water savings		1.065	-17.051	-35.951

Table 5. Quarterly breakdown of water savings (%). Treatments were flat bed no groundcover (traditional), flat bed with groundcover (FBGC), raised bed with groundcover (RBGC), and raised bed no groundcover (RBNGC).

Year	Quarter	Traditional	FBGC	RBGC	RBNGC
2016	Mar-May		-17.298	-32.250	-96.520
	June-Aug		1.003	-38.843	-71.541
	Sept - Nov		1.065	-10.674	6.450
2017	Dec-Feb	NWA	NWA	NWA	NWA
	Mar-May		7.133	-2.615	-18.452
	June- Aug		6.893	-8.483	-17.403
	Sept - Nov		2.994	-3.513	-37.590
2018	Dec-Feb		0.500	5.762	-1.531
	Mar-May		1.146	-20.654	-40.374
	June- Aug		1.146	-29.578	-40.374
	Sept - Nov	NWA	NWA	NWA	NWA
2019	Dec-Feb		1.003	-7.446	-24.734
	Mar-May		1.065	-20.877	-40.326
	June- Aug		1.103	-20.773	-40.348

Fruit estimates taken early in the 2018 harvest season showed no significant differences between treatments (Figure 6). However, more fruit were observed in the flat bed treatment with groundcover, followed by the flat bed treatment with no cover, raised bed with no cover, and raised bed with cover. This was similar to the harvested yield as seen in Table 4. While statistical differences between yields for treatments could not be calculated, flat bed treatments with groundcovers yielded approximately 30% more fruit than the traditional flat bed with no groundcover treatment. These results reflect the first year of yield, which is not typically predictive of future yields. As trees mature, yields become more stable and higher in number.

Water use efficiency (WUE) in this study is defined as the ratio of water used by the trees to the amount of fruit produced (yield). This is a measure of the efficiency of water used by the plant to produce fruit vs. how much water is lost to evapotranspiration. To improve water savings, trees need to produce more fruit per unit of water applied with less water lost to the atmosphere. Reducing the amount of water applied to each treatment is the goal of many producers because it will not only reduce input costs, but increase WUE, water savings, and optimize yield, but also reduce soil erosion and conserve water resources. In this study, WUE was greater in trees grown in the flat beds with groundcovers, followed by the flat no cover, raised no cover, and raised cover treatments (Table 6). It is likely that these results will change with next years yield as the trees will be more mature and bloom will be more evenly distributed among the treatments.

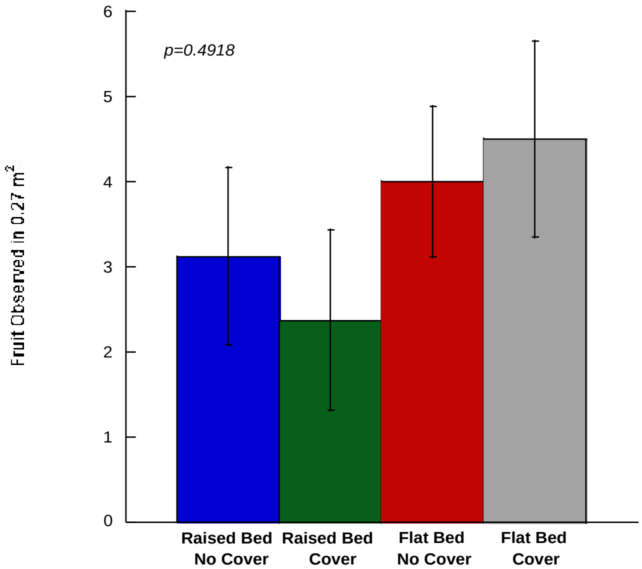

Figure 6. Fruit estimates conducted early in the 2018 harvest season.

Table 6. Yield and water use efficiency of different treatments.

Treatment	**Yield (lbs)**	**Water applied (inches)**	**WUE (lbs/inch of water applied)**
FNC	4600	16.7	275.45
RNC	1840	18.12	101.55
FC	6440	16.62	387.49
RC	920	17.51	52.54

3. Student Training

Student training was not a primary focus of this experiment, however, we did incorporate it into our project. Four graduate students, 3 undergraduates, 3 research associates, and 2 teacher interns received training in taking physiological measurements, soil moisture sensor installation, and operation at this site. They learned how to properly take measurements, download data, record data, and analyze data after collection. This hands on experience was important in their scientific training and success in graduate school and respective careers.

4. Promotion and Dissemination

2015/16

Catherine Simpson and research associate Ayako Kusakabe attended the Southern Region meeting of the American Society of Horticultural Sciences (ASHS) in San Antonio, TX on February 5-6, 2016. Ms. Kusakabe presented research related to the demonstration plots and water management strategies "The effects of water management strategies on citrus growth and yield" Kusakabe, A., Simpson, C. R.*, Nelson, S.D., Melgar, J.C., and Setamou, M. Related research was also presented at the 2016 Subtropical Agriculture and Environments Society on February 5, 2016 by graduate student Julian Gonzales III on the "Impact of citrus management strategies and nutrient applications on plant physiology, fruit quality, and yield" Julian Gonzales III, Shad D. Nelson, Mamoudou Setamou, and Catherine R. Simpson.

Catherine Simpson and Veronica Ancona traveled to Junction, TX for the Texas Academy of Sciences annual conference on March 4-5, 2016 to talk to prospective students and researchers about water saving strategies and water management research in Texas citrus. Catherine Simpson also presented related research at a regional conference "Texas Rare Fruit Growers Symposium" on September 23, 2016.

Catherine Simpson also developed a fact sheet for growers and distributed them on the Annual Citrus Center Grower Appreciation Day on October 26, 2016. Catherine Simpson also wrote a short public interest article based on that fact sheet for The Ag Mag titled 'Novel Planting Design: Raised bed with plastic mesh groundcover to improve citrus tree growth' Issue 14: 48-49. https://issuu.com/theagmag/docs/issue_14_pgs_1-72-2.

2017

During Q2 of 2017, Catherine Simpson wrote a short public interest article based on that fact sheet for The Ag Mag titled 'Novel Planting Design: Raised bed with plastic mesh groundcover to improve citrus tree growth' Issue 14: 48-49. https://issuu.com/theagmag/docs/issue_14_pgs_1-72-2. We also scheduled and arranged a field day for May in conjunction with TWRI and AgriLife Extension in order to maximize grower attendance. To reach a larger group of growers, we presented the data to growers at an irrigation expo in May, where Jimmy Pawlik, Catherine Simpson, and Shad Nelson discussed this demonstration project and its implications.

During Q3 of 2017, Catherine Simpson, Mamoudou Setamou, and Shad Nelson disseminated the results of this research at a grower field day events related to citrus production on May 9 (Figure 7) and Catherine Simpson spoke at a water forum event on May 23, 2017 (Figure 8). This research was also discussed at the TAMUK Citrus Center Advisory Board meeting on April 5th.

Figure 7. Irrigation Expo and Citrus Grower Field Day. May 9, 2017

Figure 8. Lower Rio Grande Valley Weather Outlook and Water Forum. May 23, 2017

During Q4 of 2017, Catherine Simpson, Sri Lakshmi Telagamsetty, and Shad Nelson traveled to the annual ASHS meetings in September to disseminate the results of this project. Also, Catherine Simpson worked on a promotional booklet that includes her work on this project and water savings in citrus in the Lower Rio Grande Valley along with other highlights from Citrus Center research.

2018

During Q1 of 2017/2018, Catherine Simpson, Sri Lakshmi Telagamsetty, and Shad Nelson traveled to the annual ASHS meetings in September to disseminate the results of this project. The titles are listed below:

1. Simpson, C., Gonzales III, J., Ruppert, D., Setamou, M. and Nelson, S. Citrus root distribution and turnover as a result of different management practices. 2017 ASHS Annual Conference, Waikoloa, Hawaii. September 19-22, 2017. (*Invited presentation*)

2. Telagamsetty, S., Setamou, M., Nelson, S., and Simpson, C.R. Improved irrigation and management practices for water conservation and plant growth in citrus. 2017 ASHS Annual Conference, Waikoloa, Hawaii. September 19-22, 2017.

3. Nelson, S., Simpson, C., Setamou, M., Gonzales III, J., and Telagamsetty, S. Adoption of a new orchard planting design as an integrated on-farm management approach to improve citrus production in south Texas. 2017 ASHS Annual Conference, Waikoloa, Hawaii. September 19-22, 2017.

Also, Catherine Simpson developed a promotional magazine that will include her work on this project and water savings in citrus in the Lower Rio Grande Valley along with other highlights from Citrus Center research (https://citrusphysiologylab.wixsite.com/simpson/citrus-center-highlights-magazine). During the annual Citrus Center Grower Appreciation banquet, this magazine was distributed to approximately 90 area citrus producers. We have since received very positive feedback on this research and are working on the next edition.

Additionally, Catherine Simpson was an invited speaker at the Instituto de Recursos Naturales y Agrobiologia de Sevilla in Sevilla, Spain where she presented results from this research as well. (See below for details)

Simpson, C., Nelson, S.D., and Setamou, M. Alternative management strategies for citrus in the Lower Rio Grande Valley. Research Presentations at the Instituto de Recursos Naturales y Agrobioloogia de Sevilla (IRNAS), Sevilla, Spain. November 22, 2017 (*Invited speaker*)

Catherine Simpson and Shad Nelson attended the Vegetable Workshop in Mission, TX on March 6, 2018. While we did not present results from this study, we did speak to various growers and producers about the project and got feedback about the raised beds.

Catherine Simpson, Shad Nelson, and Jimmy Pawlik held a grower demonstration day on November 15th. A total of 14 participants joined the demonstration day and discussion activities (Figure 9). We also prepared two fact sheets, an article in the annual Citrus Center Highlights magazine and a separate fact sheet for distribution at the event.

Figure 9. Photos from the grower demonstration day at Pawlik Farms on November 15th.

<u>2019</u>

Catherine Simpson and George ‘Jim’ Thomas III (graduate student) presented research related to this experiment at two scientific conferences. One was at the Southern Region ASHS meetings in Alabama in February 2019 and the others were at the annual national ASHS meeting in Las Vegas, Nevada in July 2019.

1. Thomas III, G.J., Setamou, M, Ancona, V., Enciso, J., Nelson, S.D., and Simpson, C. Impact of grove floor management and irrigation practices on citrus root distribution. Southern Region ASHS Annual Conference, Birmingham, AL. February 1-4, 2019.

2. Simpson, C.R., da Graca, J., Ancona, V., Setamou, M., Louzada, E., Kunta, M., Laughlin, D., and Mandadi, K. The state of Texas citrus in the era of HLB. In: Envisioning a US Citrus Industry with Endemic HLB workshop. American Society of Horticultural Sciences annual meeting, Las Vegas, NV. July 21-26, 2019. (*Invited speaker*)

3. Thomas III, G.J., Setamou, M, Ancona, V., Enciso, J., Nelson, S.D., and Simpson, C. Comparing root distribution in groves with different floor management and irrigation practices. American Society of Horticultural Sciences annual meeting, Las Vegas, NV. July 21-26, 2019.

The impacts of this project on growers decisions to implement these practices were great. Since beginning this project in 2016, over 7 new growers have chosen to plant new groves using these methods. Many additional growers are considering implementing these practices as well. At the time of this report hundreds of acres are now in production using groundcovers and these conservation management practices.

5. Discussion

This experiment showed that water savings, tree growth, and production can be improved through grove floor management practices. The establishment of young citrus trees requires a large amount of water and the weather conditions found in the Lower Rio Grande Valley are harsh on young trees. The use of a plastic mesh groundcover acts as a barrier against water loss from evaporation and can increase soil moisture where it is used. It also increases the amounts of salts that move deeper in the soil profile, leaching them beyond the region where roots are active and where salts can harm tree growth. Trees in the flat bed with groundcover treatment were larger, had greater canopy sizes, and overall greater yield. We believe that is largely due to the use of the groundcovers. Raised bed treatments had greater infiltration of water through the profile, and trees growing in these treatments were rapidly catching up to other trees in size and canopy circumference. Trees in the traditional planting treatments were smaller and soils were more compact and had higher salinity levels. This could result in negative impacts on tree growth and future yields.

6. Future Work

This project holds much promise in the way of improving water savings in citrus production. Future work would include continuing the growth and yield monitoring of the trees in each of the grove floor management treatments to determine if tree maturity affects water savings, WUE, and production. This could also lead to future projects that assess how these management practices affect tree growth and WUE in different areas that have different soils or irrigation practices.

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8. References

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