LIMITED IRRIGATION OF ALFALFA

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ABSTRACT

Northern Water (Northern Colorado Water Conservancy District) conducted a study of limited irrigation of alfalfa on a 4.7-acre field near Berthoud, Colorado, during the 2006-2007 seasons. The study was a collaborative effort between Northern Water and Colorado State University's Soil and Crop Sciences Department.

Irrigation was supplied via a linear sprinkler with independently controlled drops: 2-wire encoder, valve/solenoid, pressure regulator, and sprinkler nozzle. A programmable controller/logger, base station controller for the sprinkler valves, and a GPS receiver were all on-board the sprinkler cart. Unscreened irrigation water was supplied by a variable frequency pumping unit to maintain constant line pressure over the variable flow range required.

The alfalfa field was divided into 12 plots to accommodate three replicates of four different irrigation treatments:

1. Full irrigation to meet well-watered crop ET.
2. Stop irrigation following one irrigation after first cutting, then resume irrigation after third cutting.
3. Stop irrigation after second cutting.
4. Stop irrigation after first cutting.

Crop water use was estimated using meteorological data from an adjacent weather station. Soil moisture sensors tracked volumetric moisture in the top 4 feet of the alfalfa root zone. Yields for each cutting from each plot were estimated from hand samples (20-foot length of windrow by 16-foot wide swath). Results were summarized by inches of alfalfa water use per ton of harvested yield at 0 percent moisture.

INTRODUCTION

Field Layout

The alfalfa field was 260 feet (east-west) by 890 feet (north-south) and included along the west edge a 30-foot wide, grassed hose drag lane for the linear sprinkler. The soil was a silty clay

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loam. Field capacity was taken to be 0.35 inches of water per inch of soil, and the permanent wilting point was assumed to be 0.16 inches of water per inch of soil. With an allowable depletion of 60 percent, this provided 5.5 inches of useable moisture in the top 4 feet of the alfalfa root zone. The water table was typically 20 feet below the soil surface as monitored via adjacent observation wells. Because of this depth, capillary rise of groundwater has to date been neglected for potential contributions towards crop water use.

Crop Establishment and Harvest

Following harvest of a barley crop, the field was planted to Dairyland Magna Graze alfalfa from Agland on August 26, 2004. Because of intense competition with volunteer barley, it was over-seeded the following year on June 16, 2005, to achieve 92 percent of stand. The study of limited irrigation began in 2006, which was the second full season of the alfalfa crop. The alfalfa crop was harvested by swathing and green-chopping, thereby minimizing the time between cutting and green-up of the next stand. Alfalfa was often left in windrows as little as 24 hours.

Irrigation System

Irrigation was provided through a 2-span linear sprinkler utilizing a guidance furrow for the end cart. Sprinkler drops were 5 feet on center with LDN heads 3 feet above the ground. Two hydrants along the west edge of the field supplied water to the linear sprinkler through a 4-inch diameter drag hose. Electrical power was supplied via an on-board 480 VAC gas-powered generator. The travel speed of the linear sprinkler was adjusted so the nozzles applied 0.75 inches of water across the field in 9 hours of run-time.

AUTOMATION OF IRRIGATION TREATMENTS

Study Layout

The field was divided into 12 plots, 4-wide by 3-long grid, to provide three replicates of each of four irrigation treatments. Along the direction of travel for the linear sprinkler, a 15-foot wide buffer was provided between plots. The valves on each drop were turned on or off within these buffers, usually within the center 7- to 10-feet of the buffer.

Pump House

Irrigation water was delivered from the Handy Ditch to an on-site, 9 acre-foot capacity fully-lined pond. Water from the pond was supplied to the linear sprinkler via a pumping unit with a variable frequency drive electric motor and controls. The system maintained near constant line pressure from 25 percent up to 100 percent of the designed flow rate. The supply water was not filtered or screened in 2006-2007, but screens are planned to be installed before the 2008 season to reduce clogging of control orifices in the sprinkler valves.

Sprinkler Drops

Each of the 44 sprinkler drops were equipped with a 2-wire encoder, 9 VDC latching solenoid on a ¾-inch plastic sprinkler valve, pressure regulator, manual ball valve, and LDN spray head.

The 9 VDC latching solenoids were selected because of the lower power requirements. A typical 24 VAC solenoid needs 0.4 amps in-rush current and 0.2 amps current to hold, thus requiring 211 to 422 watts of power to energize 44 solenoids. In contrast, the 9 VDC latching solenoids only need a brief voltage pulse to turn the valve on or off, with no holding power requirement. A positive voltage pulse turned a valve on, and a negative pulse turned it off as provided by the on-board base station controller.

The 2-wire encoders were selected over direct wiring of each solenoid to the base station controller in order to reduce the number of conductors running from the base station controller on the cart and starting down the linear pipe. Direct wiring of 44 solenoids would have required a total of 45 conductors: 1 power/active for each of the 44 valves plus one common. In contrast, the 2-wire encoders required only two conductors, connected in turn to each of the 44 encoders. Power to, and control of, each solenoid was provided through its 2-wire encoder.

Programmable Controller / Data Logger

An on-board programmable controller/logger interfaced with the base station controller for the sprinkler valves on the linear cart to automatically control irrigation to each plot in the alfalfa field. Utilizing a GPS receiver, the controller was able to determine the position of the linear cart within 3.5 to 5 feet and control which plots were turned on or off at any given time. Data was logged by the controller every 15 minutes with communication to the headquarters office via a license-free, 100 milli-Watt spread-spectrum radio.

The programmable controller/logger, coupled with individual solenoid valves on each sprinkler drop, provides flexibility to redesign plot treatments in the future. A new program written in Basic would simply be downloaded to the controller with no hardware changes required. In addition, variable rate irrigation treatments are possible by pulsing sprinklers or by toggling every other sprinkler on/off in sequence rather than running each sprinkler constantly.

SOIL MOISTURE MONITORING

Four soil moisture monitoring stations were installed in the alfalfa field, one in each irrigation treatment. Each station employed a programmable data logger with a 100 milli-Watt spread-spectrum radio for communication to the headquarters office. A total of four soil moisture sensors were connected to each data logger, measuring the dielectric constant of the soil to determine volumetric soil moisture. Moisture sensors were installed vertically at depths of 6, 18, 30, and 42 inches below the surface. A gas-powered auger was utilized to bore a separate hole to the appropriate depth for each sensor, which was then bedded in place with soil slurry.

Each station included a tipping bucket rain gauge, an18 amp-hour rechargeable battery, and 5-watt solar panel. Additional/deeper soil moisture sensors are anticipated for the 2008 growing season.

YIELD MEASUREMENTS

All yield estimates for each plot were provided by personnel from the Soil and Crop Sciences Department of Colorado State University. Usually on the same day as the alfalfa was swathed, Colorado State University staff would sample the yield from each of the 12 plots in the field. They would typically collect and weigh a 20-foot length of windrow (16-foot wide swath) from the center of each plot. Sub-samples were weighed and placed in paper bags for oven-drying and determining moisture content. Harvest of the alfalfa occurred on the dates indicated in Table 1 with the estimated yield data provided in Table 2.

Table 1. Alfalfa Cutting Dates.

	2006 season	2007 season
1st cutting	May 30th	May 29th
2nd cutting	July 17th	July 9th
3rd cutting	August 15th	August 8th
4th cutting	September 25th	September 21st

Table 2. Estimated Alfalfa Yields in tons per acre at 0 percent moisture.

Season	Irrigation Treatment	1st cutting	2nd cutting	3rd cutting	4th cutting	Total
2006	Full irrigation to meet crop ET	2.1	2.6	1.8	1.1	7.6
2006	Stop after 2nd cutting	1.8	2.6	1.5	0.5	6.4
2006	One irrigation after 1st cutting, resume irrigation after 3rd cutting	1.9	1.9	1.0	1.2	6.0
2006	Stop irrigation after 1st cutting	1.9	1.3	0.6	0.2	4.0
2007	Full irrigation to meet crop ET	3.1	2.3	1.8	1.3	8.5
2007	Stop after 2nd cutting	3.5	2.4	1.5	1.1	8.5
2007	One irrigation after 1st cutting, resume irrigation after 3rd cutting	3.5	1.9	1.3	1.3	8.0
2007	Stop irrigation after 1st cutting	3.1	1.9	1.2	1.0	7.2
Average		2.6	2.1	1.3	1.0	7.0

CROP WATER USE

The measured precipitation for all treatments is provided in Table 3. Precipitation during the 2007 growing season was more than double the precipitation in 2006 and may have contributed to the higher alfalfa yields in 2007.

Table 3. Measured Precipitation in inches.

	1st cutting	2nd cutting	3rd cutting	4th cutting	Total
2006	1.73	1.90	1.23	1.15	6.01
2007	7.53	0.27	4.19	0.92	12.91

The gross applied irrigation for each plot is provided in Table 4 as measured with an electronic flow sensor on the pump discharge line.

Table 4. Gross Applied Irrigation in acre-inches per acre.

Season	Irrigation Treatment	1st cutting	2nd cutting	3rd cutting	4th cutting	Total
2006	Full irrigation to meet crop ET	5.62	10.82	6.06	5.20	27.70
2006	Stop after 2nd cutting	5.62	10.82	0	0	16.44
2006	One irrigation after 1st cutting, resume irrigation after 3rd cutting	5.62	4.24	0	5.20	15.06
2006	Stop irrigation after 1st cutting	5.62	0	0	0	5.62
2007	Full irrigation to meet crop ET	2.85	7.14	7.25	5.17	22.41
2007	Stop after 2nd cutting	2.85	7.14	0	0	9.99
2007	One irrigation after 1st cutting, resume irrigation after 3rd cutting	2.85	2.89	0	5.17	10.91
2007	Stop irrigation after 1st cutting	2.85	0	0	0	2.85
Average		4.24	5.38	1.66	2.59	13.87

The crop water use in acre-inch per acre for each treatment is shown in Table 5 and was estimated as the sum of gross applied irrigation, measured precipitation, and change in soil moisture in the top four feet of the root zone. Losses to surface runoff (both rain and irrigation) were assumed to be negligible, as was deep percolation. To date, upward migration of deeper soil moisture was not quantified as contributing to crop water use. Further evaluation is needed in this regard.

Table 5. Estimated Alfalfa Water Use in acre-inches per acre.

Season	Irrigation Treatment	1st cutting	2nd cutting	3rd cutting	4th cutting	Total
2006	Full irrigation to meet crop ET	13.4	12.5	6.4	6.4	38.7
2006	Stop after 2nd cutting	13.4 est	12.0	4.0	1.8	31.2
2006	One irrigation after 1st cutting, resume irrigation after 3rd cutting	12.6 est	7.7	1.8	5.0	27.1
2006	Stop irrigation after 1st cutting	12.2 est	4.7	1.5	1.7	20.1
2007	Full irrigation to meet crop ET	10.7	7.6	6.2	9.0	33.5
2007	Stop after 2nd cutting	11.7	7.4	2.6	5.5	27.2
2007	One irrigation after 1st cutting, resume irrigation after 3rd cutting	11.1	6.8	2.7	7.0	27.6
2007	Stop irrigation after 1st cutting	10.8	4.3	1.0	4.4	20.5
Average		12.0	7.9	3.3	5.1	28.3

Table 6 provides the crop water use in acre-inches per ton of yield for each treatment. Values were calculated as the crop water use in acre-inch per acre divided by the yield in tons per acre at 0 percent moisture.

The season average for estimated alfalfa water use provided in Table 6 was calculated as the total season water use divided by the total season yield.

Table 6. Estimated Alfalfa Water Use in acre-inches per ton at 0 percent moisture.

Season	Irrigation Treatment	1st cutting	2nd cutting	3rd cutting	4th cutting	Season average
2006	Full irrigation to meet crop ET	6.4	4.8	3.4	5.7	5.0
2006	Stop after 2nd cutting	7.4	4.7	2.7	3.3	4.9
2006	One irrigation after 1st cutting, resume irrigation after 3rd cutting	6.6	4.2	1.9	4.1	4.6
2006	Stop irrigation after 1st cutting	6.4	3.7	2.3	8.5	5.0
2007	Full irrigation to meet crop ET	3.4	3.3	3.3	6.8	3.9
2007	Stop after 2nd cutting	3.4	3.1	1.7	5.2	3.2
2007	One irrigation after 1st cutting, resume irrigation after 3rd cutting	3.2	3.7	2.1	5.3	3.5
2007	Stop irrigation after 1st cutting	3.5	2.3	0.9	4.5	2.9
Average		5.0	3.7	2.3	5.4	4.0

SUMMARY

The 2007 season differed from conditions experienced during the 2006 season. Overall, the 2007 season had roughly double the precipitation. With more cloudy skies and cooler weather, crop water use was 13 percent lower in 2007. As a consequence, the required irrigation for well-watered alfalfa was 19 percent lower in 2007. These combined differences contributed toward 2006 season yields being 25 percent lower overall than yields from the 2007 season.

The study results to date indicate greater water use efficiency during periods of peak seasonal crop water use (2nd and 3rd cuttings). For all irrigation treatments, typically less water was required per ton of yield for the third cutting than earlier or later cuttings. Additionally, those treatments where irrigation was withheld during some period of the growing season averaged lower crop water use per ton of yield than the treatment that was fully irrigated to meet well-watered crop ET.

The authors acknowledge that a deep rooted crop such as alfalfa growing on a silty clay loam soil without rooting limitations will extract moisture from below the 4-foot depth monitored by the installed soil moisture sensors during 2006 and 2007. Increased/deeper soil moisture monitoring is anticipated for the 2008 growing season. It is likely this will increase the crop water use calculations in this study.

To date, capillary rise of groundwater and upward migration of deeper soil moisture has been neglected as contributing towards crop water use estimates. Further evaluation is needed in this regard and is anticipated for inclusion in future reports.

DISCLAIMERS

Northern Water does not in any way endorse or recommend equipment from any particular manufacturer or distributor. Mention of a specific make or model of equipment is provided for informational purposes only and is not intended to imply any preference, higher quality, better value, etc. The authors recognize that numerous other manufacturers market comparable equipment well-suited for irrigation. No comprehensive review of available equipment or any formalized screening process for selection of equipment was attempted.

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