

IMPROVING IRRIGATION EFFICIENCIES IN PEARS CASE STUDIES



Hot summers and cork spot in d'Anjou pear can be a significant challenge in central Washington. Cork spot is responsible for an estimated \$7 to \$8 million dollars in losses to d'Anjou production every year. For example, in 2017 cork spot accounted for approximately one-third of d'Anjou culls at three major packinghouses. Irrigation frequency and timing as well as good calcium programs can affect tree growth, productivity, and fruit quality in pears. Fruit size is also critical for high returns. The following case studies illustrate common irrigation system challenges in Washington pear orchards and the results of system upgrades designed to address site specific challenges. These case studies are designed to provide growers with potential solutions to common irrigation challenges in order to improve fruit quality and profitability.

Orchard A Case Study

Site Challenges

- Runoff.
- Small fruit.
- Inability to conduct tractor work when sloping field stays wet.
- Lack of uniformity and variable, weak trees.

Standard System

The system design was impact sprinklers (Rainbird) on a 36 foot by 36 foot spacing (Figure 1; Table 1). Managers generally run one row at a time, skipping a row as they go across the field, and return to irrigate alternate rows, taking nine days to irrigate the five-acre field.

Upgrade

R10 microsprinklers were installed in every row on an 18 by 18 ft spacing in a five-acre field on one-half of the sloped field in spring 2018. The design was chosen to limit runoff and increase application uniformity. With a low application rate and a higher number of sprinklers per acre the soil can more readily absorb the water applied, reducing runoff. Reduced application rate

allows for a larger number of lines to be run simultaneously such that the field can be watered in a shorter period of time.

Table 1. Orchard A standard: system description.

Sprinklers per acre	GPM ^a	GPH per acre	Efficiency	Inches per hour
34	4.0	8,067	0.5	0.15

^a Per sprinkler head.

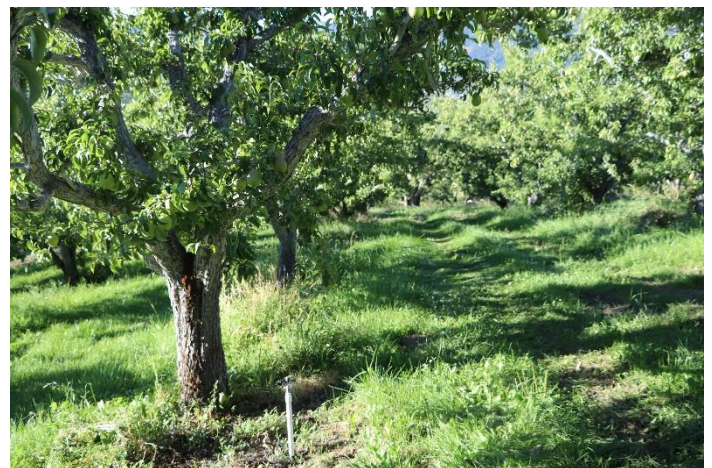


Figure 1. The standard system created runoff in order to maintain sufficient moisture at the top of the slope.



Grower Observations

“Zero runoff in the new system.”

“Leaf color was more uniform.”

“Before, the quickest we could water was nine days. Now if we want to we can water the whole block in two days (20 lines at a time), allowing for more flexibility.”

“If we need to push water it is a lot easier.”

“Good to have less water more often.”

Impact on Water Use

Water use was reduced from 400 to 700 gallons per acre (Table 2).

Table 2. Per acre water use.^a

Year	Standard		Upgrade		Savings gal
	hr	gal	hr	gal	
2018	144	1,161,600	216	749,232	412,368
2019 ^b	156	1,258,400	156	541,112	717,288
2020 ^c	180	1,452,000	252	874,104	577,896

^a Application timing and set length per grower.

^b 15 weeks.

^c 18 weeks.

Impact on Soil Moisture

In the standard system it was difficult to maintain adequate soil moisture at the top of the hill while the bottom of the hill tends to be oversaturated. This is because of runoff, low-pressure draining of water when the system is turned off, and often differences in the water tables from the top to the bottom of the orchard. The system upgrade allowed the managers to maintain soil moisture in the optimum zone, between 70% and 100% of field capacity (Figure 2).

Impact on Tree Stress

Tree water status is measured by using a pressure chamber to measure stem water potential. Water within the plants moves through a network of cells (xylem) that act like pipes carrying water from the roots. When the soil dries and the roots cannot keep pace with evaporation from the leaves, the water in the plant becomes under tension. Tension under -1.2 MPa is considered too high for pear trees indicating water limitation.

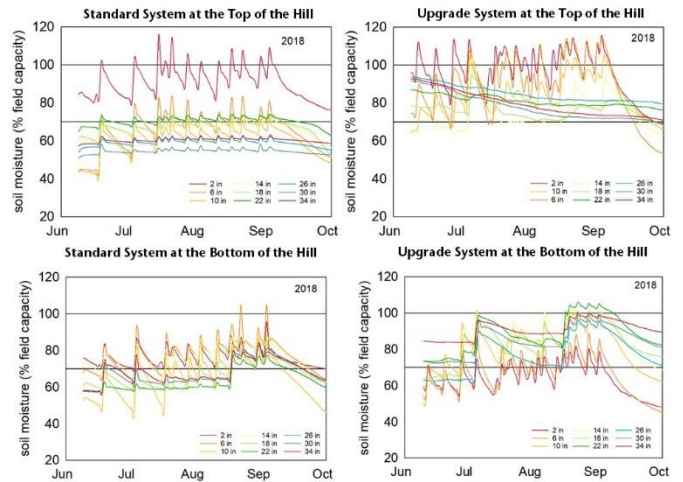


Figure 2. Soil moisture during the 2018 growing season at Orchard A from June to October illustrated as percent of field capacity.

A pressure chamber was used to measure water tension from nine trees in July 2018 and six in August 2019 and 2020 along the top of the hill in the block near solar noon. Measured leaves were bagged with silver reflective bags for at least one hour to equalize leaf and xylem water potential before measurements were taken.

Tree water limitation measured by stem water potential was lower in the upgraded block varying from -0.79 to -1.13 MPa compared to -0.81 to -1.7 MPa in the standard block at the top of the hill in July 2018; from -1.12 to -0.6 MPa in the upgrade compared to -1.25 to -0.84 MPa in the standard in August 2019; and from -1.36 to -0.51 MPa in the upgrade and -1.96 to -0.8 MPa in the upgrade on in August 2020 (Figure 3). Of note is the grower ran the upgraded system the same number of hours in 2019 as the standard system and there was less stress in the upgraded system. Additionally, soil moisture information from the sensors influenced grower watering decisions in the standard block, likely helping to reduce tree stress in the standard system in 2019 and 2020 (Figure 4).

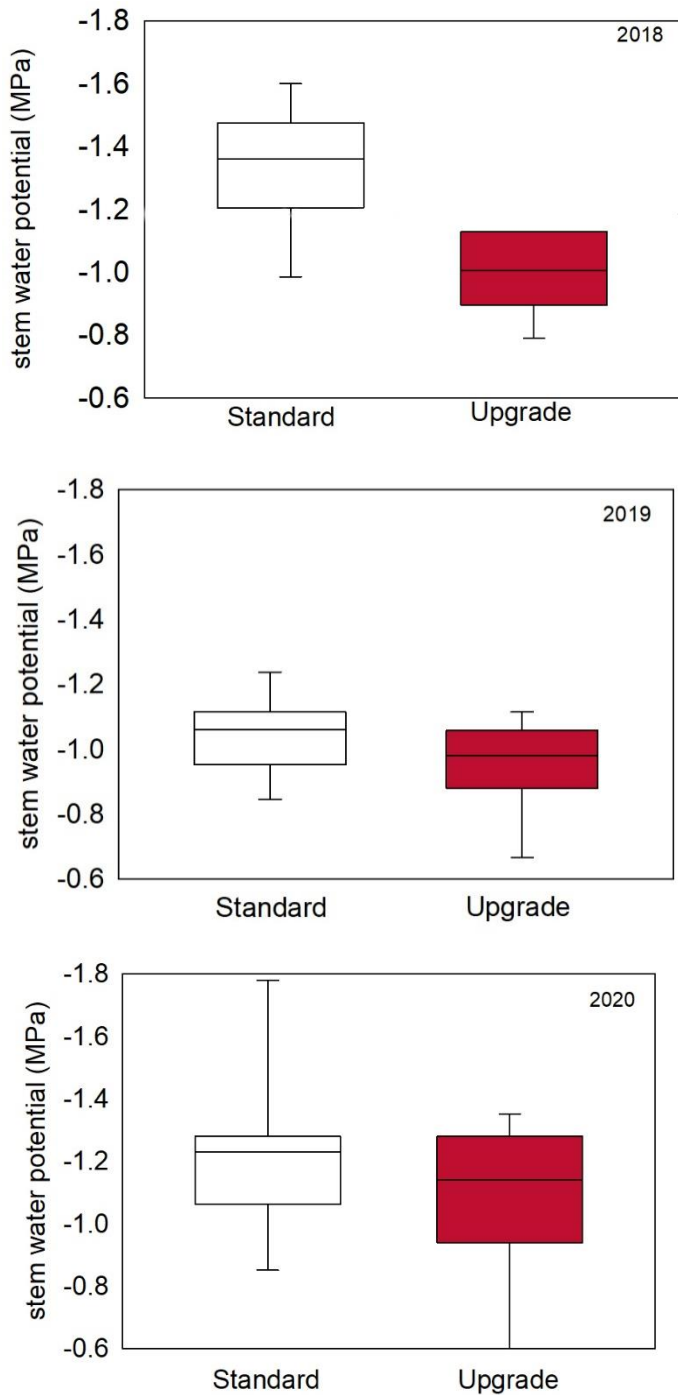


Figure 3. Tree water stress measured by stem water potential for 2018 (top), 2019 (middle), and 2020 (bottom).

Impact on Fruit Quality and Yields

Impacts of treatments on fruit were measured from 20 fruit harvested from eight trees in 2018 and six trees in 2019 in a grid

pattern across the top and bottom of plots. Fruit were stored for 12 weeks and then evaluated for size and quality.

Fruit size was more uniform in the upgraded block compared to the block irrigated using the standard system. In the standard block fruit weight measured the week of harvest was generally smaller at the top of the hill compared to at the bottom of the hill. In the upgraded block fruit size was uniform between the top and bottom of the hill with size similar to the top of the hill in the standard block (Figure 5). At the top of the hill the fruit size distribution in the upgraded block tended toward larger fruit than in the standard block (Figure 6).

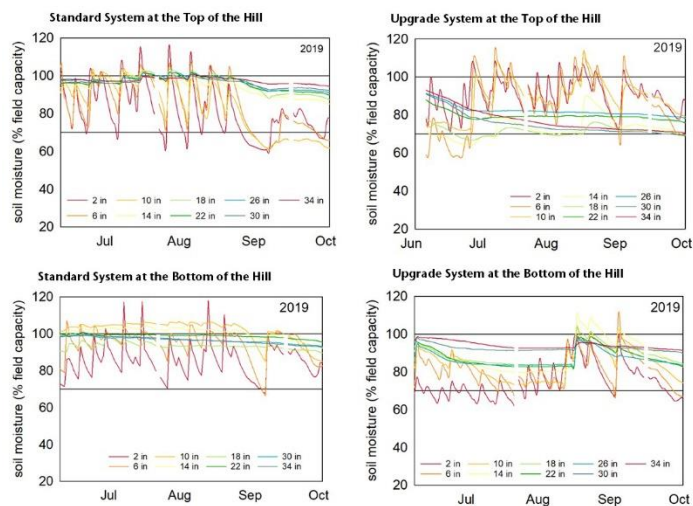


Figure 4. Soil moisture during the 2019 growing season at Orchard A from June to October, illustrated as percent of field capacity.

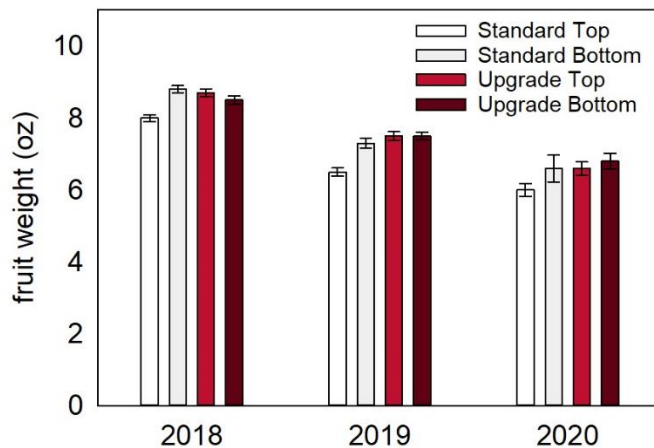


Figure 5. Fruit weight at harvest.

Fruit quality was also compared based on commercial packing of 56 bins run in each of the side by side blocks. The percentage of fruit packed varied a small amount between blocks and primarily due to factors unrelated to irrigation (e.g., cuts and limb rub).

In 2018 the pack-out for the upgraded block was 95.6% compared to 92.7% for the standard system resulting in 23 versus 22 packs per bin. Of the fruit in the upgrade, 1.5% was

rated a cull due to small fruit or cork and 2.0% in the standard system. Of the upgrade and standard, 2.9% and 5.3% were culled due to stem puncture, scuffing, and decay, respectively. In 2019 the pack-out for the upgraded block was 92.1% compared to 93.7% in the standard block. Of the fruit rated as cull due to small size or cork, 1.9% in the upgrade and 1.7% in the standard. In 2020 the pack-out for the upgraded block was 91.9%, and 91.0% in the standard. Of the fruit in the upgraded block, 0% was downgraded for cork or small size, and 1.0% of the fruit in the standard block was downgraded.

Returns were calculated for each irrigation system using average prices compiled by the Pear Marketing Association (Focht 2021) for each size class for the 2018/19 to 2020/21 crop years and fruit measurements from field collections at the top and bottom of the hill in standard and upgrade blocks. An average packing charge of \$13.50 per box was assumed and using a standardized yield of 56 bin per acre and a bin weight of 1,100 lb. Estimated revenues were improved by \$1,309 per acre in the upgraded portion of the block primarily due to larger fruit size (size class 60 to 100) at the top of the hill (Table 3).

It is important to note that revenue differences were not consistent based on commercial pack-outs. This appears to be due to differences in frost marking and stem punctures likely unrelated to irrigation systems.

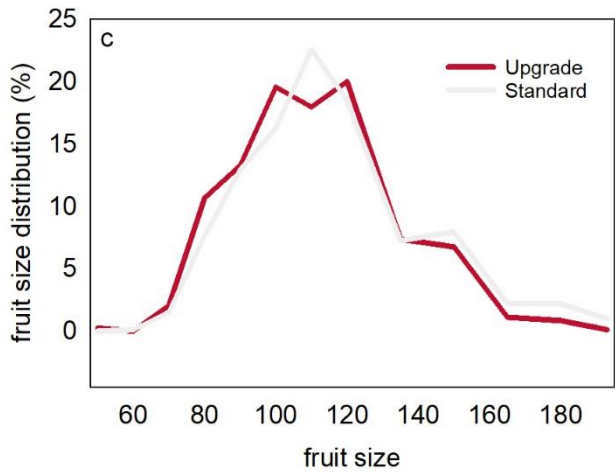
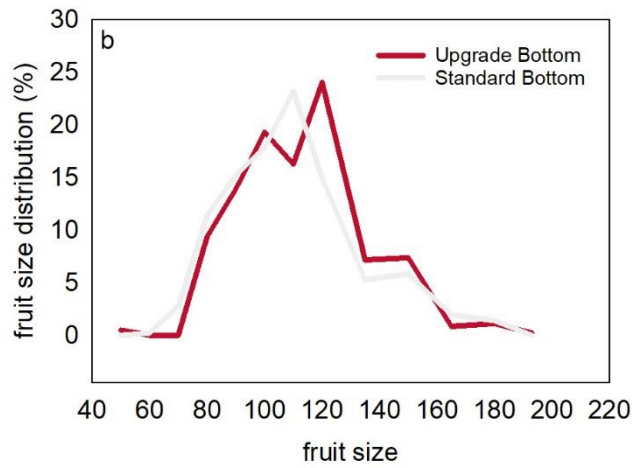
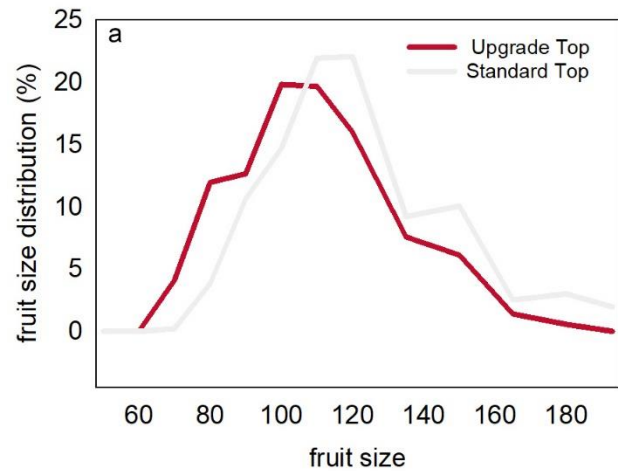


Figure 6. Fruit size distribution top of the hill (a), bottom of the hill (b), and average (c) for 2018 to 2020 crop years.

Table 3. Effect of irrigation upgrade on revenue estimates.

		50	60	70	80	90	100	110	120	135	150	165	180	193			
Fruit size distribution (%) ^a																	
Upgrade	Bottom	0.5	0.0	0.0	9.4	13.9	19.3	16.3	24.0	7.2	7.4	0.8	1.1	0.2			
Upgrade	Top	0.0	0.0	4.1	11.9	12.6	19.8	19.7	16.0	7.6	6.1	1.4	0.6	0.0			
Standard	Bottom	0.0	0.2	2.8	11.4	15.2	17.8	23.2	14.9	5.3	5.8	1.9	1.4	0.0			
Standard	Top	0.0	0.0	0.2	3.8	10.6	14.7	21.9	22.0	9.2	10.1	2.5	3.0	2.0			
Yield per size class (lb per acre) ^b																	
Upgrade	Bottom	299	0	0	5775	8556	11892	10010	14801	4406	4534	513	684	128			
Upgrade	Top	0	0	2524	7358	7786	12192	12106	9839	4663	3764	856	342	0			
Standard	Bottom	0	128	1711	7016	9368	10994	14288	9197	3251	3593	1198	856	0			
Standard	Top	0	0	128	2353	6549	9035	13498	13574	5674	6194	1546	1845	1204			
Average pricing d'Anjou 3 year average 2018/19 to 2020/21 crop years ^c																	
FOB US1		23.89	26.55	26.95	26.35	26.78	24.02	22.70	21.23	19.18	18.55	17.33					
Box Charge		13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.50					
Revenue		10.39	13.05	13.45	12.85	13.28	10.52	9.20	7.73	5.68	5.05	3.83					
Revenue per acre (\$)														Total	Change per acre	Change 10 acres	
Upgrade	Bottom	71	0	0	1686	2582	2842	2093	2601	568	520	45	0	0	\$13,010		
Upgrade	Top	0	0	771	2148	2350	2914	2531	1729	602	432	75	0	0	\$13,552		
Standard	Bottom	0	38	523	2048	2827	2628	2987	1617	419	412	104	0	0	\$13,605	-\$595	-\$5,950
Standard	Top	0	0	39	687	1977	2159	2822	2386	732	711	135	0	0	\$11,648	\$1,904	\$19,042
															\$1,309	\$13,093	

^a Size estimates from fruit hand harvested the week before commercial harvest.

^b Using a standardized yield of 56 bin/acre and a bin weight of 1,100 lb.

^c Average pricing information source Pear Marketing Association, Brian Focht. FOB = free on board, wholesale price per box paid to warehouse.

Orchard B Case Study

Site Challenges

- Cork.
- Insufficient change in elevation between the irrigation canal and the block resulting in extremely low pressure at the top of the block.
- Multiple types of irrigation sprinkler heads used in the block created uneven water distribution.

Standard System

The five acre block was located on a moderate slope with 76 sprinklers per acre (Figure 7; Table 4). Multiple types of irrigation sprinkler heads were used in the block (Figure 8). Due to lack of pressure at the top of the hill and variation in sprinkler heads used throughout the block, trees received insufficient and uneven irrigation (Table 5), likely resulting in increased cork spot.



Figure 7. Orchard B.



Figure 8. Multiple types of sprinkler nozzles were used in the standard block.

System Upgrade

In order to increase pressure to sufficient levels and provide even outputs across the block a small booster pump was installed at the canal, and R10 microsprinklers with flow regulators were installed in the upgrade portions of the block (Figures 9 and 10). Resulting pressure and flow changes increased irrigation output (Table 6).

Table 4. Standard system description.

	Sprinklers per acre	GPM ^a	GPH per acre	Efficiency	Inches per hr
Standard	76	50	3,025	0.6	0.07

^a Per sprinkler head.

Table 5. Standard system sprinkler pressure and flow.

	Top	Middle	Bottom	Average	Variation
psi	9	16	20	15	150%
GPM	0.5	0.7	0.8	0.7	60%



Figure 9. Irrigation upgrades included microsprinklers with flow regulators.



Figure 10. Flexible flow washers in flow control nozzles reduce the orifice opening and size and emit a constant flow over a wide range of pressure.

Table 6. Upgrade system description.

	Sprinklers per acre	GPM ^a	GPH per acre	Efficiency	Inches per hr
Upgrade	75	75	4,500	0.75	0.12

^a Per sprinkler head.

Impact on Soil Moisture

The system upgrade at Orchard B was designed to improve the distribution of water. The standard system provided insufficient water at the top of the hill due to insufficient pressure to run the sprinklers installed, and distribution was uneven due to multiple types of sprinkler heads across the field. A booster pump increased pressure and flow at the top of the hill in the upgraded system. Installation of standardized sprinkler heads made water distribution uniform across upgraded sections of the block. System upgrades were completed June 19, 2020. The soil moisture sensors at the top of the hill were originally installed in areas blocked to irrigation by the trees and was moved on July 17. Due to nonrepresentative early readings soil moisture interpretation is difficult (Figure 11). During the critical fruit sizing period in August, soil moisture at the top of the hill appeared to be higher in the upgraded system.

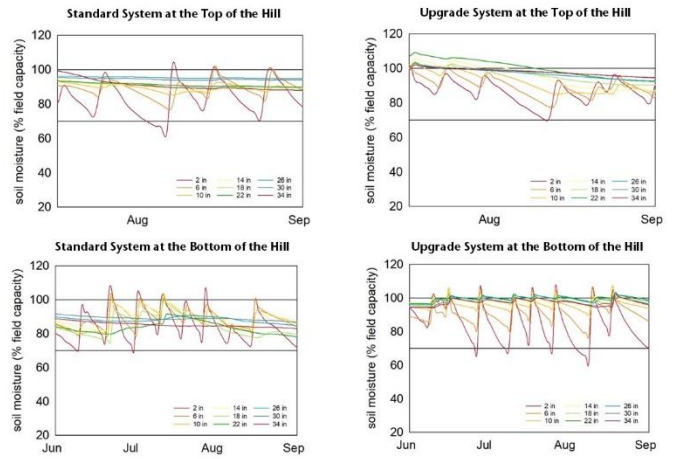


Figure 11. Soil moisture during the 2020 growing season.

Impacts on Tree Stress

Stem water potential measurements were made during a hot period at the end of August 2020 from six trees per plot in the upper and lower sections of the block that were either upgraded or were equal to the standard system.

Water limitation measured by stem water potential was lower and less variable in the areas of the orchard with an upgraded system (-1.25 MPa to -0.35) compared to the standard system (-1.96 to -0.68 MPa) measured in August 2020 (Figure 12). Narrow distribution of stem water potential and thus water limitation is important for uniformity in the block.

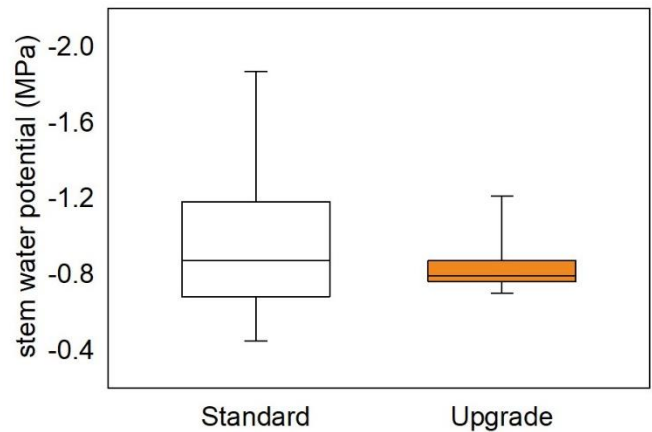


Figure 12. Tree water limitation measured by stem water potential.

Impacts on Fruit Quality and Size

Fruit size was measured in the field in late August 2020 before harvest from six representative trees in the upper and lower elevations of each treatment.

Fruit size was slightly larger in the upgraded section of the block than the standard section of the block (average 5.7 versus 5.6 oz). However, the upgraded sections of the block trees had smaller fruit in the upper elevation of the block than in the lower section (Figure 13). This may be due to problems with irrigation sensors early in the season which led to inaccurate readings and thus nonideal irrigation sets at a critical timing.

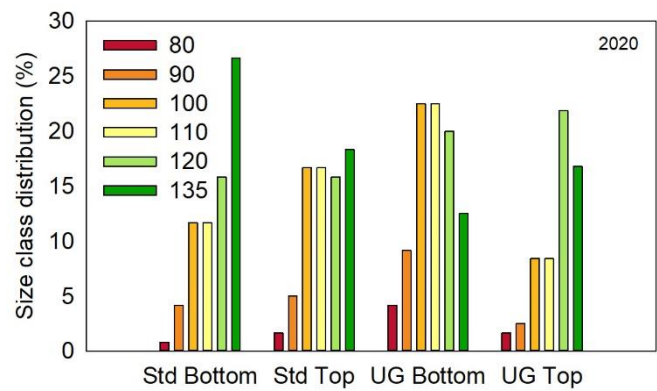


Figure 13. Percentage of fruit in different box size classifications for the standard system at the lower and upper elevations of the field (left) and in the upgraded block at the lower and upper elevations of the field.

Orchard C Case Study

Site Challenges

- Severe cork (Figure 14).
- Did not pick block in 2017 due to 80% cork (Figure 15).

Standard System

In the standard system impact sprinklers (Rainbird and R2000) were on a 24 foot by 20 foot spacing (Figure 16). Grower's standard irrigation was 12 to 24 hr sets weekly (Table 7).



Figure 14. Cork is a challenge at Orchard C.



Figure 15. Project site at Orchard C, Cashmere, WA.

Table 7. System description per acre.

Sprinklers per acre	GPM ^a	GPH per acre	Efficiency	Inches per hr
91	1.08	5,881	0.8	0.17

^a Per sprinkler head.

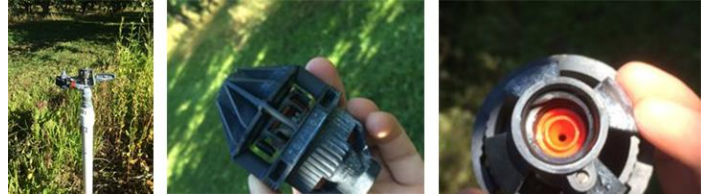


Figure 16. Rainbird sprinklers (left) and R2000 sprinklers (center and right).

Upgrade

Sentek soil moisture sensors were installed in April 2019 (Figure 17). Irrigation in 2019 in the upgrade block was done according to soil moisture needs rather than a standard schedule.



Figure 17. Telemetry for soil moisture probe installed in upgrade block.

Impact on Water Use

Table 8. Per acre water use.

Year	Standard		Upgrade		Savings gal
	hr	gal	hr	gal	
2019	120	705,672	108	635,105	70,567

Impact on Soil Moisture

Using outputs from the irrigation sensors the grower was able to maintain soil moisture between the full and refill points in the area of the block designated as experimental. In comparison the grower standard of irrigating weekly using 12 or 24 hr sets kept soil overly moist with moisture above the full point (field capacity) (Figure 18).

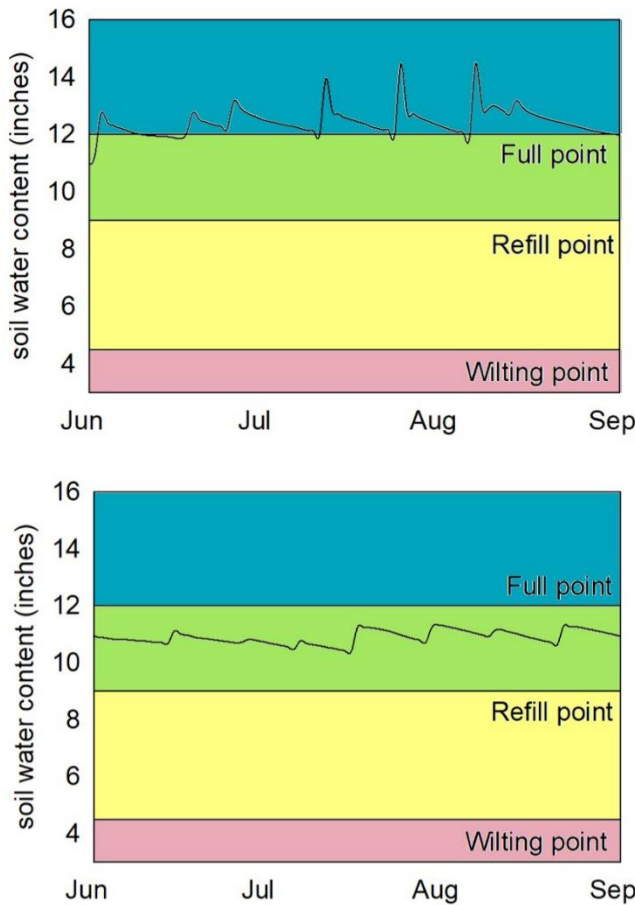


Figure 18. Soil moisture stayed above the full point (field capacity) for most of the season in the standard irrigated block (top graph). In comparison where the grower irrigated according to soil moisture sensors moisture levels maintained between refill and full (bottom graph).

Impact on Fruit Quality

Fruit quality was measured from commercial pack-out of east and west sections with standard or sensor-based irrigation. In the section of the field where irrigation sensors were used to determine watering frequency the amount of cork was reduced resulting in higher pack-outs (79% versus 70%) and 3,660 lb fewer culls due to cork (Figure 19).

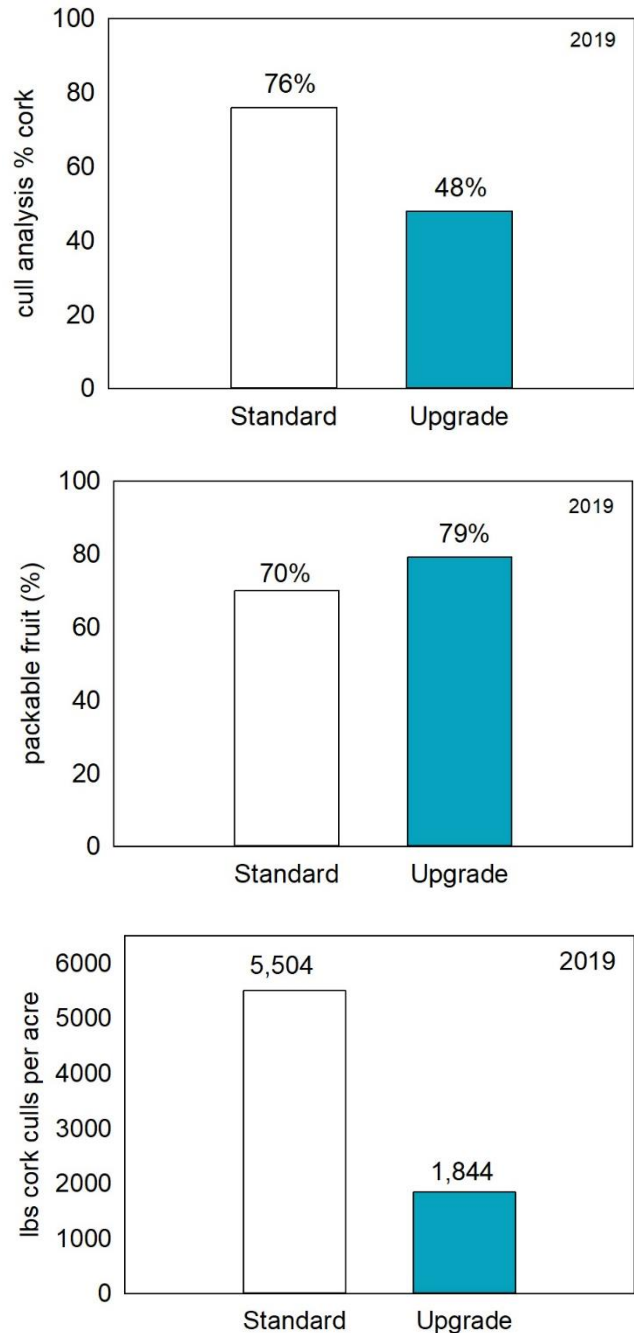


Figure 19. Fruit quality information from commercial pack-out.

Orchard D Case Study

Site Challenges

- Cork.
- Pack-out was 29% in 2017 with 52% cork.

Standard System

The standard system was impact sprinklers with 50 sprinklers per acre at block P and 39 sprinklers per acre at block W (Figures 20–22).

Upgrade

Three acres were switched from old impact sprinkler (Rainbirds) to similar volume sprinklers (Nelson R2000) with uniform output and new nozzles (block P). Soil moisture sensors were installed in April 2019 (Figure 23). Irrigation in both blocks was done with fewer 24 hr sets starting in 2018. The grower waited longer between sets and reduced 24 hr sets based on sensors starting in 2019.

Real-Time Soil Moisture Information

The irrigation sensor provided soil moisture information updated hourly. The interface shows soil moisture levels relative to field capacity and maximum allowable depletion levels input by the user (Figures 23 and 24). Levels are displayed as an average and for 8-, 12-, and 24-inch depths. See *Using Soil Moisture Sensors in Pears* (DuPont et al. 2021) for more sensor information.



Figure 21. Rainbird sprinklers (pictured) and R2000 sprinklers were standard at this site.



Figure 22. R2000 sprinkler.



Figure 20. Orchard D block, Cashmere, WA.

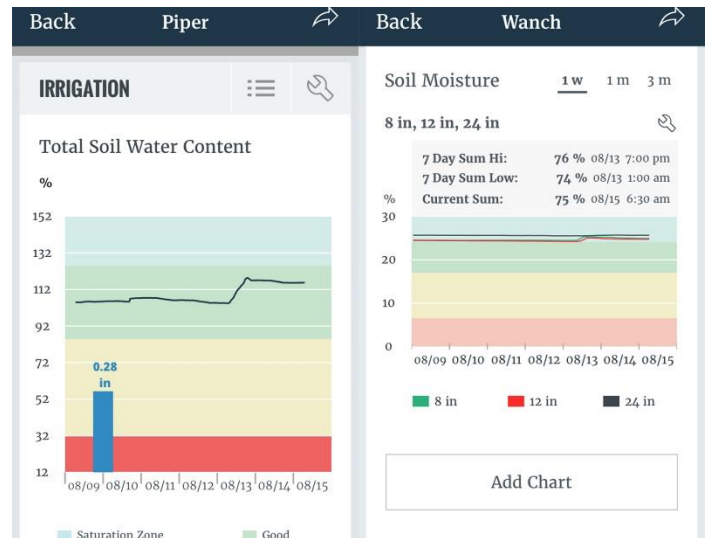


Figure 23. Irrigation application soil moisture information. The black line indicates current water status. Where the green shaded area meets the yellow shaded area is considered the refill point. The red shaded area indicates the wilting point. When the black line is in the blue area the soil is oversaturated.



Figure 24. Irrigation sensor telemetry.

Soil Moisture

Moving to fewer 24 hr sets and using soil moisture information kept soil moisture between the refill and full points in both blocks in 2019 and 2020 (Figure 25).

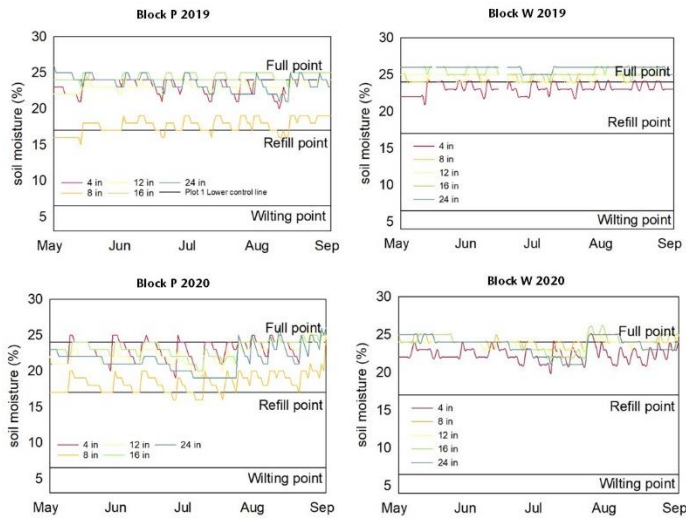


Figure 25. Soil moisture from 4 to 24 inches.

Table 9. Water use per acre.

Year	Block W		Block P	
	hr	gal	hr	gal
2019 ^a	72	343,821	60	336,600
2020 ^b	167	796,519	178	999,141

^a 2019: May 13 to Aug 19 (15 weeks).

^b 2020: May 4 to Aug 31 (18 weeks).

Water Use

In 2019, 72 hr of irrigation was applied during the 15-week irrigation season (Table 9). If 24 hr sets had been used approximately 144 hr would have been applied. A standard set length of 12 versus 24 hr reduced water use by an average of

343,821 gallons per acre over the course of the season (Table 10).

Table 10. Water savings of moving to a 12 versus 24 hr set.

24 hr set		12 hr set		Savings
hr	gal	hr	gal	gal
144	687,642	72	343,821	343,821

Impact on Tree Stress

While soil moisture as measured by the irrigation sensors was generally between the full and refill points, tree stress as measured by stem water potential was high in block P in 2019 and in both blocks W and P in 2020 at the date of July measurements (Figure 26).

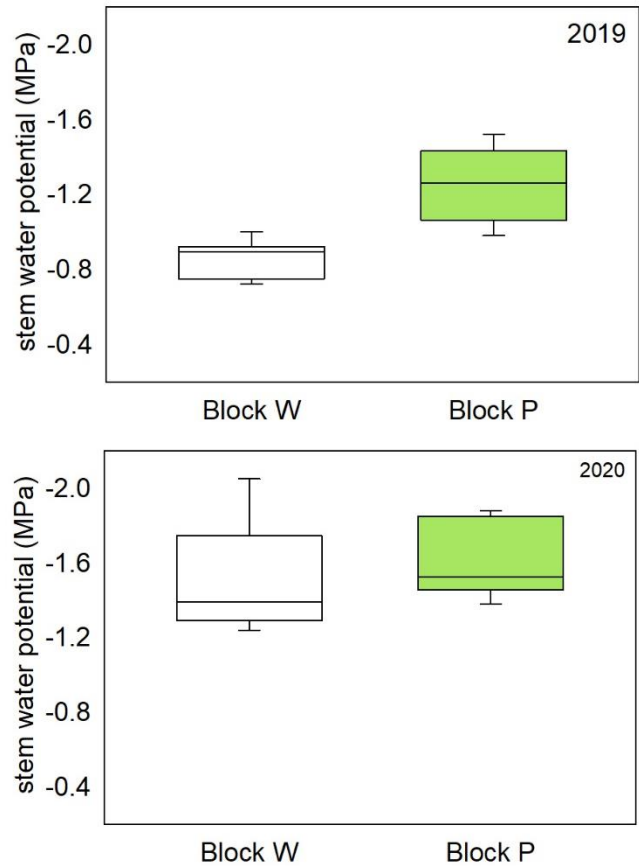


Figure 26. Tree water stress measured by stem water potential for 2019 (top) and 2020 (bottom).

Impact on Fruit Quality

Fruit quality was measured from commercial pack-outs from orchard blocks before and after irrigation changes were made. After the irrigation change was made in 2018 downgrades from

cork dropped on average. In 2017 before irrigation changes were made the pack-out was 61% and 73% for blocks W and P, respectively, with 29% and 52% cork. This resulted in 4,250 and 5,240 lb per acre of culls due to cork for blocks W and P, respectively (at 40 bins per acre). After the grower moved from a standard of 24 hr sets to 12 hr sets and used irrigation sensor information to lengthen the time between sets, culls per acre from cork in d'Anjou pears dropped to an average of 1,575 and 1,312 lb per acre of culls due to cork for blocks W and P, respectively (at 40 bins per acre) (Figure 27). A reduction in culls due to cork translates to increased returns. Assuming \$20

per 44 lb box and 40 bins per acre, revenue lost to cork culls was \$1,932 and \$2,382 per acre for blocks W and P, respectively, in 2017. After the move to 12 hr sets and changing length between sets, lost revenue to culls averaged \$716 and \$596 per acre for blocks W and P, respectively, between 2018 and 2020 (Figure 28). It is important to note that weather and other year-to-year differences could also have influenced cork, pack-out, and revenue changes. Additionally, the orchardist took over management of the block in 2017 and more aggressive pruning and other horticultural practices likely impacted the fruit quality over time.

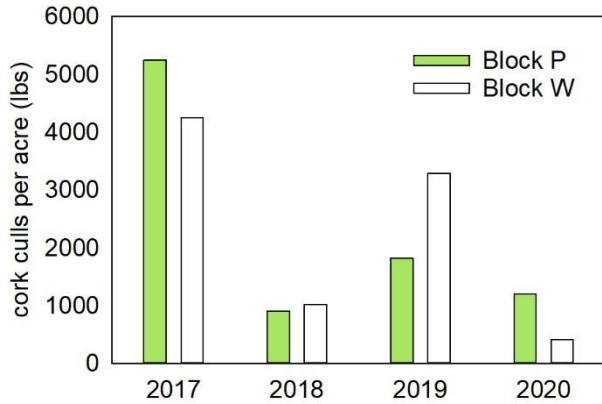


Figure 27. Effect of irrigation change on cullage from cork in blocks P and W when 24 hr sets were used (2017) versus 12 hr sets (2018 to 2020) when soil moisture sensor information was used. Cork culls per acre estimated based on commercial packing reports for each block assuming a standardized 40 bin per acre yield.

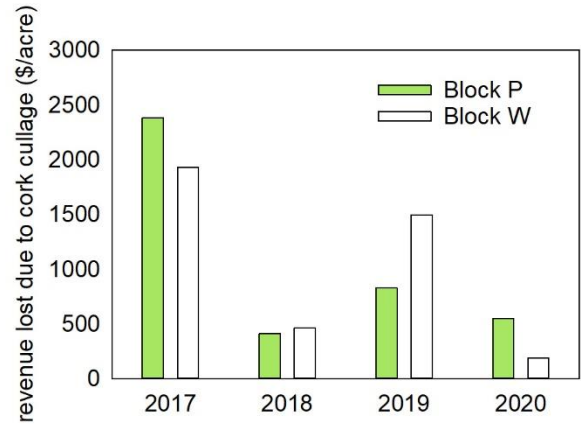


Figure 28. Revenue lost to cork cullage in 2017 when 24 hr sets were employed and 2018 to 2020 when 12 hr sets for two commercial blocks P and W where soil moisture sensor information was used assuming 40 bins per acre and \$20 per 44 lb box.

Orchard E Case Study

Site Challenges

- Reduced pressure and water application from blocked irrigation filters.

Site Description

The site has a standard filter out of the irrigation canal (Figure 29) and a standard Sontag filter before the block (Figure 30). Brush filters that can be cleaned without opening are also used on the farm in other blocks (Figure 31).

Measurements

A pressure gauge with a data logger was installed on the filter at the beginning of the growing season in order to track potential drops in pressure when filters clog (Figure 32). Pounds per square inch of pressure was measured every 15 minutes continuously from May 23 to August 15, 2019. In June the irrigation system was often turned off, especially at night, due to the wet spring, which meant watering was not always necessary. Water pressure dropped overnight occasionally during the peak irrigation season of July (Figure 33). For example, on July 19 pressure dropped to 42 psi at 6 a.m., presumably before the filter was cleaned at 7 a.m., and pressure returned to 62 psi. However, it is unclear whether pressure drops were significant enough to produce substantially reduced irrigation outputs.



Figure 30. Sontag filter.



Figure 31. Brush filter can be cleaned by turning handle and opening valve.



Figure 29. Grower cleaning irrigation canal filter.

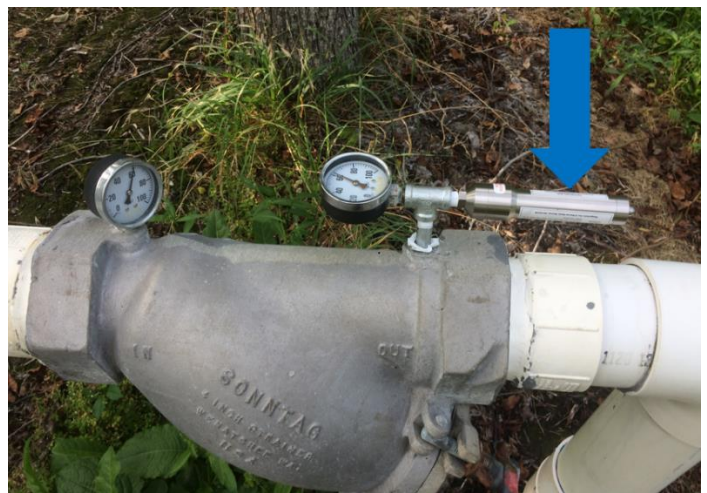


Figure 32. Pressure gauge data logger indicated by blue arrow was installed to track water pressure.

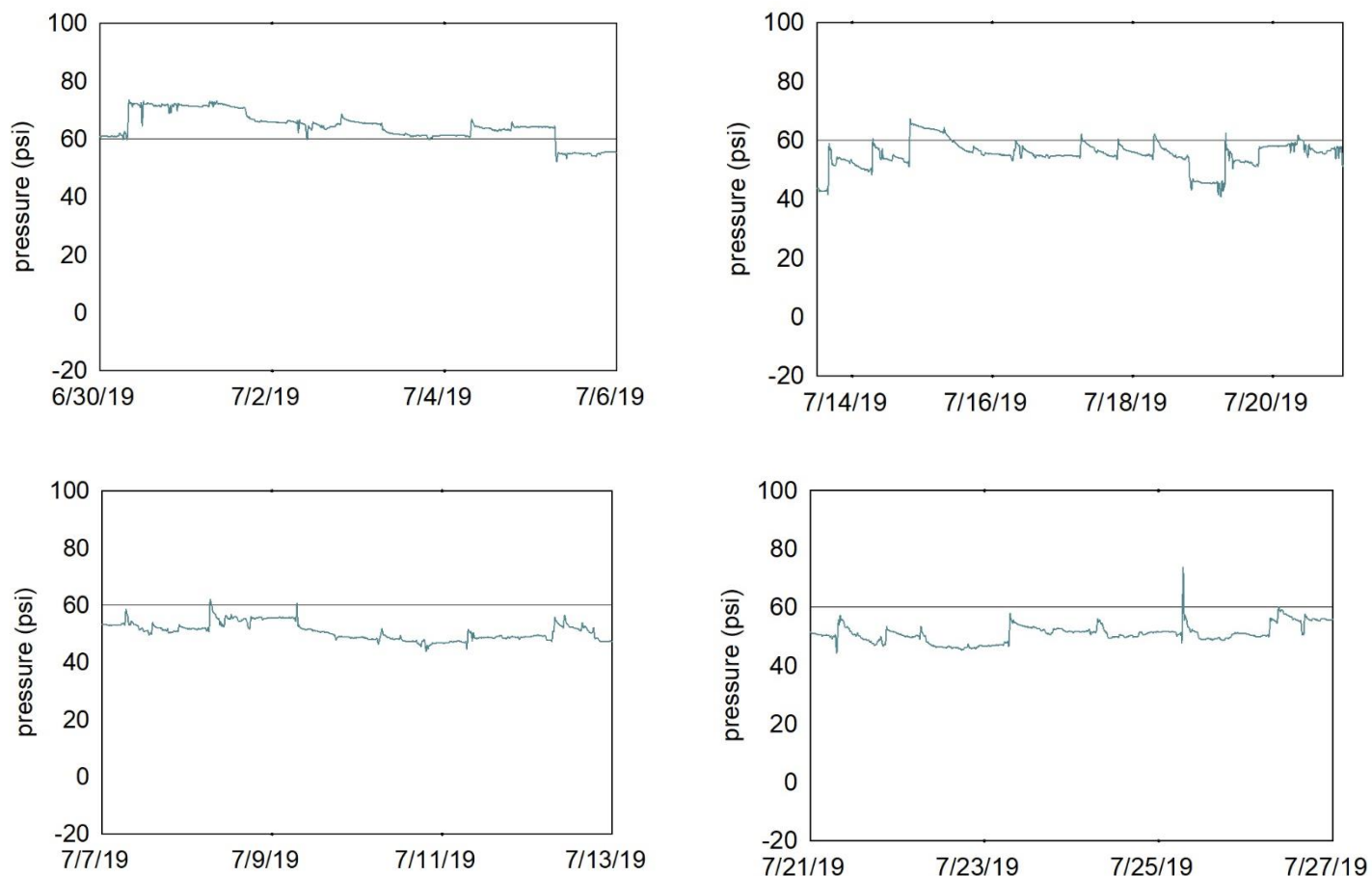


Figure 33. Filter pressure measured in pounds per square inch (psi) for the month of July.

Conclusions

Water resources in central Washington are limited. Recently, hotter summers have put increasing stress on fruit trees, impacting fruit size and quality. This stress has been particularly important in pear orchards where declining yields and pack-outs threaten profitability. Increased water use efficiency is critical to maintain a strong, profitable farming community without putting additional pressure on water resources. Washington pear orchards have a number of major common challenges: uneven pressure and distribution due to hills; irregular water distribution across the block due to old, malfunctioning equipment; sandy soils with low water holding capacity; heavy soils with limited drainage; insufficient or excess watering due to inability to time water applications; and system inefficiencies. System renovations are critical to match irrigation schedules to tree water needs. These case studies illustrate the importance of orchardists evaluating their irrigation systems (see resource *Evaluating Your Pear Irrigation System* [DuPont et al. 2022]) and implementing appropriate upgrades. Irrigation upgrades can increase fruit quality and profitability as well as result in water use efficiencies.

Acknowledgments

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Additional Resources

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