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 | 3.0         | 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%                    |
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, caneberrries, 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 size 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 handheld 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...
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.
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                 |
| 2.8        | Herbs          | Drip tape         | 92%                     | 92%       | 24      | 0                 |
| 8          | Organic        | Drip tape         | 91%                     | 91%       | 26      | 0                 |
| 6.5        | Apple          | Drip hose PC      | 90%                     | 90%       | 8       | 0                 |
| 47.5       | Raspberry      | Drip tape         | 90%                     | 90%       | 20      | 0                 |
| 10.5       | Strawberry     | Drip tape         | 88%                     | 90%       | 26      | 0.7               |
| 6          | Organic        | Drip tape         | 88%                     | 88%       | 26      | 0                 |
| 62         | Strawberry     | Drip tape         | 87%                     | 90%       | 26      | 1.1               |
| 50         | Strawberry     | Drip tape         | 84%                     | 90%       | 26      | 2.1               |
| 40         | Strawberry     | Drip tape         | 83%                     | 85%       | 26      | 0.7               |
| 20         | Red Beets      | Sprinklers        | 80%                     | 80%       | 18      | 0                 |
| 15         | Apple          | Micro-Sprinkler   | 80%                     | 85%       | 8       | 0.6               |
| 23         | Organic        | Drip tape         | 77%                     | 90%       | 26      | 4.9               |
| 100        | Organic        | Sprinklers        | 76%                     | 80%       | 12      | 0.8               |
| 9          | Organic        | Drip hose         | 75%                     | 90%       | 20      | 4.4               |
| 35         | Ornamentals    | Drip tape         | 75%                     | 85%       | 26      | 4.1               |
| 13.6       | Organic        | Drip tape         | 75%                     | 85%       | 26      | 4.1               |
| 34         | Organic        | Drip hose         | 74%                     | 90%       | 20      | 4.8               |
| 40         | Strawberry     | Drip tape         | 73%                     | 85%       | 26      | 5.1               |
| 12         | Organic        | Drip hose PC      | 72%                     | 90%       | 8       | 2.2               |
| 20         | Potted ornaments | Sprinklers       | 68%                     | 80%       | 35      | 7.7               |
| 6.3        | Organic        | Drip tape         | 67%                     | 80%       | 26      | 6.3               |
| 45         | Strawberry     | Drip tape         | 66%                     | 85%       | 26      | 8.8               |
| 10         | Organic        | Drip tape         | 57%                     | 80%       | 26      | 13.1              |
| 50         | Raspberry &    | Drip tape/        | 38%                     | 90%       | 23      | 3.5               |
|            | Blackberry     | hose              |                          |           |         |                   |
| Total acres|                |                   |                          |           |         |                   |
| =700.2     |                |                   |                          |           |         |                   |

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
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.
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.
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%).
