Title: Five Irrigation Approaches for Improving Alfalfa Yield and Quality

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Abstract

Drought is common in the West and producers need research-based irrigation strategies to stretch limited water supplies. Strategies such as regular maintenance of irrigation systems, reducing irrigation rates, and advanced irrigation scheduling, may be helpful options but have not been tested with experimental rigor. The objective of our study was to identify which inexpensive water management strategy may maintain yield with less water. An experiment was conducted at 12 alfalfa (*medicago sativa* L.) fields in southcentral Utah in 2019-2021. Alfalfa was cut and harvested 2 to 4 times each year. Existing sprinkler equipment (regulators, nozzles, sprinkler bodies) on these pivots ranged from 3 to over 20 yr old. Three equipment (existing, new, new with 10% rate reduction) treatments were implemented on one span of the pivot at each site. Four irrigation scheduling treatments (grower schedule, irrigation scheduler application, soil moisture-based, and a commercial model [FieldNET Advisor®]) were also implemented on 16 adjacent sectors (each ~50 ft wide). Results showed that new irrigation equipment did not consistently improve alfalfa yield at any of the fields in 2019 and 2020. In a wet year, there were some farms that were able to reduce irrigation by 10% without hurting yield, but other farms experienced significant yield reductions, particularly with maintaining the reduced irrigation rate across consecutive years of drought. The irrigation scheduling strategies affected yield on 5 of 46 cuts across fields and years, with an average alfalfa yield increase of 0.3 tons/acre, but these five cuts were not consistently at the same fields. At some fields, up to 15% less water was applied with the advanced scheduling methods, but at most farms these methods increased the water application above the grower recommendation due to drought and limited irrigation supply. Alfalfa feed quality was rarely affected by any of the treatments.

Introduction

IRRIGATION IS HIGH PRIORITY

Irrigation can be one of the most challenging inputs to manage in forage production because it requires constant adaptation to weather conditions, and usually involves *at least 8-10 and sometimes more than 20 decisions each season* about the timing and amount of irrigation to apply. In addition to these complexities, alfalfa does not always receive the “irrigation attention” that it needs, perhaps because it is perceived as a crop that tolerates drought and difficult growing conditions well and/or efforts are sometimes shifted to other crops perceived as more lucrative. Regular feedback from Extension, irrigation professionals, and crop advisors confirm these challenges, and suggest that concentrated effort on irrigation maintenance and innovation should be a high priority for alfalfa and forage production.

IRRIGATION STRATEGIES

Multiple technologies and strategies for advanced irrigation exist, but investments and skill required for these strategies vary widely. One common approach to advanced irrigation is new pivot irrigation technologies such low-elevation spray application (LESA), low-energy precision application (LEPA) nozzle systems and mobile drip irrigation (MDI). These technologies show promise and have documented increases in alfalfa yield through improved irrigation uniformity, coupled with frequent water savings. These investments [(additional ~$15, $75, $140/acre for LESA, LEPA, and MDI, respectively beyond a mid-elevation spray application (MESA)] in new pivot technologies can sometimes be too large for some alfalfa growers to adopt these practices. Several other less expensive strategies to improve irrigation management exist. Some of these include:

- regular maintenance of irrigation systems (replacement of worn irrigation nozzles, pressure regulators, and other equipment; Figure 1).
- reducing irrigation rates to avoid slight over-irrigation.
- advanced irrigation scheduling.

Figure 1. Moss debris clogging pivot sprinkler.

Prioritizing which method(s) of irrigation and irrigation equipment management might improve alfalfa yield and quality will help growers improve their profits, and deal with diminishing water supplies that are prevalent across the Intermountain West.

WHY SCHEDULE IRRIGATION?

The short answer is because yield, forage quality, and profit in irrigated agriculture are directly and heavily influenced by proper irrigation schedules. Arriving at the ideal irrigation schedules can, however, be quite complex. Some of the major benefits of irrigating with the proper frequency and amount are:

- optimize production and profit.
- improve irrigation efficiency.
- decrease excessive deep percolation below the root zone.
- decrease runoff.

Irrigation frequency options are sometimes limited by the timing of water availability and irrigation delivery systems. However, opportunities to refine irrigation schedules usually still exist for most applications. Irrigation rates can almost always be adjusted when using sprinklers, and irrigations can often be concentrated at critical times despite water schedule constraints. Restricted irrigation options are often cited as a reason not to attempt to set the right rate and timing of irrigation. The important concept here is to accurately define the irrigation need, and then do everything in your power to meet the irrigation need of your crop.

HOW TO SCHEDULE IRRIGATION?

Modifying irrigation schedules can be one of the simplest and most inexpensive ways to improve water management. The first step to selecting a schedule is water measurement and monitoring. The importance of this cannot be overstated. *Inaccurate water measurements will thwart almost all other efforts to refine irrigation management*. This can be as easy measuring water volume in buckets placed under moving sprinklers. The more accurate and continuous measurements can be obtained with flow meters.

Irrigation schedules for sprinklers can usually be easily modified by changing flow rates, irrigation set lengths, nozzle size, and other methods. The premise of the selecting the right schedule is to apply rates/frequencies that do not exceed soil intake rates, do not exceed the maximum allowable soil water depletion between irrigations, and meet crop water use or evapotranspiration (ET) demand. This approach will reduce or prevent runoff and unnecessary water losses. Several methods exist for selecting irrigation schedules. Some of the major types include:

- *Irrigation scheduler systems* that utilize weather data to estimate ET, calculate water balances, and recommend irrigation schedules according to maximum allowable depletion for each soil type are a great way to start scheduling irrigation. The Washington State University Irrigation Scheduler (Figure 2) is one of the widely available free programs in the Intermountain West (weather.wsu.edu/is/). Although it is a free application, it does require time to setup fields, input irrigation amounts, and interpret and apply the schedules it recommends.

- *Monitoring soil moisture* by hand using the feel method, or a with variety of soil moisture sensors. Many new soil moisture sensor companies (Figure 2) have now developed ways to access soil moisture data remotely on a computer, phone, or other device – making data more accessible than before. Utilizing this approach requires equipment purchase/rental, installation, and maintenance, along with subscription costs for remote access of soil moisture data.

- *Commercial scheduler programs* that utilize crop growth models, soil characteristics, and ET estimated from satellite or aerial imagery are also available mainly for use with pivot irrigation. One of the available programs and services, among many, includes the FieldNet Advisor® program by Lindsay Corporation (Figure 2). Many of these programs have the ability to send prescriptions directly to pivots for autonomous irrigation. They general include subscription costs and time to setup fields, input crop management details and to apply schedules.

COST OF SCHEDULING

Advanced approaches to irrigation scheduling sound great, but can I really afford them on my farm? While it is difficult to compare the cost of large variety of scheduling approaches, we provide some general guidelines below for equipment costs (not including labor nor inflation – which are highly variable). Soil moisture sensing costs are highly dependent on what equipment and data access options you want, but generally plan on at least about $3 per acre per year for these. The irrigation scheduler is a free application, but does require frequent manual input of irrigation data. FieldNet Advisor currently costs roughly $4 per acre per year. As you explore these options, be sure to remember that returns (improved yield/quality or reduced water/energy costs) from irrigation scheduling approaches need to outweigh the costs, and that you plan to adjust your irrigation based on the data you collect.

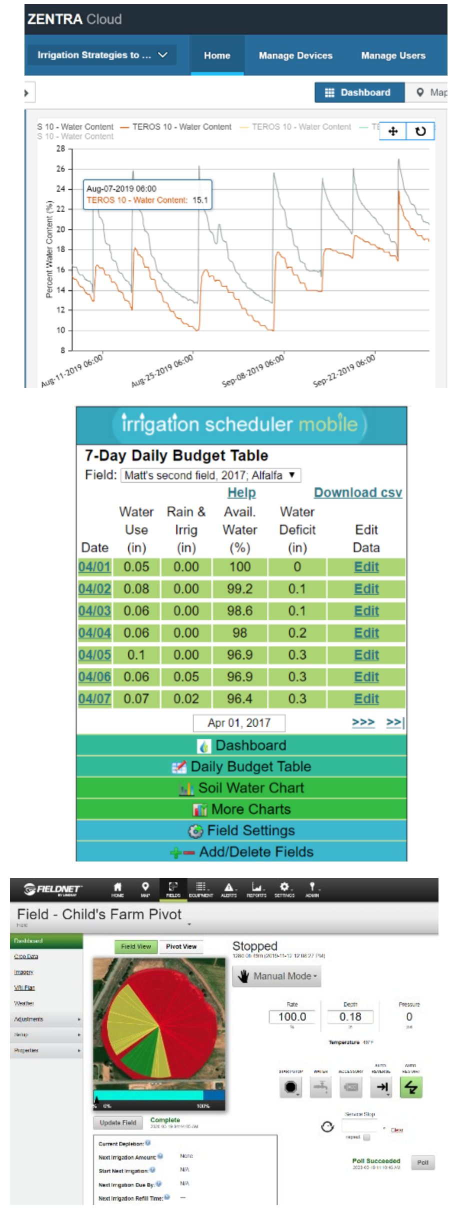

Figure 2. Soil moisture sensor program developed by MeterGROUP (top), irrigation scheduler program developed by Washington State University (middle), and FieldNet Advisor by Lindsay Corporation (bottom).

Materials and Methods

In 2019, a study was established on 12 alfalfa fields in southcentral Utah to test several irrigation strategies that might stretch limited water supplies (Figure 3). On each pivot, a single span (normally the 4th to 6th span from the center point) was split into three sections of each size. On two-thirds of the span, new sprinkler equipment (nozzles, regulators, sprinkler) of the same brand and type were installed (Figure 4). One of these thirds had slightly smaller nozzles that were designed to apply 10% less water than the other two-thirds. This allowed us to test how new sprinklers and a 10% reduction in water rates might influence alfalfa yield and water use. In each of the thirds, four alfalfa yield samples were collected each cutting by harvesting 10 ft of the windrow (15.5 ft wide) for each sample. The study was repeated in 2020 at 10 of the same fields as 2019.

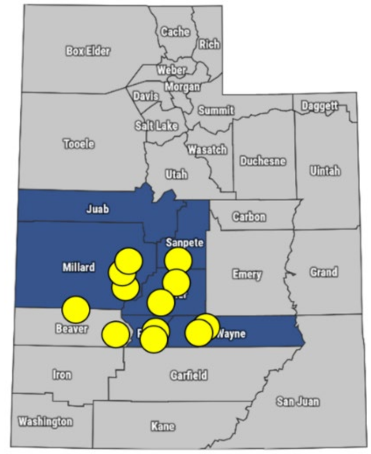

Figure 3. Location of the 12 test pivots .

On the same pivots, four irrigation schedules were tested. Irrigation rate but not timing was the difference between irrigation schedules. We intended to adjust both rate and timing but this was not possible when working in production fields. The four schedules were the i) grower's conventional irrigation rate and timing; ii) a rate based on soil moisture sensors (Teros 10 water content sensors) installed to 3 ft at a single location in each field, iii) rate determined by the irrigation scheduler application with weather data collected on-site; and iv) rate recommended by Lindsay FieldNet Advisor. Each of the four irrigation schedules were replicated four times utilizing four large sectors in 2019 or 16 smaller sectors with four replications of each schedule in 2020 and 2021. Pivot control panel updates were required on many pivots to make automated control and FieldNet Advisor operational. These updates were problematic on several pivots and resulted in only 9, 6, and 6 fields with schedule treatments in 2019, 2020, and 2021, respectively.

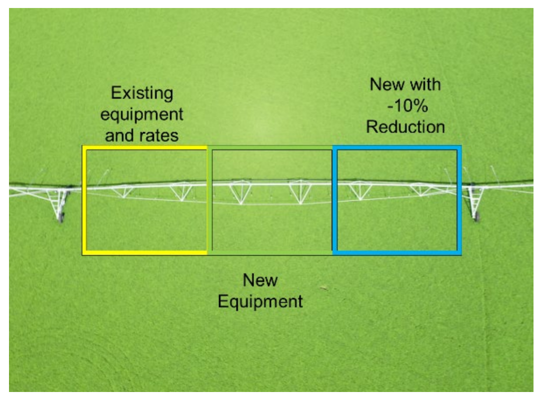

Figure 4. Design of the sprinkler maintenance and rate reduction experiment. One-third of a single span on each of the 12 test pivots was modified in this manner.

Project Objectives and Corresponding Results

Project Objectives

1. Evaluate the level of crop response from replacing worn pivot equipment (head, nozzle, regulator).
2. Determine if growers could reduce irrigation by 10% and maintain yield and quality.
3. Compare seasonal irrigation application depths and crop response when implementing a free irrigation scheduling tool, a commercial model, or a soil moisture sensor and water-balance equation to prescribe irrigation amounts.

Project Results

1. There were no consistent crop effects due to the new sprinkler equipment on pivots.
2. In a wet year, many farms were not negatively affected by reducing irrigation by 10%. Yield losses became more apparent from the reduction in the second year.
3. Three advanced scheduling tools had no consistent impact on yield or quality. At some farms the tools saved water in the wet year of 2019, but in the dry years of 2020 and 2021 the advanced methods frequently prescribed more water than the growers could apply.

Results and Discussion

Objective 1 Results - Maintaining Irrigation Equipment.

In 2019 when the study begin, the age of the sprinkler packages on the 12 pivots ranged from 3 to 20 years. The average wear on the nozzles was assessed by measuring the inner diameter of the nozzles with a caliper and comparing it to the design diameter. Nozzle wear ranged from 0 to 2% across the sites. Regulator wear was assessed by measuring pressure on the outlet site with 40 psi on the inlet side. Regulator wear ranged from 1 to 50% across the sites.

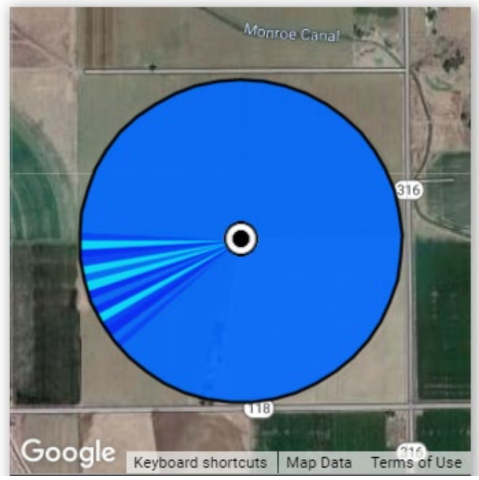

Figure 5. Screenshot of FieldNet that shows an example design of the irrigation schedule study. Each pivot had 16 small sectors with four replications of four irrigation schedules.

Replacement of sprinkler equipment impacted alfalfa yield in only 3 of 37 (8%) cuts in 2019 and 2 of 19 (11%) in 2020 (Figure 6). These yield improvements did not always happen on fields with the oldest sprinklers. They also did not consistently occur on the same farm across cuttings, but rather random cuts at various farms had yield improvements with new sprinklers. This indicates sprinkler parts may last longer than anticipated.

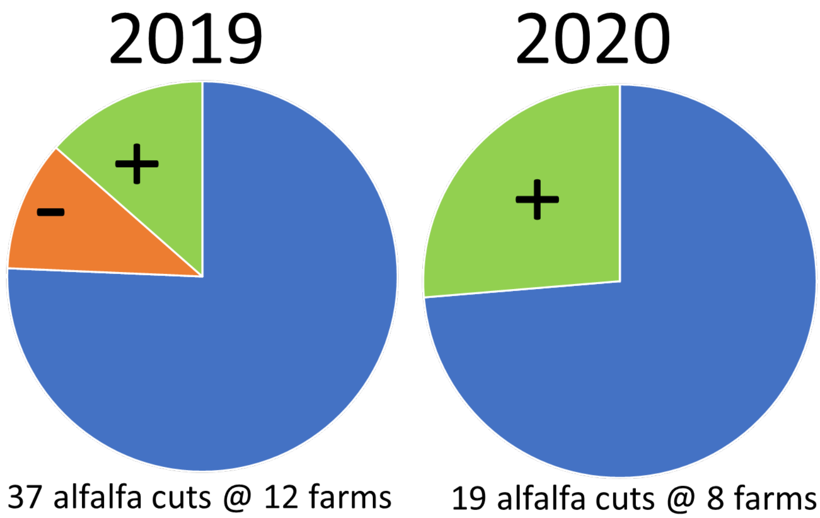

Figure 6. Summary of the impact of new sprinklers on alfalfa yield at test fields in 2019 and 2020. Green (+) indicates that yield was improved, orange (-) indicates a reduction in yield, and blue was no impact on yield.

Objective 2 Results - Reducing Irrigation Rates.

The 10% reductions in irrigation rates rarely impacted alfalfa yield in 2019 and 2020. In both years, there were a couple cuttings that had increased yield with less water. Overirrigation was not an issue on these sites so its unclear why their was a yield increase. Of more interest was whether irrigation reductions decreased yield. In 2019, only 2 of 37 (5%) cuts (Figure 7) had reduced yield with less water, and reductions occurred in different fields for various cuts. The low frequency of yield reductions was likely related to the weather in 2019. The spring and early summer was much wetter than normal at nearly all the sites. The average reduction in yield at these two cuttings was 0.44 tons/acre. In 2020, only 4 of 19 cuts (21%) had yield reductions with 10% less irrigation. This was likely related to the extremely low precipitation in 2020. Many sites received no rainfall for several summer months. The four cuttings in 2020 had an average yield reduction of 0.37 tons/acre. This indicates frequent opportunities for slight cutbacks in irrigation rates without impacting production, especially in years with more precipitation.

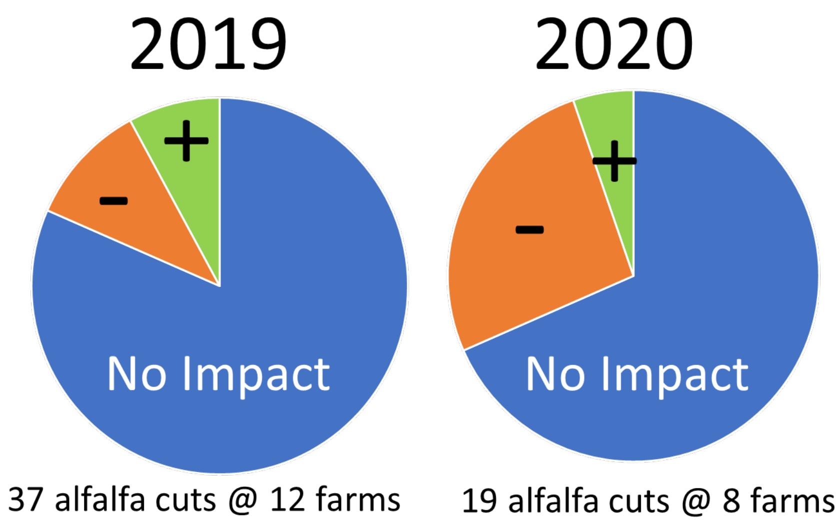

Figure 7. Summary of the impact of new sprinklers on alfalfa yield at test fields in 2019 and 2020. Green (+) indicates that yield was improved, orange (-) indicates a reduction in yield, and blue was no impact on yield.

Objective 3 Results - Irrigation Scheduling Approaches.
The advanced irrigation scheduling approaches only impacted yield at 5 of 47 (11%) alfalfa cuttings across 2019-2021 at a total of 10 different fields. Only one site had repeated effects of irrigation schedules (Farm 4, Figure 8). This site was the only site where advanced irrigation schedules improved alfalfa yield in a single cutting in 2019 and 2020. At the other three sites, advanced irrigation schedules maintained or slightly reduced yield in some cases. These results demonstrated that advanced schedules had minor impacts on alfalfa yield.

Water use differed among the irrigation schedules and differed by year. The 2019 growing season was much wetter than normal in the spring and early summer. By contrast, 2020 was drier than normal and 2021 was extremely dry with severe water shortages on many of the fields. In all three years, soil moisture sensors recommended among the lowest irrigation amounts. Field Net Advisor recommended more irrigation than all other methods in 2020 and 2021. The irrigation scheduler recommended similar or slightly more irrigation than the soil moisture sensor approach. The conventional irrigation schedule utilized by cooperating growers was often near the amount recommended by other approaches. *These results indicate that irrigation scheduling may have more potential to save water than to improve yield.*

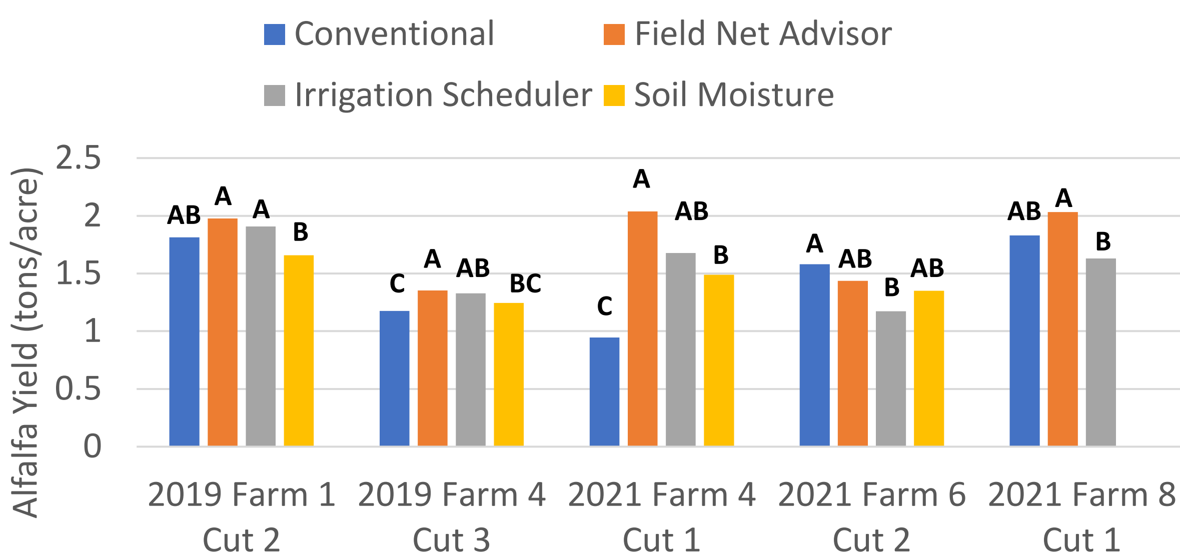

Figure 8. Impact of irrigation schedules on alfalfa yield at 5 of 47 cuts where it was tested during 2019-2021. Yield was not impacted by schedule at the other 42 cuttings.

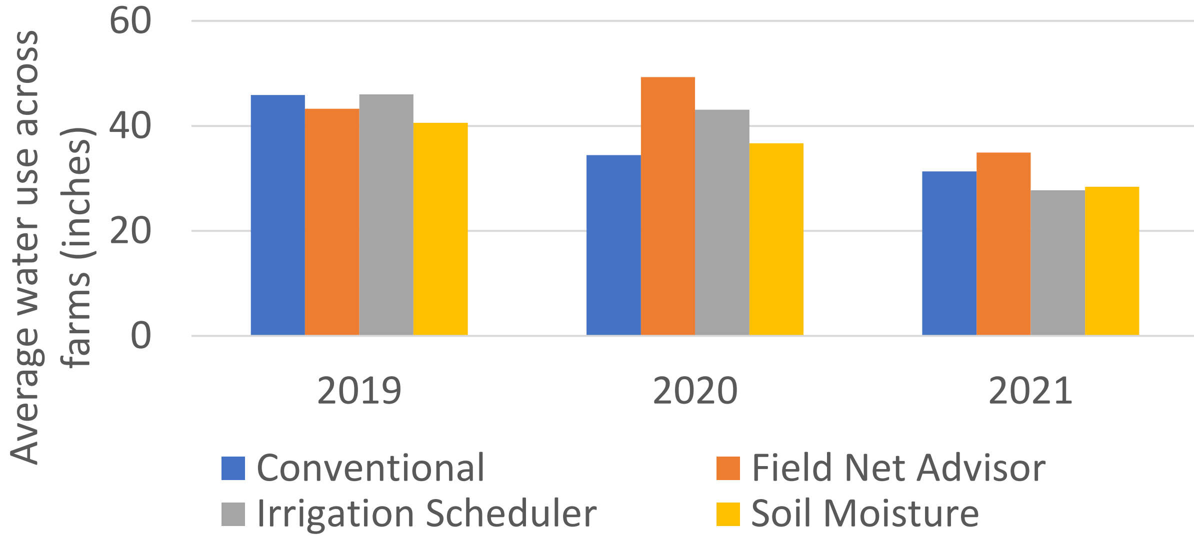

Figure 9. Average water use across farms for four irrigation schedules. 2019 was a wetter than normal year and 2020-2021 were both dry years.

Conclusions

This study suggests that many growers could cut irrigation rates by 10% without adversely impacting alfalfa yield, and that worn sprinkler equipment may not be causing as much yield loss and non-uniformity issues as expected. Advanced irrigation scheduling approaches may have more potential to reduce irrigation rates than improve alfalfa yield and should be considered where water optimization is desired or required.

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