Project Title: Evaluation of equipment to improve water and nitrogen management in lettuce

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Abstract

Lettuce growers will need to implement best management practices that lessen water quality impairments on the Central Coast to comply with Agricultural Discharge Order 4.0. The implementation of the Sustainable Groundwater Management Act (SGMA) also will require that growers use water as efficiency as possible to produce leafy green vegetables. The State Water Efficiency and Enhancement Program (SWEEP) offers approximately $50 million per year in grants to growers to improve their irrigation systems and can finance equipment that improves the efficiency of irrigation systems. Previous research has shown that drip irrigation systems in leafy greens could be better optimized through improved pressure regulation and careful monitoring of applied water using flowmeters. Additionally liquid fertilizers could be accurately applied to crops if irrigators could precisely measure the volume of fertilizer injected into the drip systems. This project tested commercially available flowmeters, pressure reducing valves, and pressure sensors for accuracy, ease-of-use, and suitability for commercial vegetable growing operations. The main objective was to identify equipment that can assist growers in achieving better water and nutrient management of lettuce.

Immediate Objectives:

The main objective is to identify commercially available flowmeters, pressure regulators and pressure sensors that are best suited for irrigation and nutrient management of leafy greens.

Objective 1. Evaluate the accuracy and suitability of several models of flowmeters that can be used for irrigation scheduling and for metering liquid fertilizer. **Deliverable:** Identification of flowmeters best suited for measuring irrigation water and fertilizer volume for leafy green production.

Objective 2. Evaluate the reliability, accuracy, and ease-of-use of several models of pressure regulators suitable for drip irrigated lettuce. **Deliverable:** Identify pressure regulators that may be easier and more reliable than equipment currently used for leafy green vegetable production.

Objective 3. Extend results to the leafy green industry. **Deliverables:** 1 to 2 oral presentations at grower meetings, 1 newsletter/blog article

Procedures (objectives 1 and 2):

Objective 1. *Evaluate the accuracy and suitability of several models of flowmeters that can be used for irrigation scheduling and for metering liquid fertilizer.*

Fertilizer flowmeters: Three models of flowmeters were identified and tested for accurate metering of fertilizer: 1 Banjo MFM100 meter, Dura-meter, and Blue White F-1000 fertilizer meter (Fig. 1). Each meter measured flow by a different mechanism. The Banjo meter measured flow using a magnetic sensor, while the Dura-meter uses a nutating disk, and the Blue white meter uses a small propeller. The accuracy of the flowmeters was tested using 25 gallons of either water, ammonium nitrate (20% N), or urea-ammonium nitrate (32% N). A testing manifold was set up in the UCCE Monterey greenhouse that pumped a calibrated volume of each fluid through the flowmeters using an electric diaphragm pump. At least 5 test runs were made for each meter and fluid. The average volume measured and standard deviation from the mean volume was calculated.

Irrigation flowmeters: The accuracy and reliability of several models of flowmeters suitable for measuring the volume of water applied to fields during irrigation events was also evaluated. The models evaluated are the Seametric AG3000, Netafim Octave, Seametric AG90, and Bermad M10. These flowmeter models were selected because they are available in 4 to 6 inch diameters, have no moving parts that would disrupt the flow of water, have digital registers, and pulse outputs which allows them to be interfaced with dataloggers. Additionally, all these models require a minimal length of straight pipe before and after the meter (2 to 5 pipe diameters). The AG3000, AG90, and M10 use magnetic sensors to measure flow rate. The Octave uses ultrasound to monitor flow. The accuracy of the meters is evaluated by assembling each flowmeter model in series along a 6-inch diameter main line separated by at least 3 feet of straight pipe. Several thousand gallons of water is pumped through the main line and flow rate and total flow volume for each meter is recorded. Since the large volume of water pumped through the meters cannot be physically measured, values recorded from each meter are compared relative to each other. The evaluation process is repeated at least 5 times so that the average and standard deviation of the total volumes can be calculated for each meter model.

Objective 2. *Evaluate the reliability, accuracy, and ease-of-use of several models of pressure regulators suitable for drip irrigated lettuce.*

Two models of pressure regulating valves (Nelson 800 series, Netafim 90 series) that were potentially simple for irrigators to operate and maintain were evaluated in drip systems in commercial lettuce fields. The valves were tested sequentially on the same commercial drip system and provide a comparison of accuracy, response time, and ease-of-use. Data on flow rate and pressure was recorded as well as the need for readjustment of the regulator. Additionally, a simple survey was administered to irrigators in Spanish to understand the reluctance to use pressure regulators to maintain a consistent pressure in the drip systems. At several field sites we installed pressure regulators and trained the irrigators to operate them. The uniformity of drip systems and water use was evaluated with and without pressure regulation.

At the end of the season we organized a discussion with the irrigators to evaluate their opinion on using pressure regulators and to identify potential problems in implementing this practice in medium to large scale vegetable production operation.

Results and Discussion

Flowmeter evaluation

All three models of flowmeters tested accurately measured water and fertilizer volumes (Table 1). Accuracy errors were generally less than 2%. The Dura-meter which uses a nutating disk to measure volume was the most accurate flowmeter of the 3 models and had an overall average absolute error of -0.2 gallons per 25 gallons measured, and a coefficient of variation of ±0.3%. The Blue White meter, which uses a paddle wheel to measure volume, was least accurate and had an overall absolute error of 1 gallon per 25 gallons measured and a coefficient of variation of ±1.3%. The accuracy of the Dura-meter was least affected by the type of liquid monitored of the three meters tested.

Testing the accuracy of flowmeters for monitoring the volume of water applied during irrigations as described in the procedures section is still ongoing, and so final results are not presented in this report. An updated report and/or a newsletter article will be provided at a later date that summarizes the accuracy of the Seametric AG3000and AG90, Netafim Octave, and Bermad M10 meters. Bench testing of the two-inch diameter Bermad M10 meter demonstrated a 98% accuracy in measuring 25 gallons of flow. A four-inch diameter version of the same meter will be evaluated on a mainline with the other three flowmeter models. Factory testing of all these flowmeter models suggest that the error rate is less than ±2%. Testing of the AG3000 and AG90 at flow rates ranging from 300 to 850 gpm showed that the difference between readings was less than 2%. Previous use of the AG3000 has shown that it is a very accurate meter if air bubbles do not get trapped in the meter or the electrodes that sense flow do not become corroded or covered in sediment. The AG3000 and AG90 are easily programmed to provide readings in a variety of units and to output a voltage pulse that can be monitored using a datalogger. The Octave cannot be programmed but has a digital register that is easily read and can also output a voltage pulse that can be recorded using a datalogger. The Bermad flowmeter is also programable through a phone app and has a voltage pulse output so that it can be interfaced with dataloggers.

Evaluation of a pressure sensor

Monitoring of pressure of drip systems is critical for optimizing application uniformity. While mechanical pressure gauges can be used by irrigators to measure pressure, electronic sensors can potentially provide continuous monitoring of pressure and could be used to alert operators when the pressure of a drip system is too high or low. The Dwyer transducer (628-10-GH-P1-E1-S1), which has an operating range of 0 to 100 psi, requires 12 Volts for powering the sensor and outputs a voltage that increases with greater pressure. The accuracy of two Dwyer pressure transducers was evaluated by comparing the voltage output with readings of a calibrated pressure gauge. Results shown in Fig. 2 show that the two sensors have very similar voltage outputs with change in pressure and that the response is linear. Regression analysis fit was a linear response with an R^2 value of nearly 1. Because of the reliability of this sensor it was used for continuous monitoring of pressure in irrigation systems in subsequent evaluations of the pressure regulating valves.

<u>Pressure reducing valve evaluation</u>

The main objective in the testing of pressure reducing valves (PRVs) was to maintain the submain of a drip system between 8 and 10 psi with minimal adjustments during an entire irrigation set. The Netafim 90 uses bonnets with a rubber diaphragm that can expand and contract to adjust flow through the valve thereby maintaining a desired downstream pressure. The Nelson 800 series uses a flexible sleeve that expands and contracts around an internal cage to regulate flow to achieve a desired downstream pressure. Initial testing of a 4-inch diameter Netafim 90 and Nelson 1000 pressure reducing valves (PRV) resulted in poor regulation of pressure in a drip system installed in a 7.5-acre vegetable field due to the flow rate (350 gpm) exceeding the maximum capacity of both valves. Six-inch diameter versions of the Netafim and Nelson valves were subsequently trialed. The 6-inch diameter Netafim 90 PRV was found to have a slow response to fluctuations in upstream pressure, which often caused drip tape laterals to either detach from the submain or burst. Additionally, the Netafim 90 required several adjustments to the pilot valve to maintain a consistent pressure during an irrigation. The Nelson 800 PRV was found to provide consistent regulation of pressure during an irrigation, and rapidly respond to changes in upstream pressure. The Nelson regulator only occasionally needed adjustment at the beginning of an irrigation. Figure 3 shows the upstream and the downstream pressure of a 6-inch diameter Nelson 800 PRV. Average downstream pressure was maintained at 10 psi despite fluctuations in upstream pressure ranging from 30 to 50 psi. Distribution uniformity evaluated in two 10-acre drip irrigated fields with pressure regulating valves ranged from 92 to 93% (data not presented).

<u>Filtration trailer for optimizing application uniformity and scheduling of drip systems</u>

To improve drip application uniformity and scheduling of irrigations, a small trailer was designed and tested with equipment to provide filtration, pressure regulation of the irrigation water, and allow monitoring of the flow rate and the pressure of the drip system (Fig. 4). The flowmeter (Seametric AG3000) and pressure sensors (Dwyer 628) were interfaced with a datalogger (Campbell Sci CR300) that included a cell phone modem to allow data to be automatically transferred to CropManage irrigation and nutrient management decision support web application (Fig. 4). The operator can view how much water was applied for each irrigation event and also receive a recommendation for the amount to apply using the CropManage application. The CropManage tool also allows the operator to review the upstream and downstream pressures during an irrigation. The operator can monitor flow rate and system pressure in real time using the loggerlink smart phone app. Initial testing of the trailer demonstrated that it can greatly improve pressure regulation of the drip system. Variation in application rate of the drip system was reduce from 33% without pressure regulation to 6% with pressure regulation using the trailer (Fig. 5). The cooperating grower built nine more similar trailers based on this prototype with funding from a CDFA sweep grant. All ten trailers were operated during the 2023 season and generally functioned as designed. The main problem encountered was that the irrigators often did not provide sufficient upstream pressure for the pressure reducing valve to regulate the pressure properly due to not fully opening the submain valve or because they were irrigating too many blocks at the same time. Further training of the irrigators will be needed to take full advantage of the trailers.

Extension of results

Results of this project were extended through 5 presentations, including the Fall and Spring Annual Leafy green research board meetings (October 2022, and March 2023), Organic farming seminar series (January 2023), 2023 UCCE Monterey Irrigation and Nutrient Management Meeting (February 2023), and the Plant and Soil Conference held in Fresno CA (February 2023).

Conclusions

This project identified and tested an assortment of equipment that can assist growers with improving the management of irrigation water and fertilizer in drip systems. Several models of flowmeters were shown to accurately measure liquid fertilizer volume, of which the Dura-meter was found to be most accurate. The Nelson 800 series pressure reducing valve was found to be ideal for regulating pressure of drip systems installed in 5 to 10-acre lettuce fields. The valve reacted quickly to changes in upstream pressure and was simple to adjust. The Dwyer pressure transducer was found to be very precise and very useful for monitoring the pressure in drip systems. Finally, outfitting small trailers with the pressure reducing valve, flowmeter, pressure transducers, and screen filter, was a convenient way to move this equipment between fields and the addition of a datalogger allowed operators to monitor the performance of the drip system in real-time.

Table 1. Accuracy of flowmeter measurements of water and two types of liquid fertilizer (AN20 and UAN32).

Flowmeter type	Reps.	Volume measured	Error	Coefficient of variation
		gallons	--------- % ---------	
	-------------------- Water -----------------			
Banjo FM100 (Magmeter)	7	24.9	-0.5	0.67
Dura Meter (Nutating Disk)	5	25.0	0.1	0.15
Blue White F-1000 (paddle)	8	25.1	0.2	0.43
	------------------ UAN32 ------------------			
Banjo FM100 (Magmeter)	5	24.6	-1.4	0.62
Dura Meter (Nutating Disk)	5	25.0	-0.1	0.14
Blue White F-1000 (paddle)	6	25.5	2.1	1.81
	------------------- AN20 -------------------			
Banjo FM100 (Magmeter)	6	24.7	-1.1	0.42
Dura Meter (Nutating Disk)	5	24.9	-0.5	0.15
Blue White F-1000 (paddle)	5	25.3	1.0	0.22
	---------------- Overall ----------------			
Banjo FM100 (Magmeter)	18	24.8	-0.9	0.69
Dura Meter (Nutating Disk)	15	25.0	-0.2	0.31
Blue White F-1000 (paddle)	19	25.3	1.0	1.29

Figure 1. Three models of flowmeters that use different mechanisms for measuring flow were evaluated for accuracy in measuring the volume of fertilizer pumped from a tank.

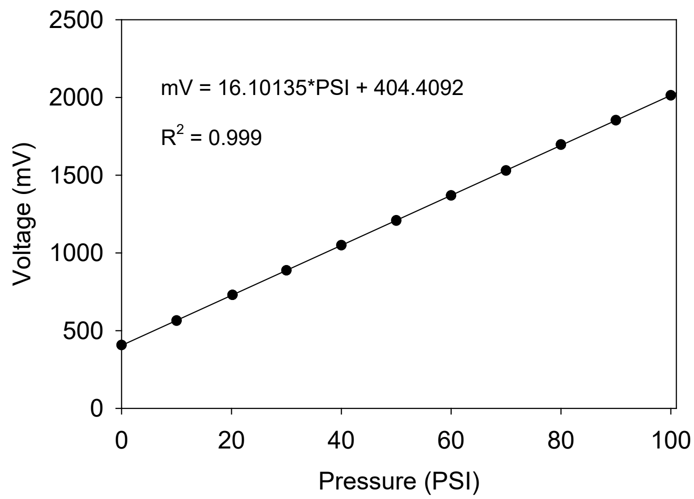

Figure 2. Voltage output response of Dwyer pressure transducers.

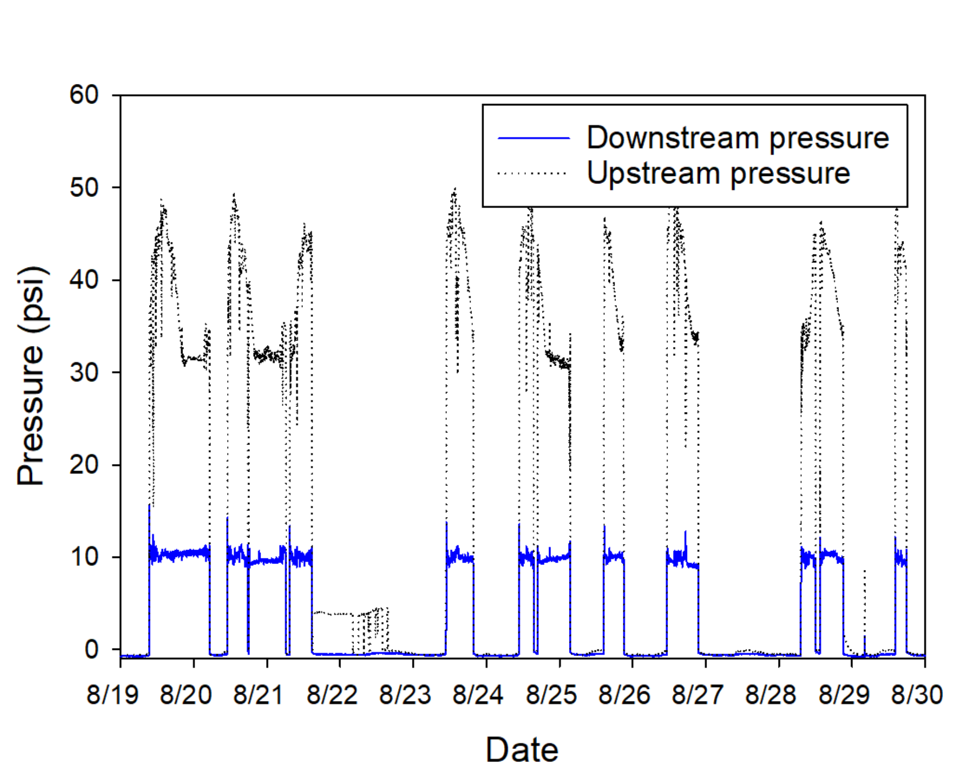

Figure 3. Pressure measured upstream and downstream of the Nelson 800 pressure reducing valve used in drip irrigated lettuce field. Average downstream pressure was maintained at 10 psi despite fluctuations in upstream pressure ranging from 30 to 50 psi.

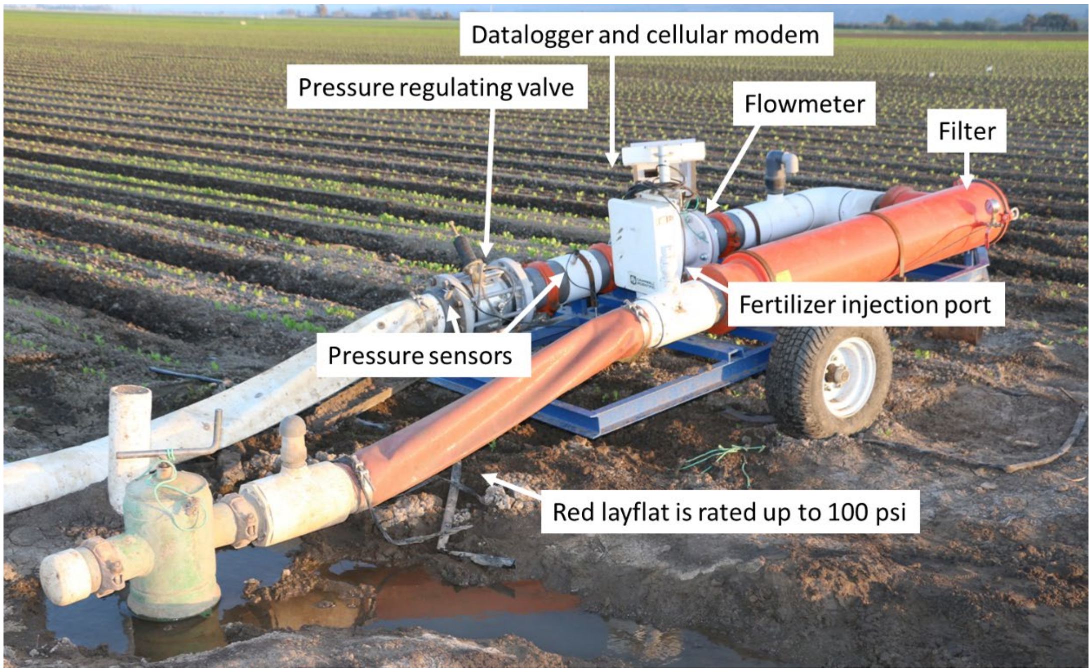

Figure 4. Filtration trailer for drip irrigation system equipped with a pressure reducing (regulating) valve, pressure sensors, flowmeter, datalogger with cell phone modem, and a screen filter.

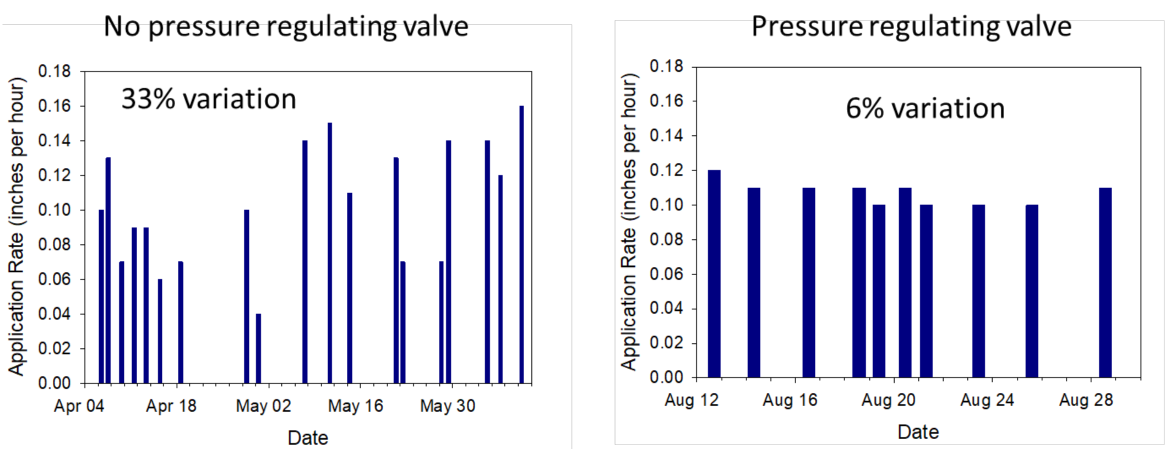

Figure. 5. Average application rate of irrigations in lettuce fields without pressure regulation (left) and with pressure regulation (right) using the filter trailer described in Fig. 4.