Evaluation of Deep Drip™ Tree Watering Stakes for water conservation and fertilizer use optimization in orchards

Phase 1 Report –Comparison of Deep Drip™ wetting pattern with surface drip

By

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Acknowledgments

This project would not have been possible without the participation of the individuals listed below. The authors recognize that the list is by no means complete and humbly apologize for the omission of any names that should have been included.

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The contribution of everyone is duly acknowledged.

Introduction

Several irrigation methods can be implemented to optimize water and fertilizer use in orchards. Traditionally, surface drip or microjet sprinkler has been used successfully for tree crop production. In this study, we are evaluating a modified drip device where emitters are placed inside a plastic "stake" to direct water droplets below the soil surface. The premise of this device, commercialized as Deep Drip™ Tree Watering Stake, is that deeper water application will promote deeper root growth and reduce soil surface evaporation or runoff; thereby resulting in greater tree growth and water conservation. Additionally, as with any drip device, fertilizer can be applied through the system.

The Deep Drip™ Tree Watering Stake is a new device and little information is available on its watering pattern and possible reduction in water use compared to traditionally utilized irrigation methods. Therefore, the overall goal of this study is to evaluate the wetting patterns, soil moisture content, tree growth, and fruit yield in soils and orchards where Deep Drip™ Tree Watering Stakes have been installed and to compare these parameters with those obtained under conventional irrigation methods, such as surface drip or microjet sprinkler.

The study is being conducted in several phases. The objective of Phase 1, as described in this report, was to compare the wetting pattern of the Deep Drip™ Tree Watering Stakes with those of a surface drip system on a bare and dry soil. The following phases will consist in installing the Deep Drip™ Tree Watering Stakes and conventional irrigation devices in orchards to assess and compare the wetting patterns around the root zone, determine the soil moisture content between irrigation events, visually assess tree growth and weed infestation, and calculate fruit yields. Several trials can also be implemented to address irrigation frequencies, flow rates, and durations.

Materials and Methods

Experimental design. The Phase 1 test was conducted at the Center for Irrigation Technology, Fresno, CA on September 10, 2009 on a dry and bare soil. Two drip lines were installed as shown in Figure 1. Both Deep Drip™ stakes and surface drip emitters were positioned along the two drip lines; therefore two replicates were installed for each irrigation method. The drip lines consisted of a 16 mm tubing spaced 10' apart and connected to a 16 mm manifold. At midpoint along the manifold, a ¾" main line connected to the water supply. A ¾" valve, 200 mesh filter, and 15 psi pressure regulator were installed along the main line. The detailed layout of the field experiment can be visualized in Figure 2.

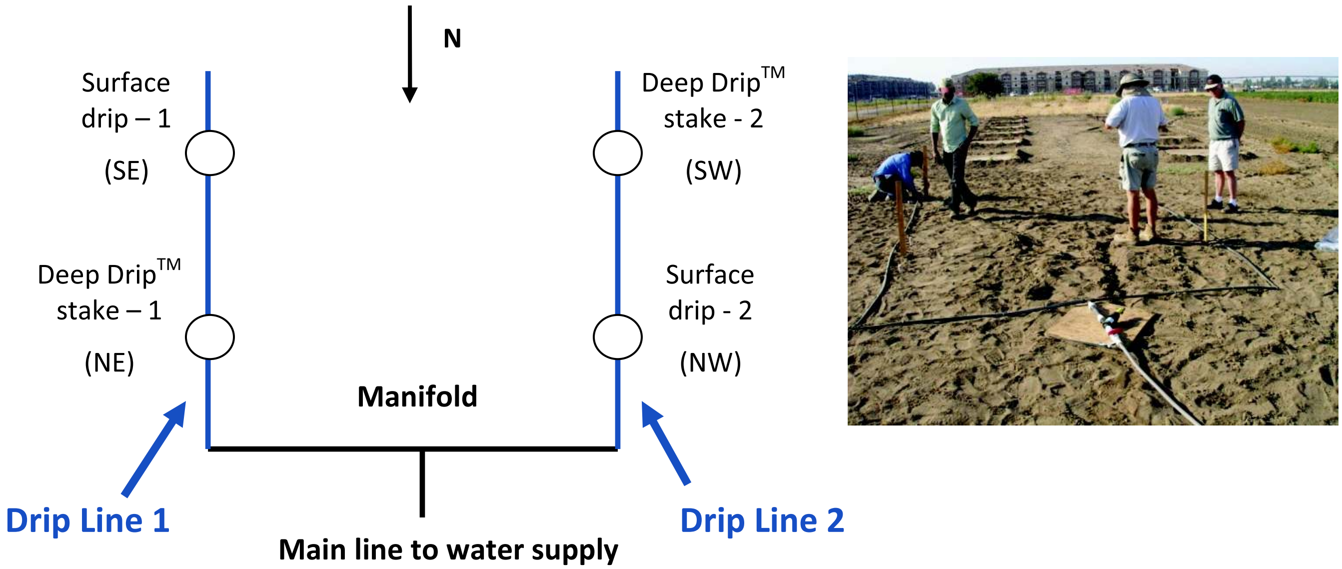


Figure 1. Schematic representation of Phase 1 - experimental design (not to scale) with picture of field setup

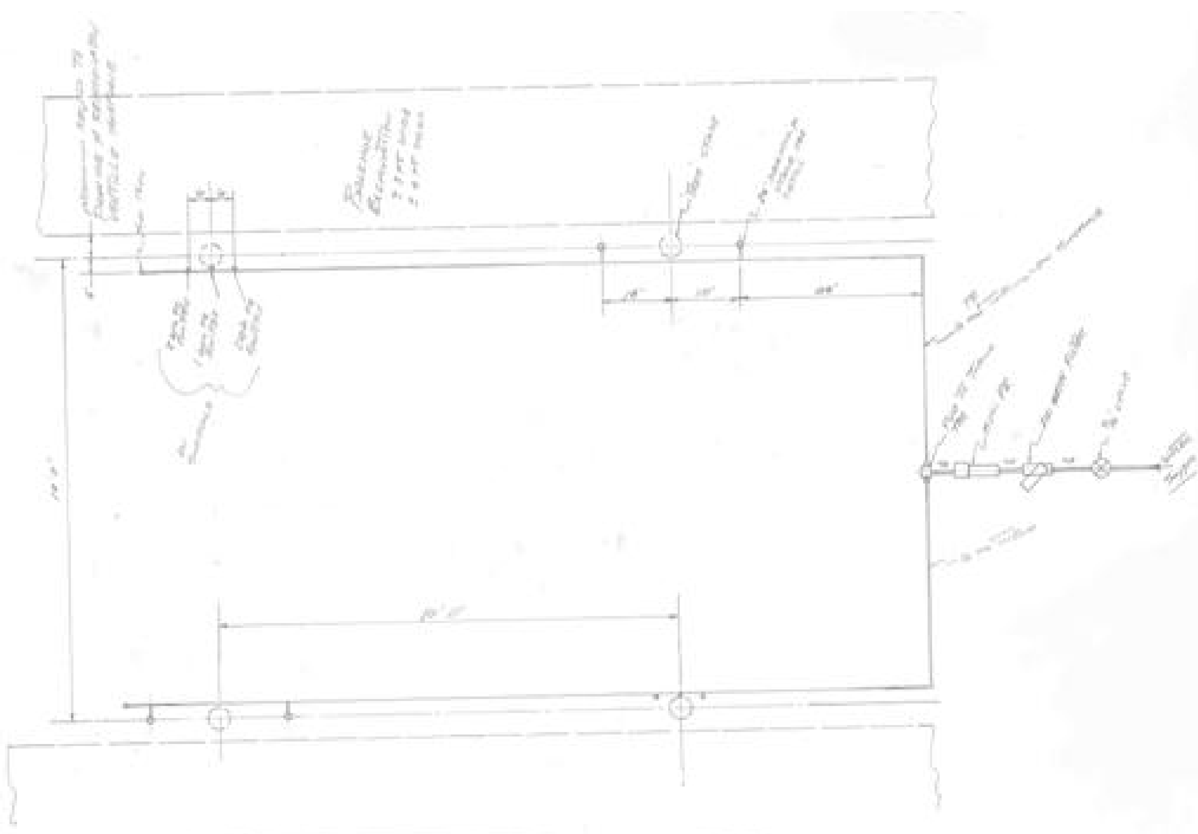


Figure 2. Drawing of experimental setup

The Deep Drip™ stake irrigation method consisted of inserting two stakes into the ground 36" apart, i.e., 18" from a wooden stake installed to represent the location of a tree trunk (Figure 3). A 2 gph emitter was then placed inside each stake, as visualized in Figure 4. The study was conducted using the 24.5" long Deep Drip™ stakes; these stakes had six openings spaced 1" apart along the bottom half of the shaft for water delivery (Figure 5). The surface drip irrigation method consisted of 3 emitters placed at the soil surface 6" apart, with the center emitter placed at the location of the "tree" stake (Figure 6). The center emitter had a flow rate of 1 gph while the other two emitters had a flow rate of 2 gph.

Figure 3. Position of Deep Drip™ stakes

Figure 4. Placement of an emitter inside a Deep Drip™ stake

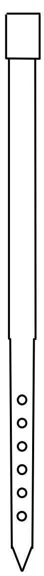


Figure 5. Schematic of Deep Drip™ stakes used in study

Figure 6. Position of surface drip emitters

Measurements. First, the Phase 1 study test consisted in applying irrigation water on a bare and dry soil for 45 minutes. Then, the dimensions of the soil surface wetting patterns were taken for each irrigation method and each replicate. A backhoe was then utilized to create a trench and measure the cross section and depth of each wetting front below the soil surface (Figure 7).

Figure 7. Backhoe used to dig trench at each testing location

At the beginning of the study, soil samples were also taken at 6" increments down to a depth of 30" to characterize the soil texture at the site and determine any textural variability among the four testing locations (SE, NE, SW, and NW). Table 1 shows the percent sand, silt, and clay obtained at each location and sampling depth. The percent sand was high, ranging from 64 to 77%; the percents silt and clay were comparable and low (9-19%). Therefore, the soil at the experimental site was classified as sandy loam. The soil texture was very consistent across the different depths and locations.

Table 1. Soil texture at experimental site

Location	Depth	% sand	% silt	% clay	Textural class
SE	0-6“	75	13	12	Sandy loam
	6-12”	72	12	16	Sandy loam
	12-18”	66	19	15	Sandy loam
	18-24”	64	17	19	Sandy loam
	24-30”	70	14	16	Sandy loam
NE	0-6“	75	19	6	Sandy loam
	6-12”	73	9	18	Sandy loam
	12-18”	75	13	12	Sandy loam
	18-24”	75	14	11	Sandy loam
	24-30”	75	13	12	Sandy loam
SW	0-6“	76	10	14	Sandy loam
	6-12”	77	12	11	Sandy loam
	12-18”	68	18	13	Sandy loam
	18-24”	68	15	17	Sandy loam
	24-30”	71	15	14	Sandy loam
NW	0-6“	73	12	15	Sandy loam
	6-12”	65	18	18	Sandy loam
	12-15”	75	9	16	Sandy loam

Results and Discussion

Soil surface. The wetting patterns at the soil surface were characterized by the length of the wetting front (l *in inches*) and the width of wetting (w *in inches*) across the point source (emitters or stakes). An example of these measurements is shown in Figure 8.

Figure 8. Measurement of wetted width (w) at surface drip location

For the surface drip system, the length of the wetting front was about 26” for each replicate and the width ranged from 16.0 to 21.5” (Table 2). For the Deep Drip™ system, no water was observed at the soil surface except at the SW location around one stake. At that particular location, the wetting pattern was almost circular with a diameter of 7”. The average data indicate a much greater wetting surface area for the conventional surface drip system (25.75” x 18.75”) compared to the Deep Drip™ devices (1.69” x 1.75” for one stake). These results suggest a lower potential for surface evaporation and runoff with the Deep Drip™ system.

Table 2. Dimensions of surface wetting pattern at each testing location

Irrigation type and location	**Point source**	**Wetted length (l)** (inches)	**Wetted width (w)** (inches)
Surface drip –Line 1 (SE)	3 emitters	25.5	16.0
Surface drip – Line 2 (NW)	3 emitters	26.0	21.5
Deep Drip™ – Line 1 (NE)	1st stake	0	0
	2nd stake	0	0
Deep Drip™ – Line 2 (SW)	1st stake	6.75	7.0
	2nd stake	0	0
Average			
Surface Drip	3 emitters	25.75	18.75
Deep Drip™	1 stake	1.69	1.75

Profile depth. The vertical wetting patterns were characterized by the diameter of the wetting front (d *in inches*) and the depth of wetting (*z in inches*) across the point source (emitters or stakes). An example of the wetted depth is shown in figure 9.

Figure 9. Measurement of wetted depth (z) at Deep Drip™ location

For the surface drip system, the wetted diameter ranged from 26.5 to 28.5" and the wetted depth from 7 to 11.5" (Table 3). These measurements represented the wetting patterns across three emitters. For the Deep Drip™ system, the wetted diameter around one stake ranged from 11.5 to 18.5" and the wetted depth reached 23-24" for all stakes. If we consider the paired stakes for each replicate, the wetted diameter would be equivalent to 23.5 and 31.5" for the NE and SW locations, respectively. Additionally, when analyzing the wetted depth data, it is important to note that the top of the wetting front was only observed 8-11" below the soil surface as water was delivered through the Deep Drip™ openings located at 12-18" depth.

Table 3. Dimensions of vertical wetting pattern at each testing location

Irrigation type and location	**Point source**	**Wetted diameter (d)** (inches)	**Wetted depth (z)** (inches)	**Depth to top of wetting front (f)** (inches)
Surface drip –Line 1 (SE)	3 emitters	26.5	7	0
Surface drip – Line 2 (NW)	3 emitters	28.5	11.5	0
Deep Drip™ – Line 1 (NE)	1st stake	11.5	24	11
	2nd stake	12	24	9
Deep Drip™ – Line 2 (SW)	1st stake	13	23	8
	2nd stake	18.5	24	8
Average				
Surface Drip	3 emitters	27.5	9.25	0
Deep Drip™	1 stake	13.75	23.75	9
Deep Drip™	2 stakes (pair)	27.5	-	-

The average data indicate that the wetted diameter was identical for both irrigation methods (27.5”) when considering the paired stakes for the Deep Drip™ system (Table 3). However, it is noteworthy that, in this experiment, the two wetting fronts created by each *Deep Drip™* stake did not join as was the case for the wetting fronts generated by the three surface drip emitters. The main differences between the two irrigation systems were explained by 1) the wetted depth which was shallower for surface drip (9.25”) compared to the Deep Drip™ (23.75”), and 2) the depth to the wetting front (soil surface for conventional drip and 9” for Deep Drip™). These findings indicate a broader wetting pattern (i.e., wetted depth) for the Deep Drip™ system compared to the surface drip system; thereby suggesting greater and deeper water availability across the root zone.

For quantitative comparison between the two irrigation methods, the data reported in Table 3 show the maximum dimension recorded for each wetted parameter (l, w, d, and z). However, the wetting patterns can be better visualized in Figures 10 and 11.

Figure 10. Wetting patterns of surface drip emitters at SE (left) and NW (right) locations

Figure 11. Wetting patterns of Deep Drip^{TM} devices at NE (left) and SW (right) locations

At the SE location, where surface drip emitters were installed, the wetting pattern was rectangular, whereas at the NW location, it was characterized by a more elliptical shape (Figure 9). The wetting fronts could be observed at the soil surface. The wetting patterns of the Deep Drip^{TM} stakes were relative uniform with oval shape observed below the soil surface (Figure 10). Comparative view of the wetting patterns obtained with each irrigation method along Drip Line 2 is shown in Figure 12. Detailed measurements of four vertical wetting patterns are included in Appendices 1 and 2.

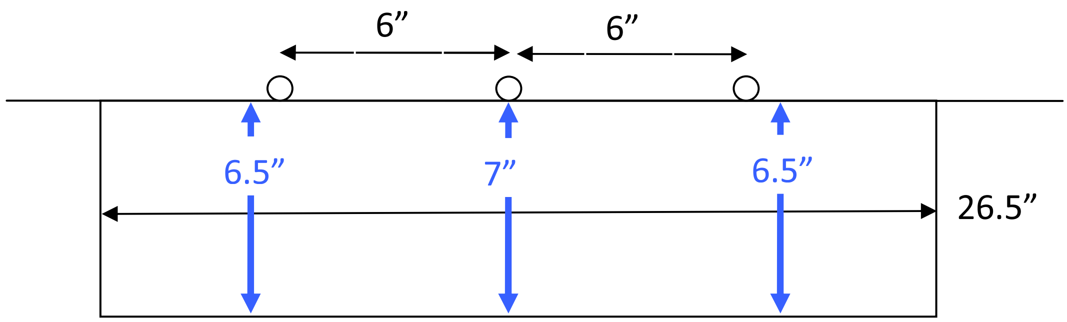
Figure 12. View of surface drip (left) and Deep Drip^{TM} (right) wetting patterns along Drip Line 2 (west locations)

Summary and conclusions

In this Phase 1 study, we evaluated the wetting patterns of Deep Drip^{TM} Tree Watering Stakes and compared them with those of conventionally used surface drip emitters. The Deep Drip^{TM} Tree Watering Stakes can be described as modified drip devices where emitters are placed inside a plastic “stake” to direct water droplets below the soil surface. The experiment was conducted on a dry and bare sandy loam soil with irrigation water applied for a period of 45 minutes. The results of the study indicated that the wetted depths were greater with the Deep Drip^{TM} Tree Watering Stakes and that little or no water was observed at the soil surface. This would tend to indicate that the *Deep Drip^{TM}* system would provide deeper water availability and reduce soil surface water evaporation and runoff. However, additional comparative studies are necessary to: 1) assess the wetting patterns in moist/wet conditions in orchards, 2) evaluate the relationships between wetting pattern and soil water availability, 3) determine water use, and 4) assess tree/root growth and fruit yield.

APPENDIX 1 – DIMENSIONS OF SURFACE DRIP WETTING PATTERN

SE location



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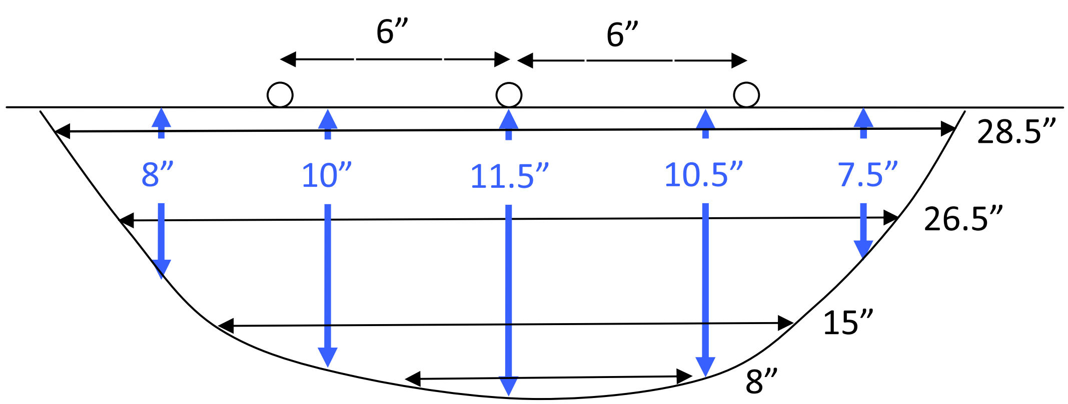
NW location



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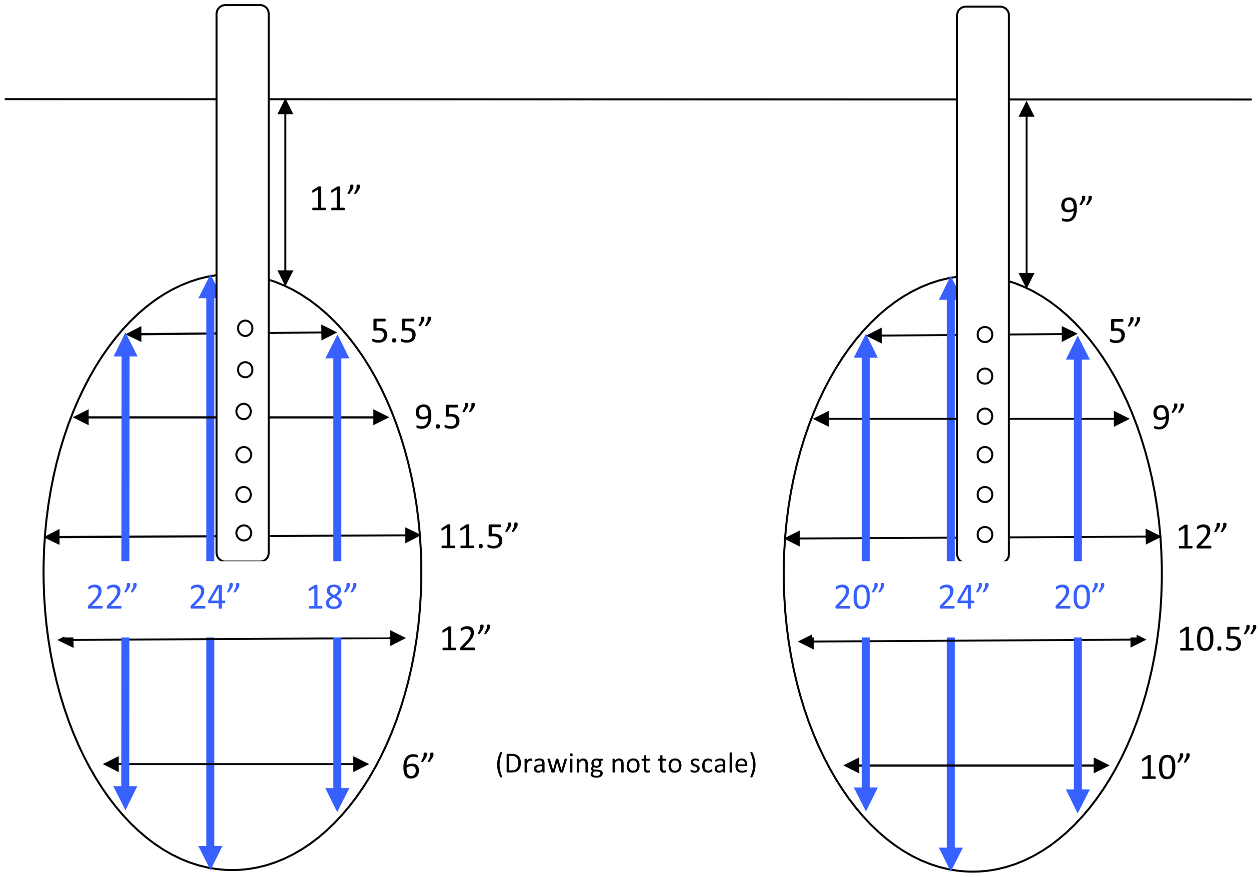
APPENDIX 2 – DIMENSIONS OF DEEP DRIP™ WETTING PATTERN

NE location



SW location