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Irrigation System Distribution Uniformity Evaluations in the Pajaro Valley, California

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Review

The Resource Conservation District (RCD) of Santa Cruz County and the UC Cooperative Extension of Monterey County performed 25 distribution uniformity (DU) evaluations in the Pajaro Valley between September 2015 and July 2017 following a method developed by Dr. Mike Cahn from the UC Cooperative Extension of Monterey County. The evaluations were performed in collaboration with interested growers and resulted in reports with recommendations to improve the performance of the irrigation system. An estimate of the potential savings, in terms of water and costs, were also included in each evaluation. Funding for the project came from PVWMA and from DWR.

Distribution uniformity is a measure of how evenly water is delivered to the crop and is an indicator of the efficiency of the irrigation system. Less water needs to be applied for a system with a high DU to meet the crop demand than a system with low DU. By improving DU of the irrigation system water conservation can be achieved at the same time avoiding over-irrigation, runoff and water logging.

Each evaluation consisted of pressure measurements taken at various points across the irrigation system, to evaluate the performance of the pumping station equipment, main and submain lines, valves and pressure regulators. In drip systems lead hose connecting the submain to the drip tape laterals and the drip tape performance were also evaluated. Catch-can experiments were performed in all evaluations, placing cups or bottles under the emitters in drip systems and setting a grid of buckets under sprinkler systems. Other indicators of the irrigation system performance and management were recorded, such as runoff and ponding produced by the irrigation, leaks, row orientation, system flushing, emitter plugging, nozzle wear etc.

Table 1: Summary of the distribution uniformity evaluation performed.

Evaluation Number	Evaluation Date	Farm size	Crop	Area evaluated	Irrigation method	Distribution Uniformity
		Acres		Acres		
137	9/23/2015	40	Strawberry	3.3	Drip tape	73%
138	10/23/2015	20	Red Beets	1.8	Sprinklers	80%
139	10/27/2015	45	Strawberry	3	Drip tape	66%
140	12-02-2015	20	Potted ornamentals	0.6	Sprinklers	68%
141	02-12-2016	10.5	Strawberry	2.6	Drip tape	88%
142	2/22/2016	50	Raspberry & Blackberry	2.3	Drip tape/Hose	38%
143	03-02-2016	62	Strawberry	2.8	Drip tape	87%
144	2/26/2016	50	Strawberry	3.3	Drip tape	84%
145	3/26/2016	34	Strawberry	3.2	Drip tape	96%
146	4/26/2016	34	Organic Blackberry	1.8	Drip tape	74%
147	05-06-2016	9	Organic Blackberry	3.5	Drip tape	75%

148	5/16/2016	23	Organic Blackberry	2.5	Drip tape	77%
149	06-09-2016	10	Organic Blackberry	1.7	Drip tape	57%
151	7/28/2016	6.5	Apple	3.5	Drip hose PC	90%
152	8/19/2016	15	Apple	3.8	Micro-Sprinkler	80%
153	9/16/2016	40	Strawberry	3.8	Drip tape	83%
154	9/22/2016	100	Organic Romaine	5.7	Sprinklers	76%
155	9/30/2016	2.8	Herbs	0.83	Drip tape	92%
156	10/21/2016	6.3	Organic Strawberry	0.9	Drip tape	67%
157	11-01-2016	12	Organic Wine Grapes	4.5	Drip tape PC	72%
158	02-01-2017	35	Ornamentals	5.25	Drip tape	75%
159	3/17/2017	47.5	Raspberry	15	Drip tape	90%
160	04-11-2017	8	Organic Strawberry	1.8	Drip tape	91%
161	5/18/2017	6	Organic Strawberry	1.4	Drip tape	88%
162	6/28/2017	13.6	Organic Strawberry	3.5	Drip tape	75%
Total 25 evaluations		Total acres = 700.2		Evaluated acres = 82.38		Average DU = 77.68%

The evaluated irrigation systems included drip tape, drip hose, pressure compensating emitters, micro- sprinklers and overhead sprinklers irrigating various crops such as strawberry, vegetables, ornamentals, caneberries, apple and wine grapes (Table 1). On each ranch, only a fraction of the total ranch area was evaluated, usually one or two irrigation blocks. The evaluated irrigation blocks ranged in side from 0.6 acres to 5.7 acres and totaled 82 acres. Ranches ranged in size from 3 to 100 acres and the area of all ranches combined was 700 acres.

Table 2: Summary of recommendations resulting from system evaluation and their frequency.

Recommendation	Frequency
Buy pressure gages and install pressure measurement points	48%
Install pressure regulators	44%
Plugging issues, better flushing and fertigation management needed	40%
Fix leaks from driptapes causing runoff	32%
Install larger diameter lead hoses	28%
Install larger oval hose	20%
Adjust pressure regulators	20%
Valve choked or bleeding off water to decrease excessive pressure	20%
Change row or tape orientation	16%
Increase size of layflat serving block	12%
Perform filter maintenance	12%
Reduce pressure, overall too high	12%
Reduce irrigated area	8%
Mixed emitters or sprinklers	8%
Uneven drainage issues	4%

Table 2 shows the recommendations resulting from the evaluations and the frequency of the recommendation. The most common recommendation was to install pressure checkpoint (Schrader valves) and to provide the irrigator with a hand-held pressure gauge to check water pressure when operating the system. The second most common recommendation was to install pressure regulators to balance pressure between different blocks; this recommendation was very common in ranches with sloped fields. Plugged emitters were the third most common cause of poor DU, particularly in ranches where liquid organic

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fertilizer was injected in the system. Recommended practices to avoid plugging were: flushing tapes and manifolds after each fertigation and stopping the fertilizer injection at least 30 to 45 minutes before the end of the irrigation set to allow the fertilizer to be completely flushed from the drip lines. Fixing leaks and installing larger diameter oval hoses were the next most common recommendation for drip systems. In some ranches, pressure regulators were present, but the irrigator was not trained on how to adjust them or did not have a pressure gauge to measure the pressure. Thus, adjusting pressure regulators was also a common recommendation. Other recommendations included increasing the irrigated area instead of closing a valve to reduce pressure in the irrigation system, changing row orientation to lessen the slope of the rows, and improving maintenance of the filters.

Table 3: Results of statistical analysis of mean separations between treatments.

Irrigation Method	Number of Evaluations (n)	Range in DU	Mean DU	Groups	ANOVA P-value
Drip hose PC	2	72% to 90%	83.40%	a	0.34
Drip tape	10	66% to 96%	81%	a	
Organic drip	8	57% to 91%	76%	a	
Sprinklers	4	68% to 80%	75.50%	a	

When grouped by irrigation method, drip tape showed the highest average DU (83%) followed by drip hose with pressure compensating emitters (81%), sprinklers (76%) and the lowest was drip tape in organic production (75.5%) (Figure 1). However, the differences in DU were not statistically significant (P-value 0.34, Table 3). In one case pressure compensating systems did not yield a better DU than traditional driptape, since the system was run at a pressure below the pressure-compensating range of the emitters. Drip tape in organic ranches yielded poorer results than in conventional production, due to emitter plugging resulting from injecting organic liquid fertilizer, and because organic ranches are often located on marginal sloping land where differences in elevation affect the DU.

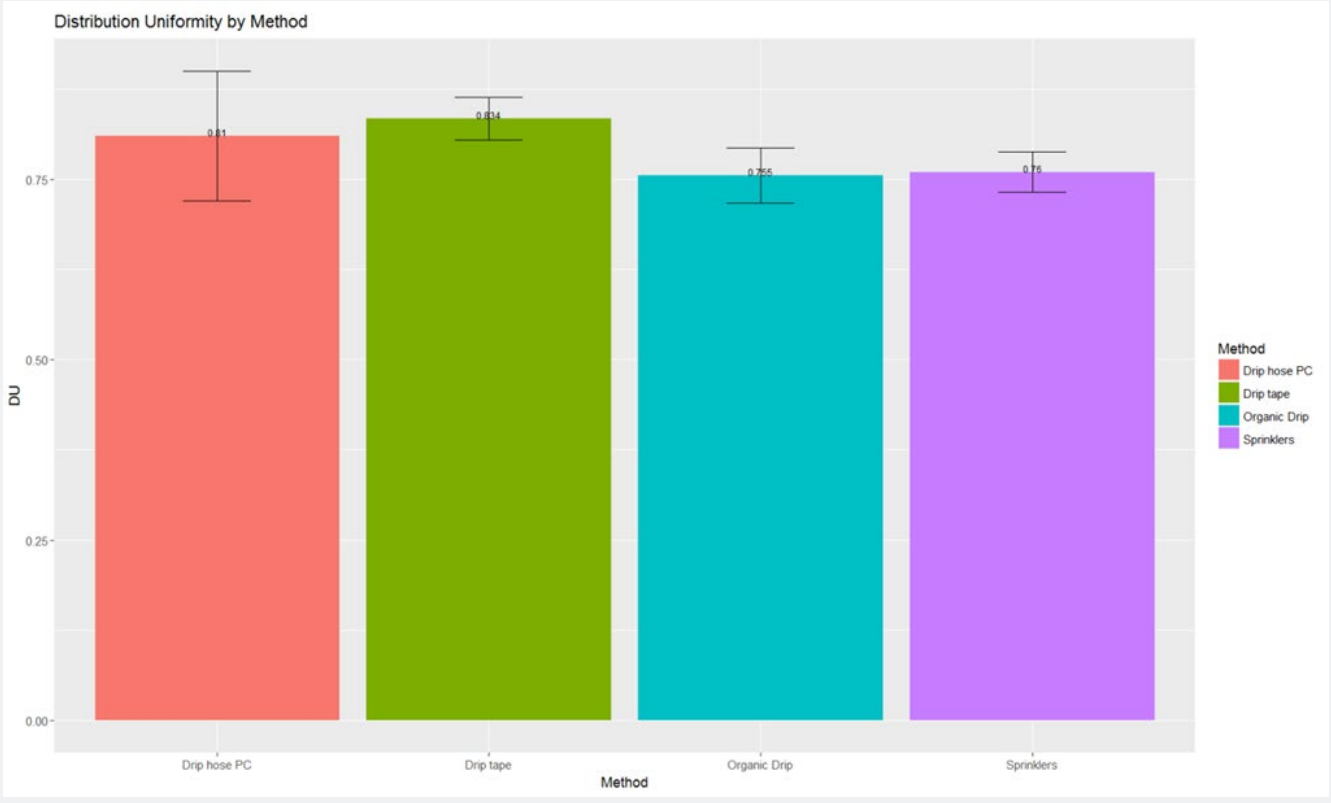

Figure 1: Results of the distribution uniformity evaluations grouped by method. The error bar represent the standard error of the mean. In the legend, "Drip Hose PC" refers to drip hose with pressure compensating emitters.

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Table 4: Estimated potential water and cash savings for each evaluation performed Based on 250$/AcFt for PVWMA augmentation fees and pumping costs.

Ranch size	Crop	Irrigation method	Distribution Uniformity	Target DU	Avg ETc	Potential Savings		
acres					inch/season	inch/season	AcFt/season	$/season
34	Strawberry	Drip tape	96%	96%	26	0	0	0
2.8	Herbs	Drip tape	92%	92%	24	0	0	0
8	Organic Strawberry	Drip tape	91%	91%	26	0	0	0
6.5	Apple	Drip hose PC	90%	90%	8	0	0	0
47.5	Raspberry	Drip tape	90%	90%	20	0	0	0
10.5	Strawberry	Drip tape	88%	90%	26	0.7	0.6	144
6	Organic Strawberry	Drip tape	88%	88%	26	0	0	0
62	Strawberry	Drip tape	87%	90%	26	1	5.1	1287
50	Strawberry	Drip tape	84%	90%	26	2.1	8.6	2149
40	Strawberry	Drip tape	83%	85%	26	0.7	2.5	614
20	Red Beets	Sprinklers	80%	80%	18	0	0	0
15	Apple	Micro-Sprinkler	80%	85%	8	0.6	0.7	184
23	Organic Strawberry	Drip tape	77%	90%	26	4.9	9.3	2337
100	Organic Romaine	Sprinklers	76%	80%	12	0.8	6.6	1645
9	Organic Blackberry	Drip hose	75%	90%	20	4.4	3.3	833
35	Ornamentals	Drip tape	75%	85%	26	4.1	11.9	2974
13.6	Organic Strawberry	Drip tape	75%	85%	26	4.1	4.6	1156
34	Organic Blackberry	Drip hose	74%	90%	20	4.8	13.6	3403
40	Strawberry	Drip tape	73%	85%	26	5	16.8	4190
12	Organic Wine Grapes	Drip hose PC	72%	90%	8	2.2	2.2	556
20	Potted ornamentals	Sprinklers	68%	80%	35	7.7	12.9	3217
6.3	Organic Strawberry	Drip tape	67%	80%	26	6.3	3.3	828
45	Strawberry	Drip tape	66%	85%	26	8.8	33	8255
10	Organic Strawberry	Drip tape	57%	80%	26	13.1	10.9	2732
50	Raspberry & Blackberry	Drip tape/ hose	38%	90%	23	35	2.9	729
Total acres =700.2			Average DU = 77.68%	Avg TargetDU = 87%			Tot Savings =149 AcFt	

Table 4 summarizes the potential savings estimated for each ranch based on the measured DU, the target DU considered achievable for the ranch conditions, and the estimated average seasonal evapotranspiration of the crop. Potential savings in terms of volumes of water in Acre-feet (Ac-ft)/season were calculated for each ranch assuming that the grower would implement recommendations across their whole ranch, improving the DU from the observed to the target value. Monetary savings were

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also calculated based on PVWMA augmentation fees and average pumping costs. In some cases, the potential cash savings exceed the costs of the equipment needed to improve the DU, which would also result in indirect revenue for the farming operation due to less nitrogen leaching, increased yields, and regulatory relief. However, the total estimated potential savings for all farms evaluated was 149 Ac-ft per season, which is a relatively modest savings, compared to PVWMA's basin-wide conservation target of 5000 Ac-ft by 2035.

In some systems evaluated, the measured application rate deviated substantially from the design application rate (Table 5), with the measured application rate ranging from 63% higher, to 32% lower than the designed application rate. This deviation was observed regardless of the measured DU and was common even in fields with very high distribution uniformity. This occurred usually because the operating pressure was higher or lower than recommended by the drip tape manufacturer. Knowledge of the actual application rate is crucial to correctly schedule irrigation events. For example the first ranch in Table 5, although presenting a DU of 96%, would be under-irrigating by 15%, whereas the third ranch, with a DU of 91% would be under-irrigating by 19%. These results suggest that even very efficient system can be hindered by improper management.

Table 5: The design application rate and the measured application rate for the irrigation systems evaluated.

Crop	Irrigation Method	Distribution Uniformity	Design Application Rate	Measured App Rate	Difference
			in/hr	in/hr	%
Strawberry	Drip tape	96%	0.222	0.19	-14%
Herbs	Drip tape	92%	0.359	0.29	-19%
Organic Strawberry	Drip tape	91%	0.193	0.23	19%
Apple	Drip hose PC	90%	0.025	0.027	6%
Raspberry	Drip tape	90%	0.076	0.08	6%
Strawberry	Drip tape	88%	0.298	0.35	18%
Organic Strawberry	Drip tape	88%	0.303	0.31	2%
Strawberry	Drip tape	87%	0.222	0.18	-19%
Strawberry	Drip tape	84%	0.222	0.15	-32%
Strawberry	Drip tape	83%	0.151	0.174	15%
Red Beets	Drip tape	80%	0.287	0.31	8%
Apple	Drip tape	80%	0.069	0.094	37%
Organic Strawberry	Drip tape	77%	0.193	0.21	9%

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Organic Romaine	Drip tape	76%	0.239	0.23	-4%
Organic Blackberry	Drip tape	75%	0.106	0.09	-15%
Ornamentals	Drip tape	75%	0.176	0.21	19%
Organic Strawberry	Drip tape	75%	0.303	0.27	-11%
Organic Blackberry	Drip tape	74%	0.212	0.16	-24%
Strawberry	Drip tape	73%	0.222	0.28	26%
Organic Wine Grapes	Drip tape	72%	0.048	0.044	-10%
Potted ornamentals	Drip tape	68%	0.509	0.83	63%
Organic Strawberry	Drip tape	67%	0.289	0.2	-31%
Strawberry	Drip tape	66%	0.151	0.22	46%
Organic Strawberry	Drip tape	57%	0.289	0.23	-20%
Raspberry & Blackberry	Drip tape	38%	0.063	0.08	28%

A negative correlation was found between the slope of the ranch and the DU measured for drip systems and a positive correlation for sprinkler systems (Figure 2). The linear regressions were not statistically significant when the data was grouped by method (Drip and Sprinkler in Table 5), due to the significant scatter in DU for ranches without significant slope. When only drip system at ranches with appreciable slope (higher than 1.5%) was considered, the linear regression was significant (Table 6 & Figure 3). This correlation appears to be caused by the high variability of pressure caused by differences in elevation and highlights the importance of pressure regulators and adequate row orientation on sloped fields.

Table 6: Linear regression analysis of the relationship between distribution uniformity and ranch slope.

Irrigation Method	Number of Evaluations (n)	Range in DU	Range in Ranch Slope	Regression Slope	P-value
Drip	21	38% to 96%	0.5% to 15%	-0.99	0.178
Sprinkler	4	68% to 80%	0.5% to 10%	0.88	0.225
Drip with ranch slope >1.5%	10	57% to 92%	1.7% to 15%	-2.2	0.00184**

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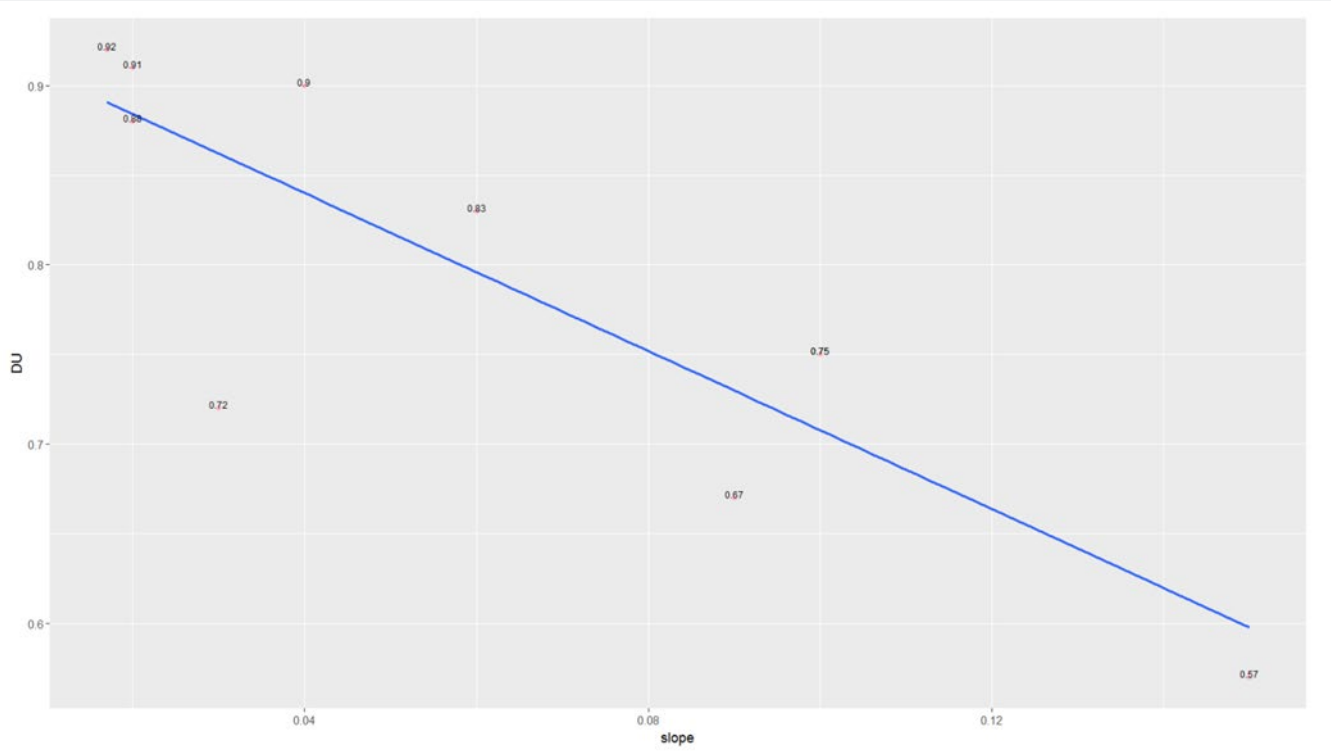

Figure 2: Linear regressions between the measured distribution uniformity (DU) and the ranch slope for drip (pink) and sprinkler systems (blue). Symbol colors differentiates between drip in conventional production, drip in organic production and sprinklers.

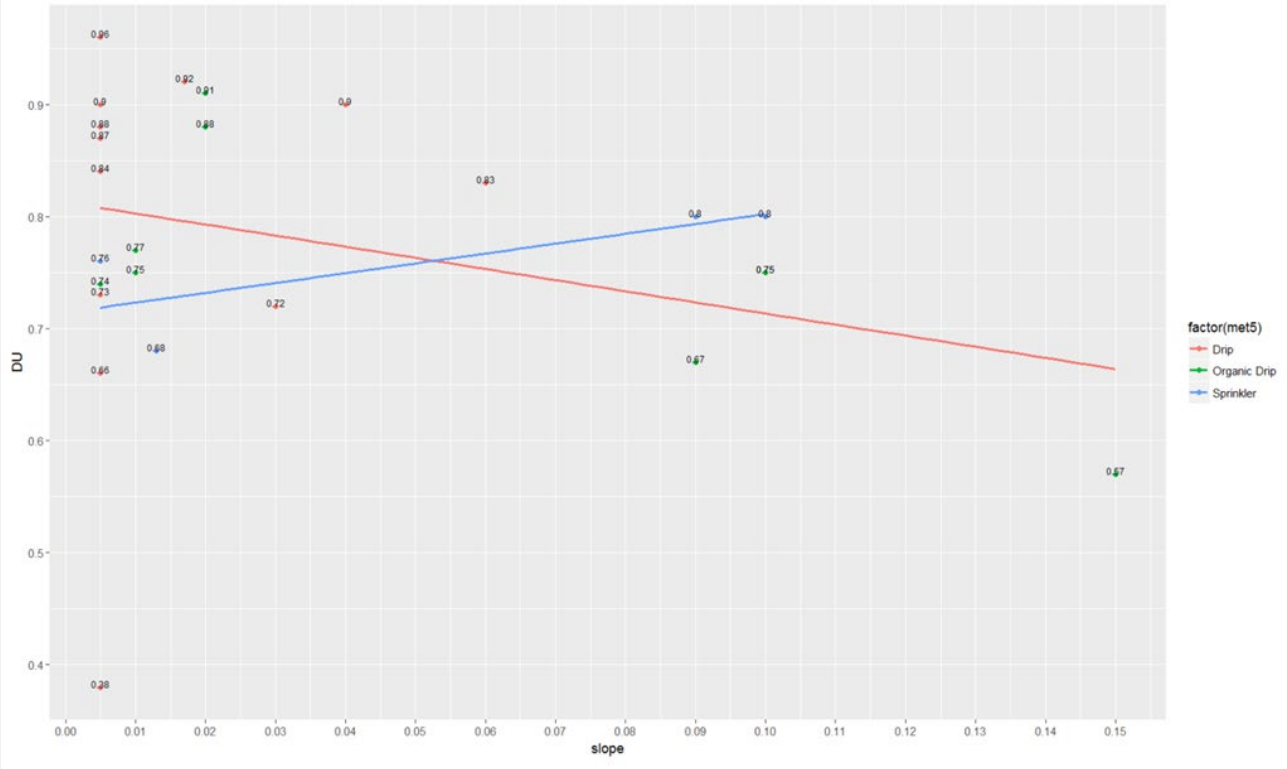

Figure 3: Linear regressions between the measured distribution uniformity (DU) and the ranch slope for drip systems with significant ranch slope (>1.5%).

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