

Evaluation of Tree Tee-Pees to Improve Irrigation Distribution for Young Citrus Trees

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Deliverable 4 - Final report documenting the results of irrigation water application, on soil water content, air temperatures during freeze events, and tree growth measurements

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Introduction

Water has been used for cold protection in past freezes with mixed success. Low dew point temperatures and high winds can promote evaporative cooling when insufficient amounts of water are used. Various methods have been used to protect young citrus trees from frost and freeze conditions. The use of covers and other structures to restrict water to the relatively small canopies of young trees have been tested. Recent research has indicated that the restriction of water and fertigation to small areas directly under young trees aid in improved tree growth leading to larger trees and earlier fruit production. Additional work is required to determine which factors may provide enhanced environmental conditions that allow young citrus trees to grow larger faster while using fewer resources (water and fertilizer).

A field trial was established in October 2014 and completed in June 2016 to examine and determine advantages and/or disadvantages provided by the Tree Tee-Pee (Tree T-Pee®) in a commercial citrus grove in Florida as compared to current production methods for young trees. Current production methods consist of a single emitter adjacent to the tree and a plastic wrap placed around the lower one foot of the tree trunk to minimize sprouting and potential herbicide injury. It has been suggested that trees grown using a cone shaped Tree T-Pee® grow larger faster, use less water and fertilizer, and provides greater freeze protection as compared to standard production systems. Thus, the objectives of this project were to determine if Tree Tee-Pees: 1) elevate air temperatures around the young citrus trees above damaging levels during freeze events, 2) increases soil moisture in the irrigation zone to a greater depth than standard micro sprinkler emitters, and 3) accelerate young tree growth.

Materials and Methods

The study site was a two rows of citrus trees planted in a commercial grove in the fall of 2014. Treatment plots were arranged in a randomized complete block design and replicated four times to provide sufficient replication for statistical analysis to demonstrate effects of Tree T-Pee® using the following methods.

Each citrus tree was irrigated by the grove irrigation manager with a single micro sprinkler delivering either 5, 7.5 or 10 gph with standard full circle spray pattern, 45 degree downward spray, and a full circle spray with tree Tee-Pees installed (Table 1). All trees were irrigated for the same amount of time regardless of the emitter output rate because the emitters were all supplied by a single irrigation tubing line.

Air temperature at a 6 inch height inside the tree Tee-Pee and 18 inches above the ground but inside the tree canopy of trees with tree Tee-Pee installed were measured. The thermocouples measuring air temperatures near the tree trunk and main stem and were secured to the trees by tape.

Soil moisture was measured at three depths (6, 12 and 18 inches below the soil surface) 8 inches from the tree trunk using capacitance soil moisture sensors recorded by a data logger every 30 minutes. Tree trunk diameter measurements were made at 3 inches above the bud union at the beginning of the study and twice during the study period (15 and 20 months) to measure tree growth. Canopy volume estimates were made at the same time as trunk were measured.

Trees trunk diameters were measured approximately three inches above the graft union at the beginning of the study because trunk diameter is the best indicator of growth for young citrus trees. Six months prior to the end of the study (January 2016), and at the end of the study (June 2016), trunk measurements were repeated along with height and canopy diameter in a north/south and east/west direction. The canopy diameters were averaged to determine average canopy diameter. Canopy volume was estimated using average canopy diameter and height assuming a spheroid shape.

Table1. Tee-Pee project treatments describing three irrigation emitters used to evaluate efficacy of Tee-pee in improving freeze protection and water conservation.

Emitter type	Jet Color	Distribution Pattern	Flow rate*
Maxi Jet	Black	360° x 14 Filled-In Streams	5.6
Maxi Jet	Orange	360° x 14 Filled-In Streams	7.7
Maxi Jet	Blue	360° x 14 Filled-In Streams	10.5
Maxi Jet	Black	45° downward fan	5.6
Maxi Jet	Orange	45° downward fan	7.7
Maxi Jet	Blue Max Cone	45° downward fan	10.5
Maxi Jet	Tee Pee Black	360° x 14 Filled-In Streams inside Tee Pee	5.6
Maxi Jet	Tee Pee Orange	360° x 14 Filled-In Streams inside Tee Pee	7.7
Maxi Jet	Tee Pee Blue	360° x 14 Filled in Streams inside Tee Pee	10.5

Results and Discussion

Air Temperatures

During freeze events. Air temperatures not influenced by the irrigation system was recorded by the Florida Automated Weather Network (FAWN) Joshua weather station less than two miles for the project site. One freeze night was recorded at the FAWN site with a minimum temperature of 29.7°F on February 20, 2015 (Fig. 1) and no freeze events were recorded in 2016. Prior to the freeze event on February 20, 2015, temperatures of approximately 35°F were recorded for only two dates (February 14, and February 19.

Irrigation was applied the morning of February 20th. Average temperature at the 6 inch height above the ground was increase to 56°F for the black emitter (Fig. 2) and 53°F for the orange emitter (Fig. 3). Temperatures at the 18 inches height above the ground dropped to 34°F for both the blue and orange emitter trees. The data logger for the blue emitters malfunctioned and no data for the freeze event was recorded. During the freeze event, air temperatures were maintained between 55 and 65°F for the same emitter sizes at both 6 and 18 inch heights (Figs. 4, and 5). No increase in temperatures were observed for the two dates that air temperatures dropped to approximately 35°F and irrigation was not turned used.

During non-freeze period. No difference in mean monthly air temperature increased at both 6 inch and 18 inch heights and for trees with Tee-Pees and without Tee-Pees from January to May in 2015 (Table 2) and 2016 (Table 3) due to high variability in temperature measurements. However, as one would expect, maximum temperatures were higher in March, April and May at the 6 inch height compared with the same height inside the Tee-Pee, but minimum temperatures were not different when irrigation was not applied on freeze nights.

Soil Moisture Measurements

Soil Moisture sensors were installed at depths of to collect soil moisture measurements within the Tee-Pees or a similar area for trees without Tee-Pees. Soil moisture increased greatly for all sites on the evening that irrigation ran for freeze protection because to the extended duration compared with irrigation events. The irrigation event on February 16 increased soil moisture for all sites at the 6 and 12 inch depths below the soil surface. However, soil moisture did not increase at the 18 inch depth for the black and blue emitters (Figs. 6 and 7) and increased only slightly at 18 inch depth for the orange emitter (Fig. 8). However, substantial increases in soil moisture were observed at the 18 inch depth for all three Tee-Pee treatments (Figs. 9, 10 and 11).

Soil moisture for the coldest months of the year (January and February) and highest water demand months (April and May) were compared for 2015 (Table 4) and 2016 (Table 5). Lower mean daily soil moisture was maintained at 0.095 to 0.163 in³ in⁻³ at the 6 inch depth without Tee-Pees installed compared with 0.134 to 0.159 in³ in⁻³ for treatments with Tee-Pees installed. Similarly, lower mean daily soil moistures were maintained at the 18 inch depth for treatments without Tee-Pees compared with treatments with Tee-Pees installed. Differences were also noticed in monthly maximum and minimum measurements with lower values recorded for trees without Tee-Pees. These measurements indicate that irrigation was concentrated within a smaller area at the base of each tree with Tee-Pees installed and would indicate that less time is needed to fill the limited area irrigated under the Tee-Pee compared with the larger areas irrigated by the unrestricted emitters.

Soil Temperature

Monthly mean soil temperature did not vary significantly with depth for 2015 or 2016 (Tables 6 and 7). However, mean, maximum and minimum soil temperatures were lower for trees with Tee-Pees. Lower soil temperatures are probably due to shading by the Tee-Pees but should not have a substantial negative effect on tree growth.

Tree Growth

Significant differences were found among treatments in tree diameter at the beginning of the study (Table 8, October 17, 2014). Greatest trunk diameters were measured for trees with orange emitters and Tee-Pees installed. Smallest trees were found in plots with black emitters with a 45 degree down spray pattern. The differences were not related to treatments as the treatments had begun only recently. Similar significant differences were found in trunk diameter on January 21, 2016 and June 10, 2016 (Table 8). Trunk diameters for all treatments with Tee-Pees installed were significantly greater than the blue 360 degree emitter pattern without Tee-Pee on June 10, 2016.

Tree heights were not significantly different among treatments at any measurement date. However, for the January 2016 measurement, tree canopy widths and canopy volumes were not significantly different at the 95% confidence level normally used but was significantly greater at $p \leq 0.10$ for the orange emitter with Tee-Pee installed compared with the blue 360 degree treatment without Tee-Pee. These differences could have been related to larger trunk diameter at the beginning of the study as trees with larger trunk diameters at planting tend to maintain a size advantage to competition of the study period. Canopy widths were not significantly different on June 10, 2016 because rainfall the previous day and night caused the limbs to bend towards the ground reducing canopy height, thereby impacting diameter. However, canopy volumes on June 10, 2016 were significantly higher for the black and blue emitter treatments with Tee-Pee installed compared with the blue 360° emitter without Tee-Pee.

Conclusions

Only one freeze event occurred during the two winters of this study with minimum temperatures of 35°F. Air temperatures measured during the freeze event indicates that installation of tree Tee-Pees significantly increases at six inches inside the Tee-Pees by 18 to 21°F. However, air temperatures at the 18 inch height above the Tee-Pee dipped to the same air temperature as trees without the Tee-Pees. Soil temperatures below the Tee-Pees were lower than soil temperatures where Tee-Pees were not installed. Soil moisture measurements at 6 and 18 inch depths were consistently higher under the Tee-Pees compared with treatments without Tee-Pees installed. These higher soil moisture measurements indicate that the irrigation schedule used in this study would have resulted in leaching of nutrients below the root zone of the trees. These results would indicate that irrigation water savings could have resulted from reduced irrigation of trees with Tee-Pees

installed. Tree trunk diameter is the best indicator of growth for young citrus trees. Trunk diameters were significantly greater at the beginning of this study for one of the treatments with Tee-Pees installed. These trees maintained the size advantage throughout the study. Trunk diameters for all treatments with Tee-Pees installed were significantly greater than the blue 360 degree emitter pattern without Tee-Pee at the end of the study. Tree heights were not significantly different among treatments at any measurement date. However, tree canopy widths and canopy volumes were significantly greater for the orange emitter with Tee-Pee installed compared with the blue 360 degree treatment without Tee-Pee. These growth measurements indicate the trees with Tee-Pees installed grew at a greater rate than trees without Tee-Pees installed but may have been related to higher soil moisture content.

The results described above were relevant for the 18 months of this study. However, long term use of the Tee-Pees must be investigated to evaluate the effect of the restricted irrigation zone under the Tee-Pee on tree growth beyond 18 months after installation. Additionally, the cost of the Tee-Pee and installation may be greater than grower budgets allow unless they are reused by moving the Tee-Pees to newly planted trees after 2-3 years.

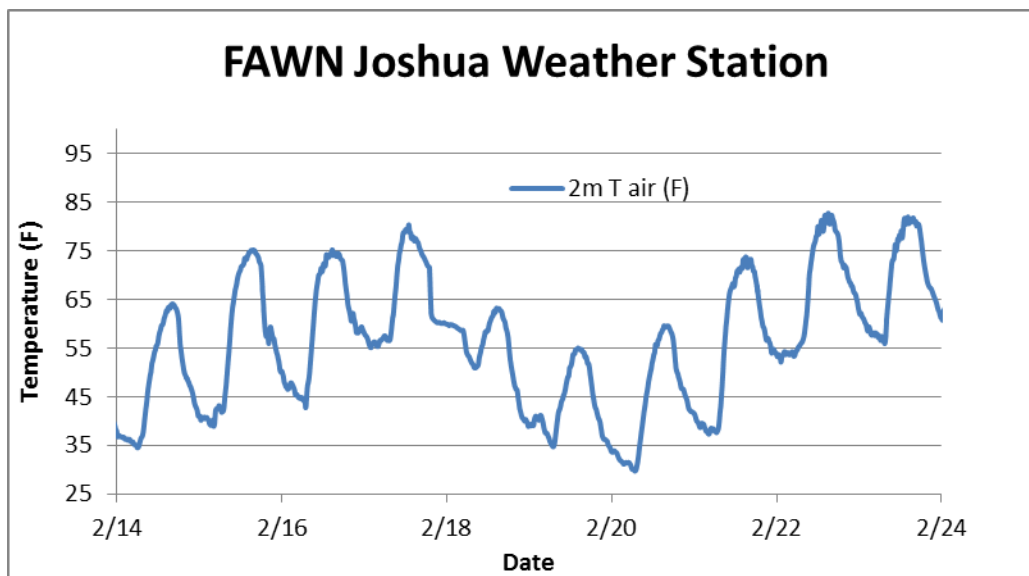


Fig. 1. Two meter temperatures from FAWN Joshua weather station for February 14 to February 24, 2015.

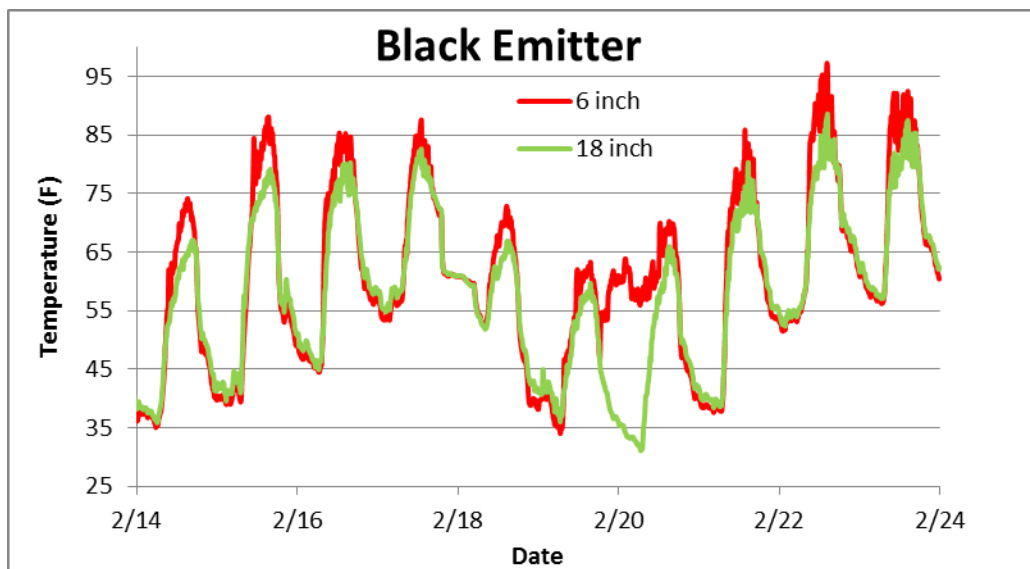


Fig. 2. Average air temperatures from 360 and 45 degree black emitters at 6 and 18 inches above ground for February 14 to February 24, 2015.

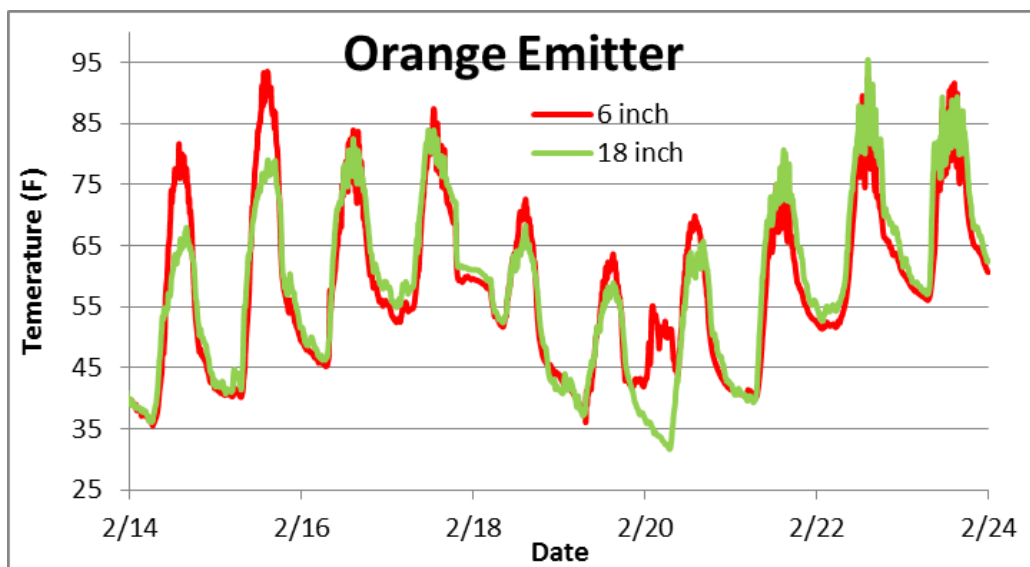


Fig. 3. Average air temperatures from 360 and 45 degree orange emitters at 6 and 18 inches above ground for February 14 to February 24, 2015.

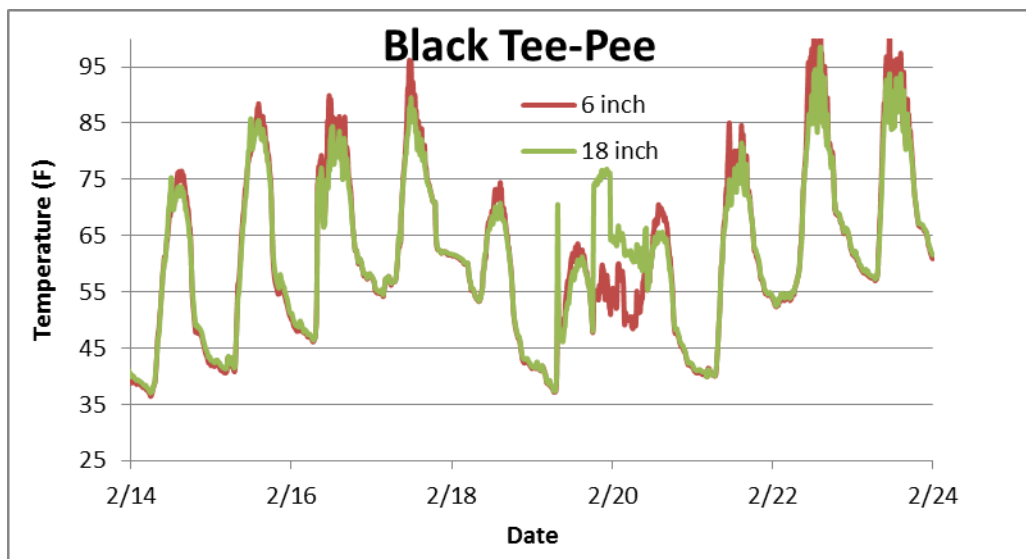


Fig. 4. Air temperatures from black emitter inside Tee-Pee at 6 and 18 inches above ground for February 14 to February 24, 2015.

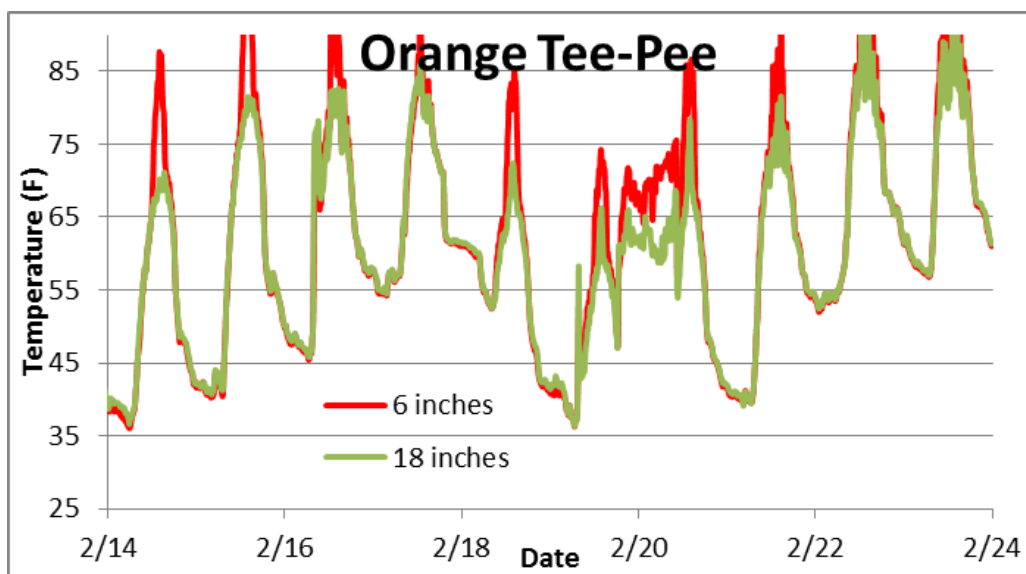


Fig. 5. Air temperatures from orange emitter inside Tee-Pee at 6 and 18 inches above ground for February 14 to February 24, 2015.

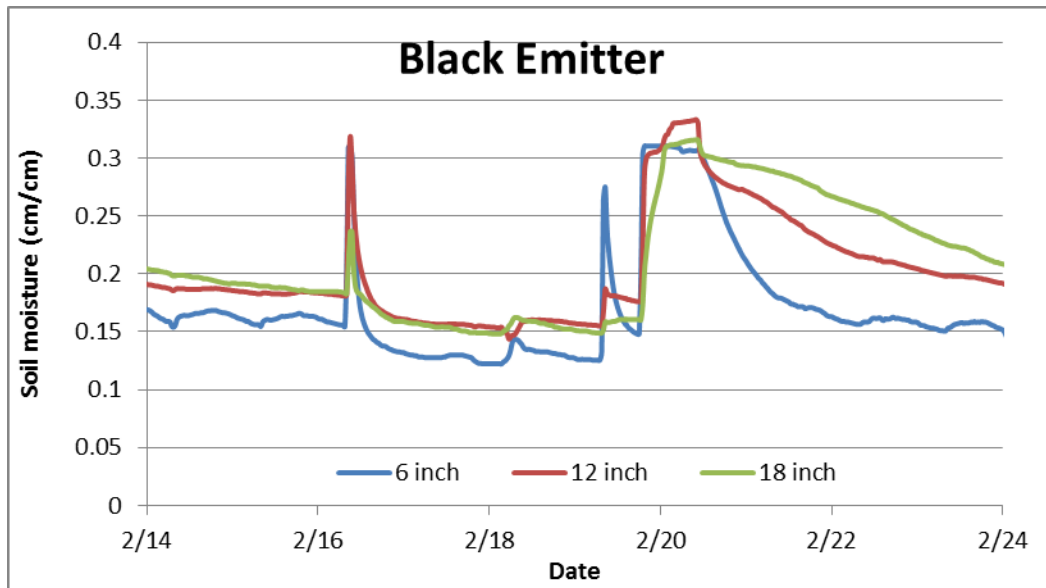


Fig. 6. Average soil moisture from 360 and 45 degree black emitters at 6, 12 and 18 inches below ground for February 14 to February 24, 2015.

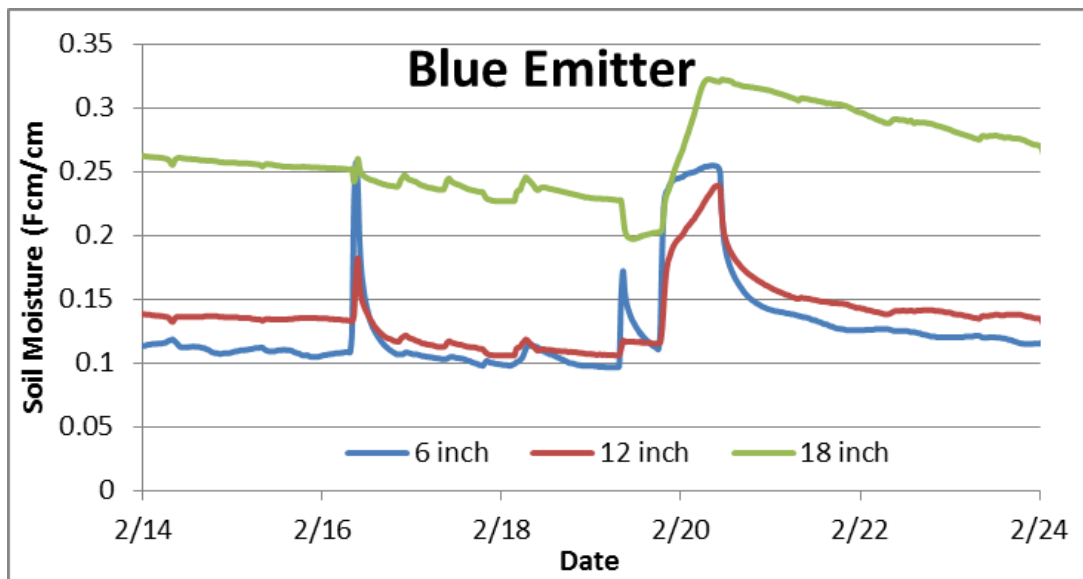


Fig. 7. Average soil moisture from 360 and 45 degree blue emitters at 6, 12 and 18 inches below ground for February 14 to February 24, 2015.

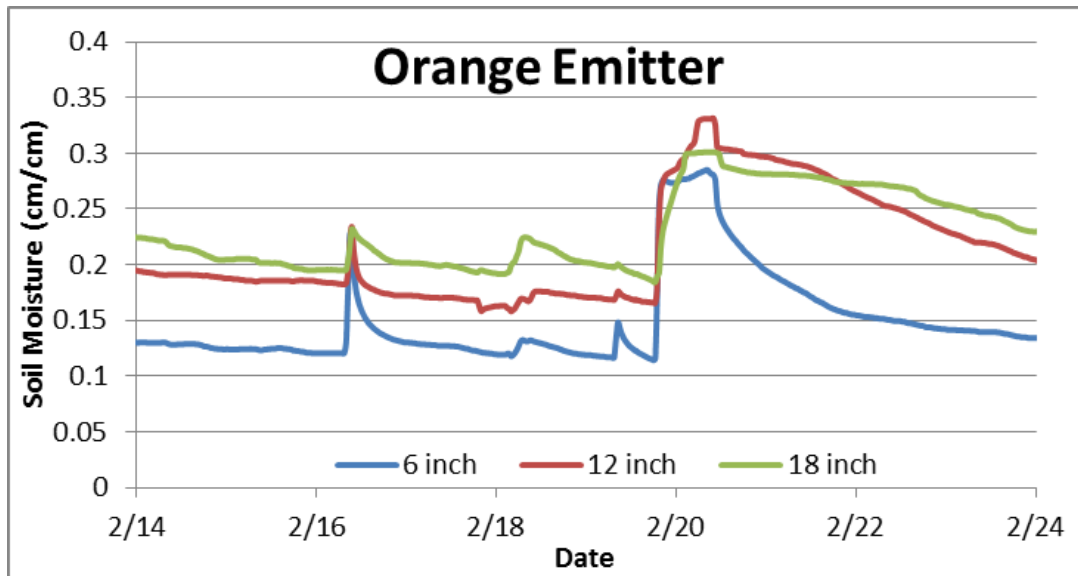


Fig. 8. Average soil moisture from 360 and 45 degree orange emitters at 6, 12 and 18 inches below ground for February 14 to February 24, 2015.

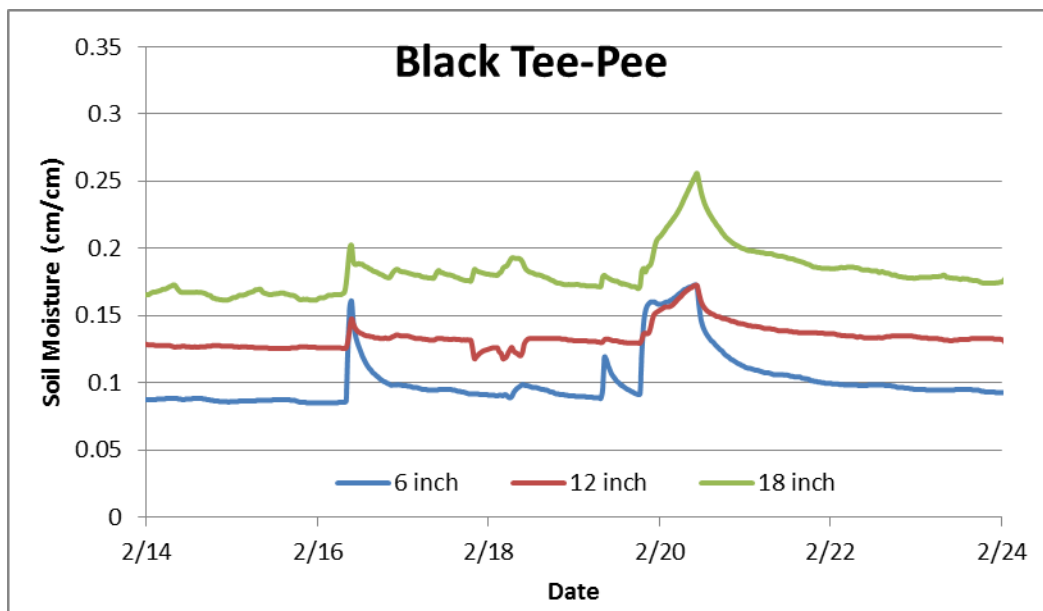


Fig. 9. Average soil moisture from black emitter inside Tee-Pee at 6, 12 and 18 inches below ground for February 14 to February 24, 2015.

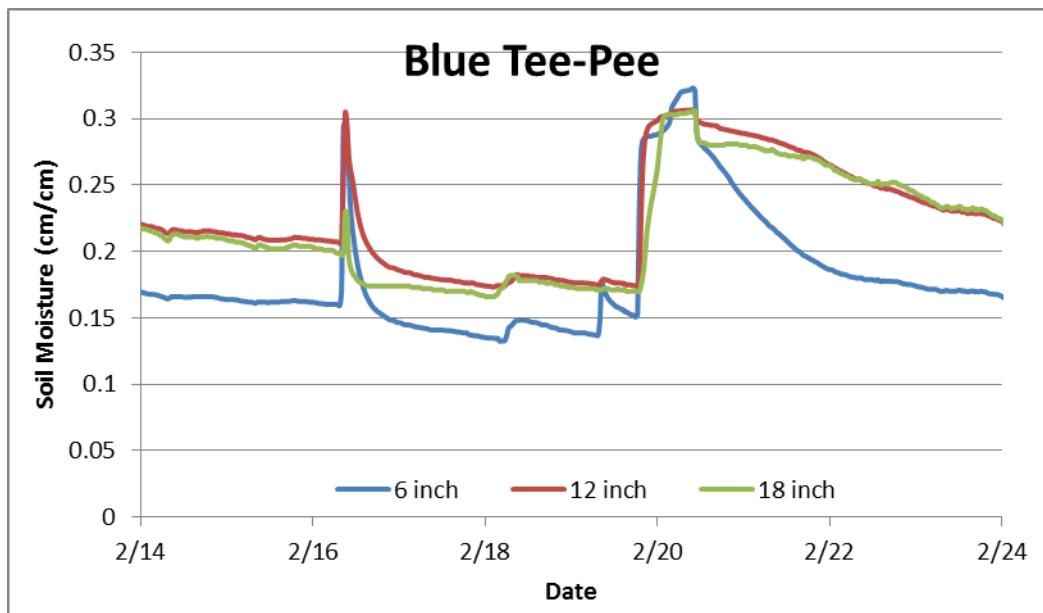


Fig. 10. Average soil moisture from blue emitter inside Tee-Pee at 6, 12 and 18 inches below ground for February 14 to February 24, 2015.

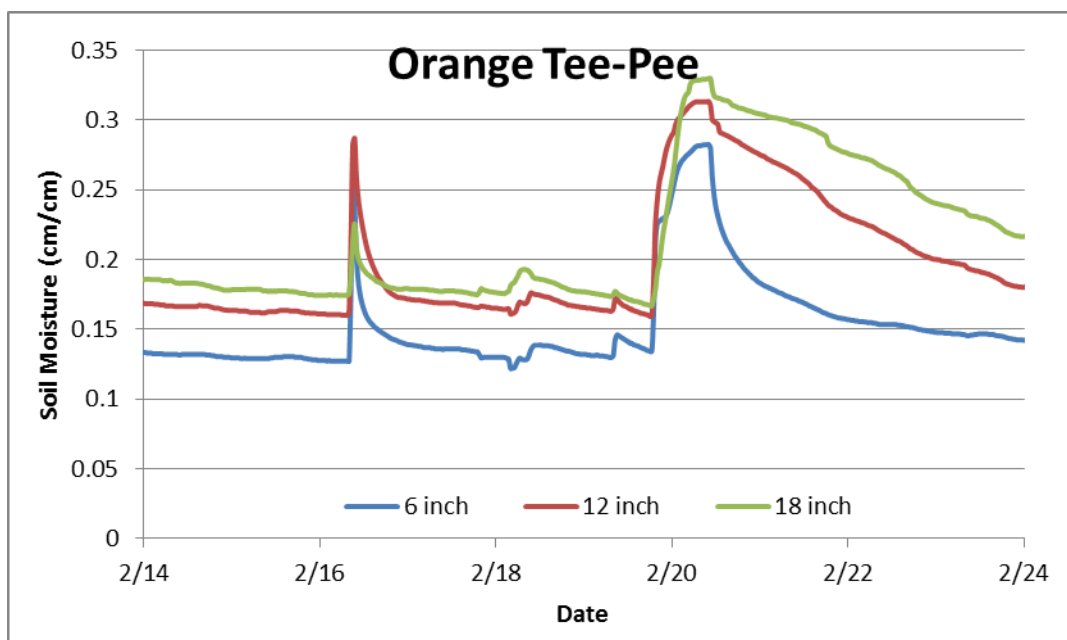


Fig. 11. Average soil moisture from orange emitters inside Tee-Pee at 6, 12 and 18 inches below ground for February 14 to February 24, 2015.

Table 2. Summary of air temperatures recorded at 6 and 18 inch height from January to May 2015.

	6 inch Air Temperatures (°F)					18 inch Air Temperatures (°F)				
	January	February	March	April	May	January	February	March	April	May
	Trees without Tee-Pee									
Mean	58.3	61.3	73.1	78.8	76.9	56.7	61.5	74.2	78.7	78.2
Standard Deviation	12.8	13.1	13.5	14.1	13.9	12.9	13.4	13.7	13.2	12.3
Maximum	83.2	94.9	113.4	118.8	121.3	73.6	97.8	120	120	116.3
Minimum	45.2	33.7	43.9	57.6	62.3	47.8	33.5	44.3	73.9	72.6
	Trees with Tee-Pee									
Mean	56.7	62.9	73	77.8	80.3	58.9	62.9	74.5	79.2	85.3
Standard Deviation	11.3	10.9	9.5	10.9	10.8	11.8	13	11.9	12	11.6
Maximum	81.6	88.7	103	104.5	118.3	83.2	102.9	109.6	114.2	116.9
Minimum	46.2	37.3	46.8	58.5	62.8	48.6	35.1	45.6	59.4	60.3

Table 3. Summary of air temperatures recorded at 6 and 18 inch height from January to May 2016.

	6 inch Air Temperatures (°F)					18 inch Air Temperatures (°F)				
	January	February	March	April	May	January	February	March	April	May
	Trees without Tee-Pee									
Mean	53.4	64.6	72.1	79.3	74.5	59.3	63.8	76.1	75.8	75.4
Standard Deviation	11.8	16.1	12.7	12.3	16.3	11.3	12.5	11.2	11.3	11.7
Maximum	85.3	91.4	102.5	105.4	109.4	72.7	99.2	115.6	116.4	113.5
Minimum	42.6	35.6	47.4	59.8	66.4	45.3	35.6	46.8	78.4	76.7
	Trees with Tee-Pee									
Mean	54.6	61.8	72.6	73.5	82.4	56.9	65.9	79.7	76.3	89.2
Standard Deviation	11.8	9.6	9.9	11.9	10.6	10.9	11.6	10.3	11.5	13.7
Maximum	83.5	83.6	106.3	107.3	123.5	87.3	106.7	119.5	118.4	118.6
Minimum	46.8	38.4	47.9	56.3	64.6	49.8	38.3	48.7	62.5	63.7

Table 4. Summary of soil moisture measurements recorded at 6 and 18 inch depths from January to May 2015.

	6 inch Soil Moisture (in ³ in ⁻³)					18 inch Soil Moisture (in ³ in ⁻³)				
	January	February	March	April	May	January	February	March	April	May
	Trees without Tee-Pee									
Mean	0.101	0.105	0.108	0.125	0.114	0.138	0.152	0.147	0.168	0.168
Standard Deviation	0.015	0.019	0.018	0.0306	0.024	0.01	0.024	0.024	0.036	0.022
Maximum	0.198	0.195	0.2	0.286	0.205	0.182	0.223	0.226	0.248	0.224
Minimum	0.087	0.082	0.083	0.09	0.075	0.121	0.116	0.116	0.123	0.131
	Trees with Tee-Pee									
Mean	0.129	0.14	0.137	0.159	0.155	0.194	0.222	0.21	0.23	0.242
Standard	0.019	0.031	0.025	0.048	0.023	0.059	0.037	0.038	0.047	0.026
Maximum	0.245	0.271	0.251	0.38	0.253	0.252	0.307	0.307	0.324	0.304
Minimum	0.05	0.104	0.1	0.107	0.122	0.169	0.159	0.156	0.168	0.198

Table 5. Summary of soil moisture measurements recorded at 6 and 18 inch depths from January to May 2016.

	6 inch Soil Moisture (in ³ in ⁻³)					18 inch Soil Moisture (in ³ in ⁻³)				
	January	February	March	April	May	January	February	March	April	May
	Trees without Tee-Pee									
Mean	0.163	0.095	0.112	0.115	0.123	0.126	0.124	0.142	0.168	0.148
Standard Deviation	0.015	0.016	0.018	0.034	0.041	0.012	0.022	0.023	0.036	0.024
Maximum	0.178	0.185	0.231	0.266	0.227	0.162	0.213	0.219	0.248	0.206
Minimum	0.107	0.076	0.093	0.098	0.065	0.101	0.096	0.106	0.123	0.091
	Trees with Tee-Pee									
Mean	0.136	0.152	0.134	0.143	0.175	0.163	0.224	0.216	0.23	0.212
Standard	0.012	0.036	0.023	0.077	0.036	0.019	0.032	0.047	0.032	0.025
Maximum	0.225	0.236	0.243	0.238	0.224	0.232	0.327	0.307	0.346	0.324
Minimum	0.065	0.094	0.110	0.097	0.092	0.129	0.139	0.156	0.138	0.162

Table 6. Summary of soil temperatures recorded at 6 and 18 inch depths from January to May 2015.

	6 inch Soil Temperatures (°F)					18 inch Soil Temperatures (°F)				
	January	February	March	April	May	January	February	March	April	May
	Trees without Tee-Pee									
Mean	65.3	62.8	74.5	79.3	80.2	66.7	63.7	73.8	78.8	80.2
Standard Deviation	4.99	5.35	4.88	4.59	4.81	2.90	2.93	2.86	2.29	2.66
Maximum	78.1	75.9	86.2	91.4	90.9	73.4	69.6	80.1	84.4	85.8
Minimum	53.6	47.6	61.2	68.4	68.9	60.6	54.1	67.3	72.0	74.1
	Trees with Tee-Pee									
Mean	57.2	55.0	63.1	66.9	67.6	58.3	55.8	63.1	67.1	68.2
Standard	3.51	3.20	3.19	2.38	2.74	2.21	1.78	0.47	1.51	0.25
Maximum	66.0	62.2	71.2	73.2	73.2	63.1	59.7	68.2	71.2	72.1
Minimum	48.9	47.3	54.3	60.3	60.1	53.3	51.3	58.1	62.2	63.1

Table 7. Summary of soil temperatures recorded at 6 and 18 inch depths from January to May 2016.

	6 inch Soil Temperatures (°F)					18 inch Soil Temperatures (°F)				
	January	February	March	April	May	January	February	March	April	May
	Trees without Tee-Pee									
Mean	63.1	61.9	78.4	76.1	74.8	60.1	65.5	79.3	79.7	82.9
Standard Deviation	5.20	4.81	4.70	4.82	4.93	3.11	2.65	2.61	2.61	2.45
Maximum	74.1	86.9	92.8	98.2	94.6	74.1	74.5	85.6	80.2	85.8
Minimum	58.5	36.5	55.0	56.1	70.9	56.7	61.5	60.1	72.7	79.5
	Trees with Tee-Pee									
Mean	56.1	62.2	64.2	62.2	62.2	54.9	61.3	61.5	65.3	74.8
Standard	3.04	3.15	2.65	3.02	3.02	2.43	2.81	1.42	2.41	1.75
Maximum	65.1	64.9	71.2	83.5	74.5	61.5	67.6	78.4	72.9	85.5
Minimum	47.1	45.7	42.3	63.1	56.5	53.2	56.5	55.0	61.3	55.0

Table 8. Summary of tree measurements from October 2014 to June 2016.

	October 17, 2014	January 21, 2016				June 10, 2016			
Treatments	Trunk Diameter (mm) ¹	Trunk Diameter (mm) ¹	Height (in)	Width (in) ¹	Canopy Volume (ft ³) ¹	Trunk Diameter (mm)	Height (in)	Width (in)	Canopy Volume (ft ³) ¹
Black 360	5.09 BC	29.83 BC	50.70	50.75 AB	65.54 ABC	35.80 AB	56.15	64.80	115.62 BC
Orange 360	5.46 AB	29.44 BC	48.00	50.40 AB	66.49 ABC	35.54 AB	55.10	63.65	116.80 AB
Blue 360	5.32 ABC	27.58 C	47.20	43.38 C	47.05 C	33.09 B	54.30	60.35	99.09 C
Black 45°	4.97 C	27.95 C	48.20	45.53 BC	55.49 BC	34.74 AB	53.25	63.25	108.86 BC
Orange 45°	5.25 BC	30.51 ABC	49.70	46.83 BC	55.53 BC	36.43 AB	55.00	61.98	103.23 BC
Blue 45°	5.19 BC	29.72 BC	49.05	48.88 BC	59.85 ABC	36.33 AB	55.70	65.00	115.56 BC
Black Tee- Pee	4.99 BC	32.79 AB	51.82	54.25 A	77.27 AB	39.81 A	60.10	68.75	140.72 A
Orange Tee-Pee	5.73 A	34.01 A	52.75	54.85 A	83.65 A	39.74 A	58.80	71.13	148.65 A
Blue Tee- Pee	5.34 ABC	32.68 AB	50.95	52.30 AB	67.19 ABC	39.93 A	56.75	68.73	128.24 AB
Statistics (p)	0.012	0.005	0.647	0.088	0.055	0.033	0.523	0.260	0.027

¹ Duncan multiple range test for measurement with probability of significant differences (P) among treatments less than 10% ($p \leq 0.10$). Treatments with different letters are significantly different.