Alternative Agricultural Water Transfer Methods: Progress Report – 3rd year

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Author: Calvin Pearson

Contract Summary

Applicant: Colorado State University: Colorado Water Institute, CSU Extension

Water Activity Name: Quantification of Water Savings Benefits on Subsurface Drip Irrigated (SDI) Alfalfa in the Grand Valley

Water Activity Purpose: Demonstration of water savings potential through using subsurface drip irrigation on alfalfa.

County: Mesa

Water Source: Colorado River

Amount Funded: $8,841.

Matching Funds: $1,000 cash Colorado River District, $7,782 from CSU

Partnering Project: Investigation of Water Savings, Water Quality benefits and Profitability of Subsurface Drip on Alfalfa in the Grand Valley. $46,894 WSRA project sponsored by Colorado RT. Accounts for parallel on-farm demonstration of SDI alongside gated pipe.

Summary: The study is a side-by-side comparison of furrow and subsurface drip irrigation (SDI) on alfalfa over three years starting in 2012. The study is being performed on about 3 acres at the Western Colorado Research Center at Fruita in the Grand Valley of Western Colorado. The study work plan is being completed by Agricultural Experiment Station staff with assistance by NRCS staff.

Objectives: The study is a test of SDI configuration (tape depth) for water savings, and forage yield and quality compared to furrow irrigation, which is the traditional irrigation system for the Grand Valley.

With savings and benefits quantified, the findings of this study can be used to educate local farmers and ranchers on the advantages/disadvantages of SDI. With a broader understanding of SDI adoption of subsurface drip in the Grand Valley among commercial alfalfa producers.

Eligibility Criteria

The application meets all five of the eligibility criteria including no funds being spent on legal assistance and $1,000 in cash match (10%) from the Colorado River District (via Dave Kanzer).

1st Year Progress Summary

Upon successful grant procurement the applicant contracted with Watson Boring and Excavation Inc. to refurbish existing research scale subsurface filters and install subsurface drip tape at CSU's Agricultural Experiment Station in Fruita.

The filtration refurbishment was completed Thursday, May 10, 2012. After filter testing, the subsurface tape was installed at two depths (8 and 16 inches) in a 1.5 acre plot at the Western Colorado Research Center at Fruita on Friday, May 11, 2012. Following seedbed preparation and alfalfa planting, irrigation to wet the bed began on Thursday, May 16, 2012. The Roundup-Ready® alfalfa variety "Denali" variety was planted at a rate of 20 pounds/acre in furrow-irrigated plots on May 14, 2012 and then in the SDI irrigated plots (at the same rate) on May 15, 2012.

Completed wetting of the soil surface was challenging and much was learned about bed preparation for SDI in the process. To completely wet the upper layers of the soil profile where the seed was located a short surface irrigation was required. A complete wetting of the soil surface was important to achieve adequate germination, emergence, and establishment of alfalfa seed which requires shallow planting. Lessons learned at the research center were successfully translated to the on-farm (WSRA) portion of the project that was installed during late August.

In parallel with the subsurface drip irrigated (SDI) plot another 1.5 acre plot was concurrently planted with the same alfalfa variety, the only difference being the second plot was irrigated with gated pipe (surface irrigated). Seedbed preparation, planting date, and commencement of irrigation were the same for both the SDI plot and the furrow-irrigated plot.

Two alfalfa cuttings were taken during 2012, one on July 27, 2012 and another on September 23, 2012 with the SDI plots at 3.35 and 3.58 tons/acre of total annual dry matter for the 8-inch deep and 16-inch deep tape treatments, respectively. The furrow-irrigated plot averaged an annual total of 3.62 tons/acre of dry matter.

As of September 26, 2012 the CoAgMet weather station at the Experiment Station at Fruita suggested the cumulative evapotranspiration (ET) for a full stand of alfalfa with the described planting and cutting was 32.05 inches. The seasonal average ET according to the Colorado Irrigation Guide (1988) for alfalfa grown in the Fruita area is 36.22 inches. Water applied by the SDI was calculated at 44.96 inches for the same period. Seasonal efficiency can be estimated at 71 percent or better (noting this is an establishment year).

2nd Year Progress Summary

The work plan for this project includes:

Task 1: Installation. **Completed**.
SDI filtration units were refurbished and tape was installed May 11, 2012. Irrigation commenced May 16, 2012. The SDI system worked very well during the 2013 growing season. The results of the 2013 growing season are presented in the report submitted for 2013.

Task 2: Planting. **Completed.**
The alfalfa plant stands in the SDI treatments and the furrow irrigation block are thick, uniform, and vigorous. All alfalfa is free of weeds.

3rd Year Progress Summary

Task 3: Monitoring. **In Progress.**
Water use during 2014 was again monitored with a CoAgMet weather station onsite at the research center, with gated pipe flow meters, and with tailwater flumes. Based on data from our CoAgMet weather station ET from May 1 to Sept 30 was 42.5 inches (Fig. 1).

Rainfall during the period May 2014 through September 2014 was 4.85 inches (Fig. 2). Of this amount the effective rainfall that possibly contributed to alfalfa production was estimated to be 2.4 inches.

During 2014 we applied irrigation water in the SDI at a rate of 0.12 inches per hour. We began irrigating with the SDI on April 17, 2014 and we irrigated 4 hrs per zone once a week until the second cutting. After second cutting we applied irrigation water in the SDI at 4 hrs/zone twice a week. The SDI irrigation system was shut down at the end of the growing season during the second week of September given the rainfall we experienced during August and September (Fig. 2).

Based on readings from an inline flow meter in the SDI irrigation system 16.42 inches of water were applied to each of the SDI treatments. Given the application rate and dates for the SDI irrigation system, we applied 16.3 inches of irrigation water to alfalfa during the growing season (Fig. 3). Thus, the amount of water applied to the SDI was determined by two different methods with these two calculations being in close agreement.

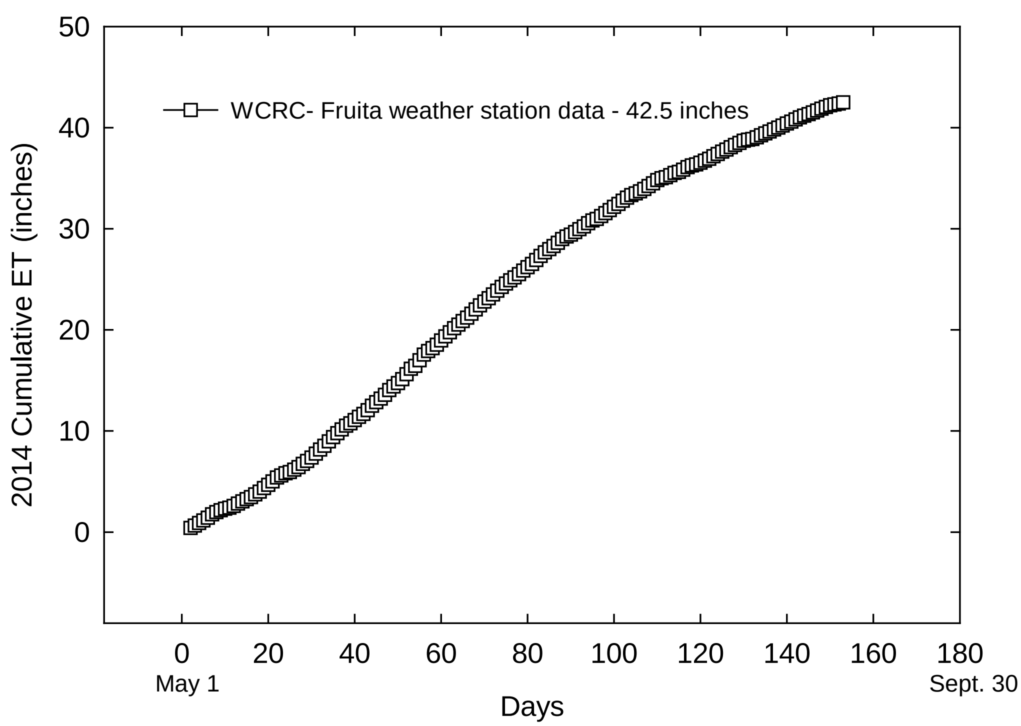

Fig. 1. Seasonal ET from the CoAgMet weather station at WCRC-Fruita.

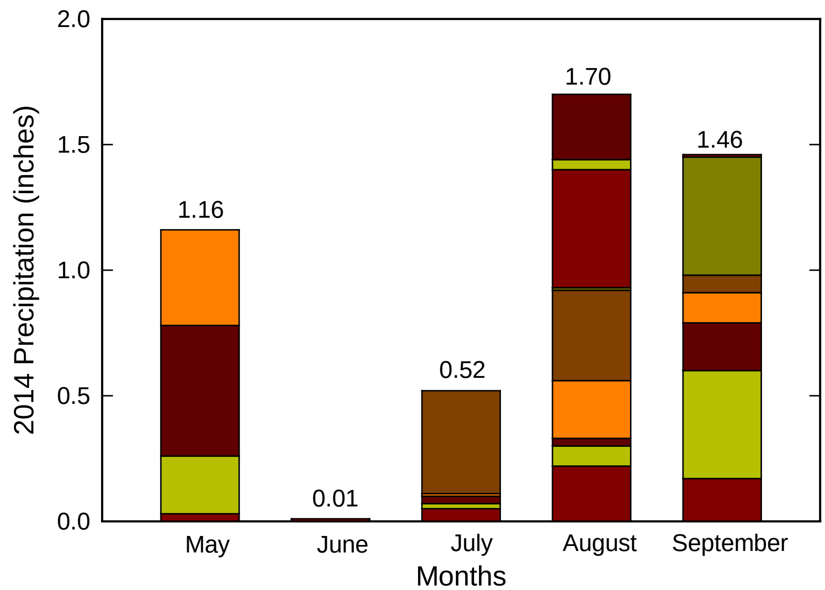

Fig. 2. Monthly cumulative rainfall during the 2014 alfalfa growing season at the Western Colorado Research Center at Fruita. Rainfall totals for each month are enter above the stacked bar.

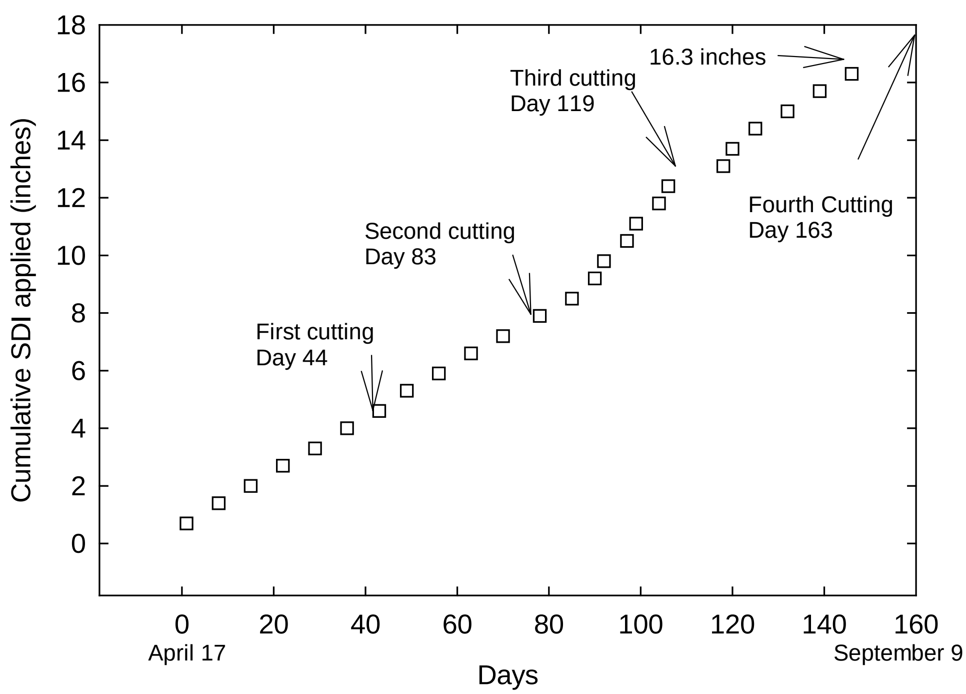

Fig. 3. Calculated cumulative irrigation water applied to alfalfa using a subsurface drip system at the Colorado State University, Western Colorado Research Center at Fruita during 2013.

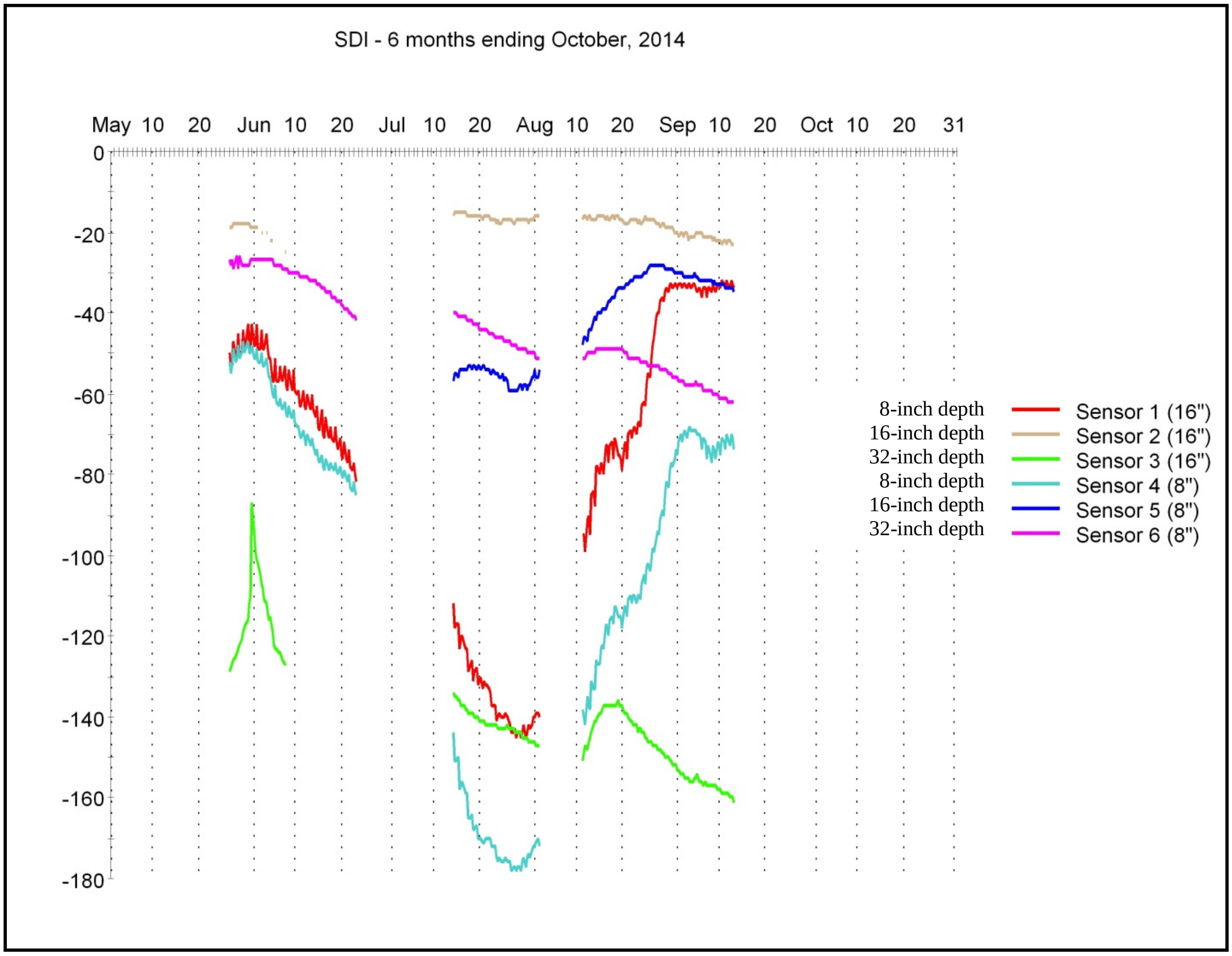

Fig. 4. Soil moisture contents of alfalfa grown with subsurface drip irrigation (SDI) with drip lines installed at 8-inch and 16-inch depths during the 2014 growing season at the CSU Western Colorado Research Center at Fruita. Calendar date is the x-axis and the units on the y-axis are centibars.

The data in Fig. 4 indicate that good irrigation efficiency can be achieved with SDI. The soil surface in the SDI was not wetted during the growing season and thus evaporation was minimized, if not eliminated, as noted by the responses of Sensors #1 and #4. Additionally, as shown by the responses of Sensor #3 and #6 positioned at a 32-inch depth the soil was dry and deep percolation did not occur. The responses of Sensors #2 and #5 show that irrigation water was concentrated at the 16-inch depth at a location where water was readily available to the alfalfa root system, thus, irrigation water was provided to the alfalfa plant without applying water that was subject to losses from evaporation or deep percolation. We had considerable rain events during the month of September and this response is indicated by the data from Sensors #1 and #4 during the last half of August and early September.

The data presented in Fig. 4 also indicate the irrigation efficiency that can be achieved with SDI when the drip lines are located at both the 8 and 16-inch depths. The data in Fig. 4 indicate there is a range of soil moisture contents that are acceptable and result in the production of high alfalfa yields without causing soil moisture losses to evaporation or deep percolation.

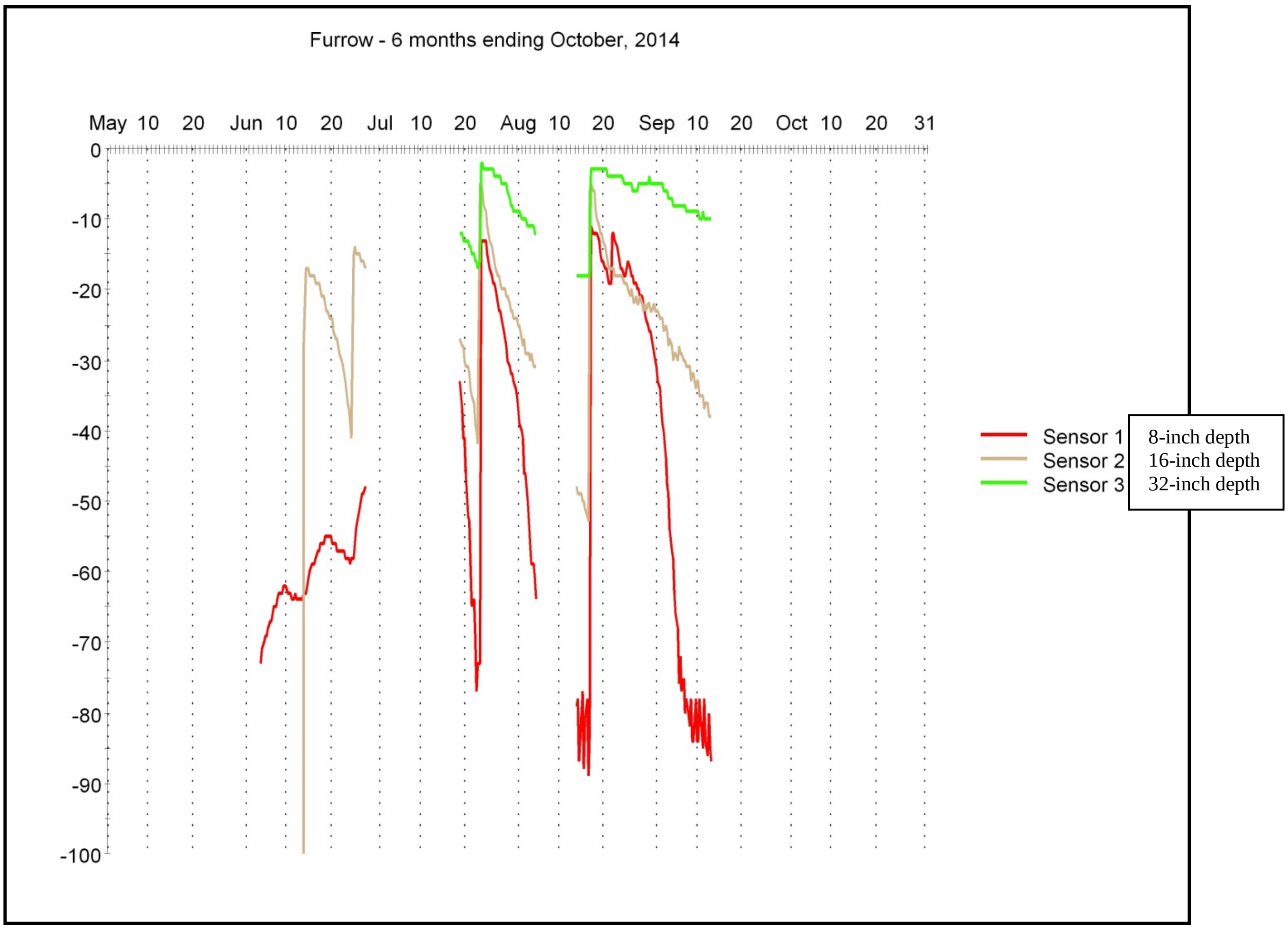

Fig. 5. Soil moisture contents at the top end of the field in alfalfa grown with furrow irrigation during the 2014 growing season at the CSU Western Colorado Research Center at Fruita. Calendar date is the x-axis and the units on the y-axis are centibars.

The responses obtained from sensors located at the three soil depths at the top end of the furrow-irrigated alfalfa field readily show the large variations in soil moisture that occur under furrow irrigation (Fig. 5). These responses of soil moisture under furrow irrigation in 2014 as shown in Fig. 5 are similar to those observed in 2013. Furrow irrigation wets the soil profile increasing the potential for deep percolation and increasing evaporation at the soil surface. Thus, substantially more irrigation water is needed to accommodate losses to evaporation, deep percolation, and runoff in order to obtain high crop yields.

Task 4: Yield Comparison. **In progress.**

There were no significant differences in alfalfa forage yields between irrigation treatments in the first, third, fourth, and total 2014 forage yields (Table 1). The forage yield in the furrow irrigation treatment in the second cutting was significantly higher than in the SDI treatments. This finding indicates that we were not applying enough irrigation water in the SDI treatments to obtain high alfalfa yields. We observed this at the time of the second cutting and accordingly we increased irrigation water application in the SDI from once a week to twice a week.

Table 1. Alfalfa forage yields in the subsurface drip irrigation study at Colorado State University, Western Colorado Research Center, Fruita, CO during 2014.

Treatment	First cutting May 28	Second cutting July 7	Third cutting Aug. 11	Fourth cutting Sept. 24	Total 2014 forage yield
	Dry matter (tons/acre)				
16-inch drip line depth	3.07	2.54	2.03	1.44	9.08
8-inch drip line depth	2.89	2.48	2.13	1.37	8.87
Furrow irrigation comparison	3.01	2.94	2.15	1.45	9.55
Ave	2.99	2.65	2.10	1.42	9.17
CV (%)	6.7	6.5	8.7	6.5	6.1
LSD (0.05)	NS	0.30	NS	NS	NS

*Numbers in the same column followed by different letters are significantly different at the 5% level of probability.

Moisture concentrations of alfalfa were determined at harvest. There were no significant differences in harvested alfalfa moisture concentrations between irrigation treatments in the third and fourth cuttings (Table 2). The moisture concentration of harvested alfalfa in the first cutting in the furrow irrigation treatment was significantly higher than in the 8-inch depth and in the 16-inch depth treatments. In the second cutting the opposite situation occurred. The moisture concentration of harvested alfalfa in the second cutting in the furrow irrigation treatment was significantly lower than in the 8-inch depth and in the 16-inch depth treatments. A possible explanation for these results is that under the cooler temperatures during the first cutting soil moisture was higher under furrow irrigation which maintained higher hay moisture at harvest. During the second cutting the opposite occurred, with higher temperatures during the second cutting soil moisture was lower under furrow irrigation which caused lower hay moistures at harvest than in the SDI treatments.

Table 2. Moisture concentration of harvested alfalfa hay in the subsurface drip irrigation study at Colorado State University, Western Colorado Research Center, Fruita, CO during 2014.

Treatment	First cutting	Second cutting	Third cutting	Fourth cutting
	Moisture content (%)			
16-inch drip line depth	21.3	24.1	22.4	20.2
8-inch drip line depth	21.4	23.2	22.0	20.0
Furrow irrigation comparison	23.4	21.9	22.5	20.7
Ave	22.0	23.1	22.3	20.3
CV (%)	3.8	2.4	3.0	4.8
LSD (0.05)	1.5	1.0	NS	NS

Growing alfalfa using SDI was much more efficient in producing harvestable alfalfa hay than when alfalfa is produced using furrow irrigation (Table 3). In 2014, 16.42 acre inches of water were applied to each of the SDI treatments, and under furrow irrigation 65.5 inches of water were applied to the field with 39.8 inches of tailwater (runoff) and 31.2 inches of infiltration water. Thus, with furrow irrigation nearly 4 times more water was needed than in the SDI to produce the same amount of alfalfa hay. In other words, compared to furrow irrigation, 49.1 inches less water was required under SDI to produce the same amount of alfalfa hay compared to alfalfa grown with furrow irrigation. Effective rainfall was not included in these calculations.

Table 3. Subsurface drip irrigation demonstration: water applied per dry ton of alfalfa at the Western Colorado Research Center, Fruita, CO.

Treatment	**Inches of water per dry ton of alfalfa**
16-inch drip line depth	1.81
8-inch drip line depth	1.85
Furrow irrigation	6.86[1]

[1]Total amount of irrigation water applied under furrow irrigation was used in the calculation.

Soil samples were collected in March 2014 from 4 depths- the soil surface, 1, 2, and 3-foot depths in the three irrigation treatments. Soil salinity was determined using a Kelway tester and the data obtained were corrected to a saturated paste electrical conductivity test. Soil salinity tended to increase with soil depth, but there did not appear to be salinity differences among the irrigation treatments (Table 4). Furthermore, salinity values among the irrigation treatments at the soil surface were all less than 1 mmhos/cm and did not reach a level that would be damaging to alfalfa (Soltanpour and Follett, 1995. Crop tolerance to soil salinity. No. 0.505. Colorado State University Cooperative Extension. Fort Collins, CO). A concern has been expressed that SDI could increase soil salinity at or near the soil surface. Although these data are non-replicated it appears that SDI does not increase soil salinity at the soil surface or at deeper depths that would be detrimental to crop production beyond what occurs under furrow irrigation. Keeping in mind that SDI does not allow for periodic leaching irrigations to flush soils in which salinity levels may increase to a damaging level.

Table 4. Soil salinity determined in the subsurface drip irrigation study at Colorado State University, Western Colorado Research Center, Fruita, CO during spring 2014.

Irrigation treatment	Soil sampling depth (ft)	Soil salinity (mmhos/cm)
Furrow	0	0.4
	1	0.4
	2	0.6
	3	1.2
16-inch	0	0.4
	1	1.0
	2	1.6
	3	1.6
8-inch	0	0.7
	1	1.1
	2	1.4
	3	0.7

Forage quality of alfalfa is important to producers and buyers. Forage quality of the alfalfa grown under the three irrigation treatments was excellent for all four cuttings in 2014. Alfalfa grown under SDI and furrow irrigation in 2014 did not affect ADF, fat, phosphorus, or TDN in any of the four cuttings (Table 5).

Alfalfa grown under SDI and furrow irrigation in 2014 affected one or more forage quality factors in all four cuttings (Table 5). In the first cutting only one forage quality factor was affected by irrigation treatments. In the second cutting, six forage quality factors were affected. In the third cutting four forage quality factors was affected while three forage quality factors were affected by irrigation treatments in the fourth cutting.

In the first cutting in 2014 potassium concentrations in the 16-inch and the 8-inch SDI treatments were increased by 23% and 16%, respectively, compared the furrow irrigation treatment (Table 5).

The six forage quality factors affected by irrigation treatment in the second cutting in 2014 were ash, potassium, magnesium, neutral detergent fiber (NDF), crude protein, and relative feed value (RFV) (Table 5). Ash concentrations in the 16-inch and the 8-inch SDI treatments ash were increased by 12% and 10%, respectively, compared to the control treatment. Potassium concentrations in the 16-inch and the 8-inch SDI treatments were increased by 37% and 39%, respectively, compared to the control treatment. Magnesium concentrations in the 16-inch and the 8-inch SDI treatments were decreased by 7% and 10%, respectively, compared to the control treatment.

NDF in the 16-inch SDI treatment was decreased by 10% compared to the control treatment. There was no significant difference in NDF concentration between the 8-inch SDI treatment and the furrow irrigation treatment in the second cutting in 2014. Neutral detergent fiber is a forage quality factor for digestibility. NDF is an indicator of the structural components of the plant. NDF is a predictor of voluntary intake because it provides bulk fiber. In general, low NDF values are desired because NDF increases as forages mature.

Crude proteins in the second cutting in 2014 were increased in the 16-inch and the 8-inch SDI treatments by 11% and 7%, respectively, compared to the control treatment. RFV in the 16-inch SDI treatment was increased by 16% compared to the control treatment. There was no significant difference in RFV concentration between the 8-inch SDI treatment and the furrow irrigation treatment in the second cutting in 2014.

The four forage quality factors affected by irrigation treatment in the third cutting in 2014 were potassium, NDF, crude protein, and RFV (Table 5). Potassium concentrations in the 16-inch and the 8-inch SDI treatments were increased by 26% and 14%, respectively, compared to the control treatment. NDF in the 16-inch SDI treatment was decreased by 11% compared to the control treatment. There was no significant difference in NDF concentration between the 8-inch SDI treatment and the furrow irrigation treatment in the second cutting in 2014.

Crude protein in the third cutting in 2014 in the 16-inch and the 8-inch SDI treatments was increased by 11% compared to the control treatment. There was no significant difference in crude protein concentration between the 8-inch SDI treatment and the furrow irrigation treatment in the second cutting in 2014. RFV in the 16-inch SDI treatment was increased by 18% compared to the control treatment. There was no significant difference in RFV concentration between the 8-inch SDI treatment and the furrow irrigation treatment in the second cutting in 2014.

The three forage quality factors affected by irrigation treatment in the fourth cutting in 2014 were calcium, potassium, and magnesium (Table 5). Calcium concentrations in the 16-inch and the 8-inch SDI treatments were decreased by 12% and 9%, respectively, compared to the control treatment. Potassium concentrations in the 16-inch and the 8-inch SDI treatments were increased by 26% and 31%, respectively, compared to the control treatment. Magnesium concentrations in the 16-inch and the 8-inch SDI treatments were each decreased by 13% compared to the control treatment.

Data obtained in 2014 indicate that not only is irrigation water used much more efficiently to produce high yields but important forage quality factors can also be improved when alfalfa is grown under SDI as compared to furrow irrigation.

Table 5. Forage quality analysis for acid detergent fiber (ADF), ash, calcium (Ca), far, potassium (K), magnesium (Mg), neutral detergent fiber (NDF), and phosphorus (P) in subsurface drip and furrow-irrigation alfalfa at the Colorado State University, Western Colorado Research Center at Fruita during the 2014 growing season.

Treatment	ADF	Ash	Ca	Fat	K	Mg	NDF	P
	%	%	%	%	%	%	%	%
First cutting								
16-inch depth	28.8	9.37	1.46	2.14	2.56a	0.31	33.68	0.36
8-inch depth	30.0	9.23	1.42	2.04	2.42a	0.29	34.88	0.35
Furrow	28.6	8.88	1.57	2.19	2.08b	0.34	33.45	0.34
Second cutting								
16-inch depth	31.5	9.82a	1.38	1.70	2.66a	0.28b	37.05b	0.32
8-inch depth	33.7	9.57a	1.34	1.65	2.70a	0.27b	39.58ab	0.33
Furrow	34.4	8.73b	1.50	1.74	1.94b	0.30a	41.20a	0.32
Third cutting								
16-inch depth	30.4	10.5	1.50	1.92	2.68a	0.32	34.98b	0.35
8-inch depth	31.9	10.0	1.50	1.87	2.42ab	0.29	36.85ab	0.33
Furrow	33.5	9.4	1.59	1.89	2.12b	0.33	39.52a	0.34
Fourth cutting								
16-inch depth	29.0	11.3	1.77b	1.75	2.58a	0.34b	33.45	0.35
8-inch depth	28.3	11.8	1.83b	1.86	2.68a	0.34b	31.68	0.35
Furrow	28.2	11.1	2.02a	2.00	2.05b	0.39a	32.10	0.35

[†]Denotes digestible NDF at 48 hours of incubation.

Table 5 (continued). Forage quality analysis for crude protein, relative feed value (RFV), and total digestible nutrients (TDN) in subsurface drip and furrow-irrigation alfalfa at the Colorado State University, Western Colorado Research Center at Fruita during the 2014 growing season.

Treatment	Crude protein	RFV	TDN
	%	%	%
First cutting			
16-inch depth	19.1	184	70.3
8-inch depth	18.6	175	69.0
Furrow	19.0	186	70.5
Second cutting			
16-inch depth	20.2a	162a	67.3
8-inch depth	19.5a	148ab	64.8
Furrow	18.2b	140b	64.1
Third cutting			
16-inch depth	21.0a	174a	68.5
8-inch depth	20.5ab	162ab	66.9
Furrow	19.0b	147b	65.0
Fourth cutting			
16-inch depth	21.7	185	70.0
8-inch depth	22.2	196	70.8
Furrow	22.4	194	70.9

<u>Task 5: Outreach and Reporting. **In progress**.</u>

The subsurface drip irrigation study at the Western Colorado Research Center at Fruita has been highlighted on the home page of the Colorado Agricultural Experiment Station for many months during 2014 and early 2015 at http://aes.agsci.colostate.edu/.

Pearson, C. H. 2014. Using subsurface drip irrigation in alfalfa in western Colorado. pps. 14-25. In: Western Colorado Research Center 2013 Research Report. Colorado State University, Agricultural Experiment Station and Extension, Technical Report TR14-06. Fort Collins, Colorado.

Tour of current alfalfa research at the Western Colorado Research Center at Fruita for alfalfa seed industry representatives from around Colorado. July 31, 2014. Fruita, Colorado. 5 people attended. We had an extensive tour at the Research Center on alfalfa which included detailed information about the SDI system.

Tour of current research at the Western Colorado Research Center at Fruita for local VIPs. August 27, 2014. Fruita, Colorado. 50 people attended. We had several stops around the Grand Valley with one stop being at the Research Center where I gave an oral presentation which included information about the subsurface drip irrigation system.

This document is the report for 2014.

Program Contact

Calvin Pearson

Dr. Calvin H. Pearson, Professor
Research Agronomist
Colorado State University
Western Colorado Research Center
1910 L Road
Fruita, CO 81521
970-858-3629, ext. 2
fax 970-858-0461
calvin.pearson@colostate.edu
website: www.colostate.edu/programs/wcrc