Remote Valve Control System and Precision Irrigation Scheme for Multi-Variety Almond Orchards

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Abstract

Since most almond varieties are self-incompatible, farmers typically plant almond orchards in rows alternating between two or three different varieties for effective cross-pollination. The phenological schedules differ among the varieties, resulting in contrasting water needs at the same time. This complexity of almond orchards presents a unique application of remote valve control systems for implementing precision irrigation schemes based on variety-specific phenological schedules. We applied a remote valve control system to schedule various regulated deficit irrigation (RDI) treatments during the hull-split period in three varieties according to variety-specific phenological schedules. We coupled the remote valve control system with a software program to extract daily crop evapotranspiration observations from the California Irrigation Management Information System (CIMIS) to produce an irrigation scheduling program for multi-variety almond orchards. Commercial remote valve control systems in conjunction with in-line pressure and soil moisture sensors can be integrated with existing drip irrigation systems for a closed-feedback control system to implement precision irrigation schemes. The precision irrigation system demonstrated in this study can optimize irrigation management resulting in enhanced water productivity.

Introduction

- The Nonpareil variety is highly valued for its soft thin outer shell, smooth attractive kernel, and consistently high yields.
- Farmers often gear irrigation management of multi-variety almond orchards toward the phenological schedule of the Nonpareil variety.
- As almonds approach maturity in mid-summer, hull-split occurs, as shown in Figure 1.
- The hull-split period offers potential water savings through moderate RDI without significantly reducing yield or quality.
- Different varieties in the same orchard undergo hull-split at different times, RDI should be independently scheduled in each variety.
- Remote valve control systems improve the convenience of scheduling irrigation and can be integrated with existing microirrigation systems.
- Remote valve control systems in conjunction with drip irrigation systems also offer the opportunity to conveniently continue irrigating after the almonds have been harvested and are left on the ground to naturally dry for about a week before pickup (Figure 2).

Figure 1: Hull-split in almonds begins in July or August for most varieties in California.

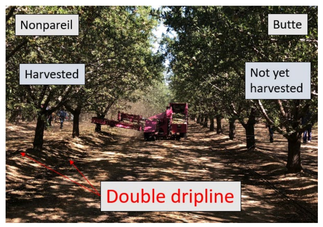

Figure 2: Almonds are shaken, windrowed, and left to naturally dry on the ground for several days before pick-up.

2019 Dates	Nonpareil	Aldrich	Butte
1% hull-split initiation	July 9	July 27	August 7
Harvest date	August 22	September 11	September 11
Pickup date	September 4	September 25	September 25

Objectives

1. Establish an automated precision irrigation system capable of remotely irrigating almond trees by variety.
2. Evaluate regulated deficit irrigation in Nonpareil, Butte, and Aldrich in the period from hull-split initiation to harvest and quantify effects on total yield, nut quality, water applied, and water productivity.

Methodology

- We used a battery-powered remotely controlled irrigation system to implement two RDI treatments, 50% ETc and 75% ETc, from hull-split initiation until harvest in Butte, Aldrich, and Nonpareil trees in two different schedules.
- Schedule (1) involved irrigating all varieties according to Nonpareil hull-split initiation and harvest dates to simulate an orchard in which irrigation management decisions are driven by Nonpareil growth stages.
- Schedule (2) involved irrigating according to variety-specific hull-split initiation and harvest dates to simulate an orchard with the ability to irrigate by variety.
- The ETc was calculated using the single crop coefficient method using the reference evapotranspiration from the Williams CIMIS station and crop coefficients for mature almonds.
- We replicated each combination of RDI and irrigation schedule five times in a split block experimental design, as shown in Figure 4.
- We collected stem water potential measurements using a pressure chamber and soil water content using a neutron probe twice a week in each of the 60 experimental units to gather feedback on the irrigation treatments.
- We used a Generalized Linear Mixed model at 95% confidence level to analyze differences in yield and quality parameters using the Proc Glimmix procedure in SAS.

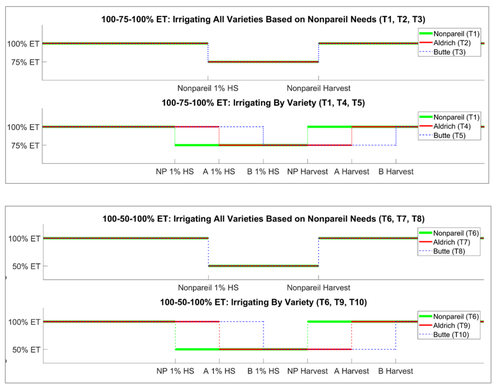

Figure 3: Schematic of irrigation treatments where ET stands for evapotranspiration, HS stands for hull-split, A stands for Aldrich, B stands for Butte, and NP stands for Nonpareil.

Figure 4: A diagram of the experimental design where the 5-acre orchard is split into 60 subplots that can be independently irrigating using a remote valve control system.

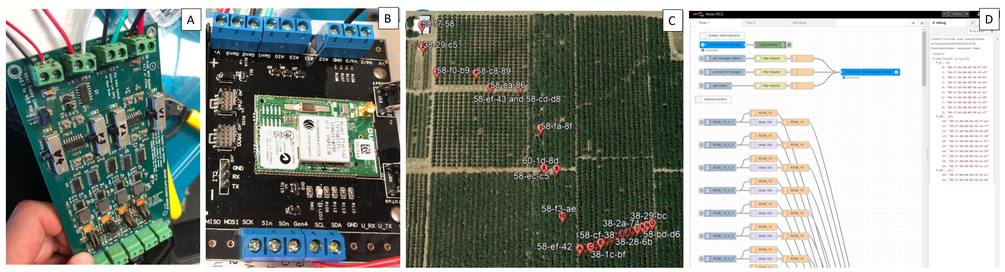

Figure 5: The far left image shows the valve actuator boards for opening and closing up to four latching solenoid valves. The second image from the left shows the motes that are used to communicate between the valve actuator boards and the gateway, which received the valve commands from the internet. Second from the right: A map of the wireless network of motes that relay the valve commands from the field house to the valve actuator boards. Right: The website for programming the runtime for each of the 60 valves.

Results

- No significant differences in kernel yield or kernel count per ounce were found between irrigating according to variety-specific hull-split and irrigating according to nonpareil-specific hull-split in either 50% ET or 75% ET treatments after one year of treatments.
- Delaying RDI until Butte hull-split initiation was associated with a reduction in percent sealed shells compared to implementing RDI according to Nonpareil hull-split timing in Butte.
- No other quality parameters were found to be significantly different between irrigating according to variety-specific hull-split timing and irrigating according to nonpareil hull-split timing.
- Stem water potential measurements indicate clear differences in water stress levels across varieties by irrigating according to variety-specific hull-split timing.

Irrigation Treatment Hull-Split to Harvest		Average Kernel Yield (lb/acre)			Kernel Count per Ounce		
		Aldrich	Butte	Nonpareil	Aldrich	Butte	Nonpareil
S1	75% ETc From Nonpareil Hull-Split Initiation to Harvest Dates	1774 c	2911 ab	3045 ab	28.1 bcd	24.9 e	35.5 a
S2	75% ETc From Variety-Specific Hull-Split Initiation to Harvest Dates	1679 c	2796 b		28.7 b	26.5 bcde	
S3	50% ETc From Nonpareil Hull-Split Initiation to Harvest Dates	1594 c	2707 b	2745 b	28.1 bcd	25.8 de	33.9 a
S4	50% ETc From Variety-Specific Hull-Split Initiation to Harvest Dates	1676 c	2626 b		28.5 bc	26.2 cde	
S5	100% ETc From Nonpareil Hull-Split Initiation to Harvest Dates	n/a	n/a	3493 a	n/a	n/a	34.1 a
S6	100% ETc From Nonpareil Hull-Split Initiation to Harvest Dates	n/a	n/a	3001 ab	n/a	n/a	34.2 a

Note: Letters indicate that the treatments are not significantly different.

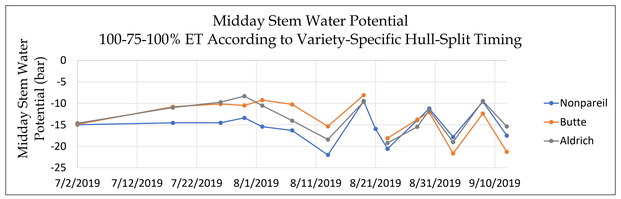

Figure 6: Stem water potential in 75% ET treatment during variety-specific hull-split.

Conclusions

- Remote valve control systems offer almond farmers a convenient option for independently irrigating varieties according to growth stages and minimizing loss of irrigation during the harvest period by opening the valves only in the areas without almonds drying on the ground.
- In-line pressure sensors and soil moisture sensors are critical to producing a reliable remote irrigation control system to ensure that valves properly open and close.
- RDI according to variety-specific hull-split initiation in the Butte variety could decrease the percent sealed almonds upon harvest and reduce machine-based shelling requirements.
- One year of treatments testing the differences between irrigating according to variety-specific hull-split and irrigating according to nonpareil hull-split was not long enough to show differences in yield, so the treatments will be continued in 2020.

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