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Colorado State University

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Western Colorado Research Center

2013 Research Report

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Agricultural Experiment Station

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Contents

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Site Descriptions

Fruita Site

1910 L Road
Fruita, *CO 81521*
Tel (970) 858-3629, *fax* (970) 858-0461

The Fruita site is located 15 miles northwest of Grand Junction. With an average growing season of 180 days at an elevation of 4600 feet, a diversity of agronomic research is conducted at the Western Colorado Research Center at Fruita, including variety performance trials in alfalfa, corn silage, corn grain, canola, grasses, small grains; new and alternative crops; irrigation; cropping systems; soil fertility; and new crop trait evaluation. The Colorado Foundation Bean Program is located at Fruita.

Orchard Mesa Site

3168 B1/2 Road
Grand Junction CO 81503
Tel (970) 434-3264, *fax* (970) 434-1035

The Orchard Mesa site is located 7 miles southeast of Grand Junction. Site elevation is approximately 4700 feet with an average growing season of 182 frost-free days. The research conducted at this site includes tree fruits, wine grape production, and ornamental horticulture. This site has alternative crops (e.g. pistachio nuts and edible honeysuckle), greenhouses, offices, and laboratory facilities.

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NC-140 Apple Rootstock Evaluation

Amaya Atucha[1,2]

Summary

An apple rootstock experiment designed to evaluate new apple rootstocks was established in 2010 at WCRC-Orchard Mesa as part of a multistate NC-140 collaborative study. 'Honeycrisp' scion grafted on 30 rootstocks were planted in May 2010 in a completely randomized block design with 9 replications. Data on tree survival, trunk circumference growth, and the number of suckers have been recorded since 2010, and fruit yield, total number of fruit per tree, and yield efficiency has been recorded since 2013. The results of 2013 growing season are presented in this report.

Introduction

Over the last decade, apple production in Western Colorado has experienced a substantial decrease due mainly to high labor costs and low returns. High vigor trees that can take up to a decade to achieve their maximum yield potential are not an economically viable option for growers. However, the introduction of new dwarfing and more productive rootstocks in combination with higher priced new varieties has the potential of achieving high early and mature yields of improved fruit quality with reduced labor costs. The objective of this study is to evaluate the influence of rootstocks on 'Honeycrisp' apple tree characteristics grown in Western Colorado using sustainable management systems.

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[2] Assistant Professor, Fruit Specialist, Dept. of Horticulture and Landscape Architecture, Agricultural Experiment Station, Western Colorado Research Center at Orchard Mesa.

Materials and Methods

As part of the 2010 NC-140 Apple Rootstock Trial, a planting of 'Honeycrisp' on 30 rootstocks was established at CSU Western Colorado Research Center at Orchard Mesa. The planting includes three replications in a randomized-complete-block design, with up to three trees of a single rootstock per replication. Trees were spaced at 4x12 feet, and trained to the tall spindle system. Tree trunk circumference was first recorded at planting, and thereafter yearly during the fall (October). The total number of suckers and tree mortality has been recorded yearly since 2010. Yield was recorded as total kilograms of fruit per tree, and average fruit weight (grams) was calculated as the ratio between total kilograms of fruit per tree and total number of fruits per tree. Yield efficiency (kg/cm^2) was calculated as the ratio between total kilograms of fruit per tree and tree trunk cross sectional area (TCSA).

Results

The most vigorous stocks included B.70-20-20, B.64-194, and B.7-20-21. The most dwarfing stock in this trial was B.71-7-22 (Table 1). The trial had a poor crop this year due to spring frost and alternate bearing. The most yield efficient stock in 2013 was CG.4004, followed by CG.5222 and Supp.3. Fruit size was largest on M.9Pajam2, followed by B.70-20-20, and smallest on CG.5087.

Table 1. Colorado 2010 Honeycrisp Apple Rootstock Trial (2013 Data)

Rootstock	Yield 2013 (kg/tree)	Fruit Weight (g/fruit)	TCSA 2013 (cm^2)	TCSA 2013 (% of M9)	Yield efficiency 2013 (kg/cm^2)	Yield efficiency Cumulative
B.71-7-22	0.3	83	3.16	28	0.10	0.32
B.9	0.7	148	5.58	50	0.13	0.61
CG.2034	1.3	179	6.85	62	0.18	0.36
CG.4003	0.7	162	9.46	85	0.07	0.36
CG.4214	2.6	168	10.30	93	0.25	0.68
G.11	1.2	131	10.47	94	0.12	0.41
G.202N	0.2	72	11.02	99	0.02	0.12
M.9	1.0	168	11.12	100	0.09	0.58
B.10	2.3	152	11.27	101	0.20	0.41
G.41TC	2.5	164	11.80	106	0.21	0.42
CG.4814	0.1	100	12.08	109	0.01	0.42
CG.5087	0.1	50	12.37	111	0.01	0.31
M.26EMLA	2.0	152	12.38	111	0.16	0.41
Supp.3	3.5	152	12.84	115	0.27	0.32
G.935TC	1.1	188	12.91	116	0.09	0.40
CG.3041	1.5	159	13.09	118	0.11	0.32
G.202TC	2.6	156	13.21	119	0.19	0.30
CG.4004	5.5	173	14.78	133	0.37	0.46
CG.5222	4.5	190	15.16	136	0.30	0.35
B.70-6-8	1.1	150	16.91	152	0.06	0.15
G.5202	3.3	168	17.09	154	0.19	0.50
PiAu51-11	2.2	166	17.23	155	0.13	0.27
B.7-3-150	3.1	160	17.65	159	0.18	0.31
B.67-5-32	2.6	162	17.68	159	0.14	0.16
M.9Pajam2	2.7	229	18.31	165	0.15	0.42
CG.3001	0.0	0.0	18.52	167	0.00	0.35
PiAu9-90	2.6	109	18.72	168	0.14	0.17
B.7-20-21	3.9	160	21.61	194	0.18	0.26
B.64-194	5.6	178	23.24	209	0.24	0.26
B.70-20-20	4.2	192	28.67	258	0.15	0.16

NC-140 Peach Rootstock Evaluation

Amaya Atucha[1,2]

Summary

A peach rootstock experiment designed to evaluate new peach rootstocks was established in 2009 at WCRC-Orchard Mesa as part of a multistate NC-140 collaborative study. 'Redhaven' grafted on 17 rootstocks (Controller 5; Krymsk1; Fortuna; HBOK-10; KV010-123; HBOK-32; P. Americana; Guardian; Mirobac; Lovell; Penta; KV010-127; I. California; Krymsk 86; Viking; Br. Hybrid 5; Atlas) were planted in May 2009 in a completely randomized block design with 8 replications. Data on tree survival, trunk circumference growth, and number of suckers have been recorded since 2009, and fruit yield, total number of fruit per tree, and yield efficiency has been recorded since 2011. The results of 2013 growing season are presented in this report.

Introduction

In the past decade multiple new peach rootstocks have been introduce in the country from breeding programs all over the world. These new rootstocks may have the potential of improving orchard management efficiency through specific attributes such as: dwarfism, resistance to pests and diseases, and greater survival under adverse conditions. A multiyear evaluation of these rootstocks under multiple locations varying on climatic, edaphic and biotic conditions is essential to determine the strength and limitations of each new rootstock. The aim of this study is to evaluate and identify new peach rootstocks suitable for Western Colorado.

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[2]Assistant Professor, Fruit Specialist, Dept of Horticulture and Landscape Architecture, Agricultural Experiment Station, Western Colorado Research Center at Orchard Mesa.

Materials and Methods

'Redhaven' scion grafted to 17 different rootstocks (Controller 5; Krymsk1; Fortuna; HBOK-10; KV010-123; HBOK-32; P. Americana; Guardian; Mirobac; Lovell; Penta; KV010-127; I. California; Krymsk 86; Viking; Br. Hybrid 5; Atlas) were planted at WCRC-OM site (Grand Junction, CO) during the spring of 2009 in a completely randomized block design with 8 replications. Tree trunk circumference was first recorded 2 weeks after planting, at 18" above ground level, and during the fall (October) every year since 2009. The total number of suckers and tree mortality was recorded yearly since 2009. Yield was recorded as total kilograms of fruit per tree, and average fruit weight (grams) was calculated as the ratio between total kilograms of fruit per tree and total number of fruits per tree. Yield efficiency (kg/cm^2) was calculated as the ratio between total kilograms of fruit per tree and tree trunk cross sectional area (TCSA).

Results

During 2013 several trees in the peach rootstock trial had to be removed due to Cytospora canker. Viking had the poorest survival rate (50%), followed by Atlas, Krymsk 86, and KV010- 123 (Table 1). The high tree mortality with Viking rootstock has been observed in other research plots at the station, and is probably due to its high sensitivity to water stress during the establishing years. The most vigorous stock was Atlas followed by Br. Hybrid 5, Viking, and Krymsk 86. The most dwarfing stock was Controller 5 followed by Krymsk 1, and Fortuna. Yield in 2013 was highest on Atlas, followed by Br. Hybrid 5 and Viking, and lowest on Imp. California. The most yield efficient stock in 2013 was Krymsk 1, followed by Guardian. Average fruit size fruit size was largest on Viking, followed by Atlas, and smallest on Fortuna. Trees on Mirobac had the most root suckers per tree, followed by Guardian.

Table 1. Colorado 2009 'Redhaven' Peach Rootstock Trial (2013 Data)

Rootstock	Yield 2013 (kg/tree)	Fruit Weight 2013 (g/fruit)	TCSA 2013		Yield efficiency		Root suckers 2013 (#/tree)	Survival Alive/ planted
			(cm^2)	(% of Lovell)	2013 (kg/cm^2)	Cum. Y.E.		
Controller 5	1.63	129	23.87	82	0.07	0.26	0.00	7/8
Krymsk 1	3.39	176	23.99	82	0.15	0.37	2.83	7/8
Fortuna	1.54	115	27.99	88	0.06	0.16	0.00	7/8
HBOK-10	3.39	145	28.44	89	0.12	0.36	0.00	7/8
KV010-123	3.10	169	32.49	95	0.09	0.38	3.83	6/8
HBOK-32	2.95	152	32.65	95	0.09	0.26	1.75	8/8
P. americana	2.46	144	35.16	99	0.07	0.19	2.00	7/8
Guardian	4.19	177	35.88	100	0.14	0.42	5.86	7/8
Mirobac	3.13	170	39.06	104	0.08	0.23	8.14	7/8
Lovell	3.34	153	39.28	105	0.08	0.25	4.50	8/8
Penta	2.95	164	39.90	105	0.07	0.25	0.14	7/8
KV010-127	2.99	160	40.82	107	0.07	0.28	4.86	7/8
I. California	1.34	184	40.85	107	0.03	0.22	0.00	8/8
Krymsk 86	3.39	166	47.08	115	0.07	0.21	0.00	6/8
Viking	4.80	195	49.92	118	0.09	0.25	0.00	4/8
Br. Hybrid 5	5.67	187	51.03	119	0.11	0.30	0.86	7/8
Atlas	6.34	191	53.79	122	0.12	0.36	0.17	6/8

Using Subsurface Drip Irrigation in Alfalfa in Western Colorado

Calvin H. Pearson,[1] Denis Reich[2], Wayne Guccini[3], and Luke Gingerich[4]

Summary

Increasing competition for water resources and demands for irrigation practices that are environmentally friendly are ongoing motivations to use irrigation water more efficiently. The objective of this study was to compare irrigation performance, forage yields, and forage quality of subsurface drip irrigation (SDI) with traditional furrow irrigation at the Colorado State University, Agricultural Experiment Station, Western Colorado Research Center at Fruita during the 2013 growing season. Based on data obtained from soil moisture sensors, soil moisture was concentrated in the soil profile where alfalfa roots can readily obtain soil moisture without water losses occurring to evaporation or deep percolation. There were no significant differences in alfalfa forage yields between irrigation treatments in the first, third, fourth, and total 2013 forage yields. The forage yield of the furrow irrigation treatment in the second cutting was significantly lower that SDI treatments. Forage quality of the alfalfa grown under the irrigation treatments was excellent for all four cuttings in 2013. There were no significant differences among irrigation treatments for any of the forage quality factors evaluated. In 2013, 18.6 inches of water were applied to SDI, and under furrow irrigation 71.0 inches of water was applied to the field with 39.8 inches of tailwater (runoff) and 31.2 inches of infiltration water. Compared to furrow irrigation, 12.6 inches less water was required under SDI to produce the same amount of alfalfa hay.

Introduction

Increasing competition for water resources and demands for irrigation practices that are environmentally friendly are motivating factors to use agricultural irrigation water more efficiently. Additionally, sustainable crop production systems require more efficient irrigation water applications. This dictates the use of improved management by irrigators to avoid overwatering to reduce deep percolation and salt and selenium loading and other contaminants into water supplies that affect downstream users.

When irrigation water is cheap, plentiful, readily accessible, and is a major factor to achieve high crop yields, overwatering is likely (Sadler and Turner, 1994). Good management along with proven technology is essential to apply irrigation water in an optimum manner. The use of good management and proven technology would likely result in a reduction in the amount of water needed to meet crop water requirements (Clegg and Francis, 1994).

In Colorado, nearly 660,000 acres (6,578 farms) are furrow irrigated (USDA, 2008). Furrow irrigation is a partial surface flooding method of irrigation where water is applied in furrows at

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the top of a sloping field and gravity moves the water to the end of the field. Numerous conditions influence the amount of water that infiltrates into the soil along the length of the field and the amount of water that drains off the end of the field as runoff or tailwater (Pearson et al., 1998).

Subsurface drip irrigation (SDI) is a low pressure, high efficiency irrigation system that uses buried drip lines (tube or tape) to meet crop water needs. SDI technology has been commercialized since the 1960s, but in recent times has gained in popularity primarily because of increasing scarcity of water resources and advancements in SDI technologies (Reich, 2009).

With SDI, water is applied below the soil surface at a depth to meet crop water needs while allowing for crop production using mechanization. Optimum management and performance of SDI systems can reduce soil crusting, use less water, eliminate surface water and evaporation, eliminate deep percolation, eliminate irrigation water runoff, and reduce weeds and diseases. Furthermore, high fertilizer application efficiencies are possible when fertilizers are applied through SDI systems.

Purchase and installation costs of SDI systems are higher than those for furrow irrigation. The cost of the SDI equipment and associated installation costs vary from $1,000 to $2,000 per acre depending on various factors specific to the farm and field situation. The life of an SDI system is expected to range from 12 to 15 years (Reich, 2009).

The objective of this study was to compare irrigation performance, forage yields, and forage quality of SDI with traditional furrow irrigation at the Colorado State University, Agricultural Experiment Station, Western Colorado Research Center at Fruita. SDI drip lines were installed at 8-inch and 16-inch depths to compare the performance of these two drip lines. Drip lines at a 16-inch depth are preferred in many cases over 8-inch deep drip lines to allow tillage operations without damaging the buried drip lines. This report describes results obtained during the 2013 growing season.

Materials and Methods

The refurbishing of the existing irrigation water filtration system was completed on May 10, 2012. Subsurface drip tape was installed in a 1.5 acre field on May 11, 2012. The drip tape was installed two lines at a time using a heavy duty drip tape applicator pulled by a John Deere 2955 tractor (Fig. 1). The drip tape was installed at two depths (8 and 16-inch depths 30-inches apart. The two drip line depths were separated into two irrigation zones (Fig. 2).

Along with the SDI field another 1.5 acre field, with the same soil type and located nearby, was concurrently planted with the same alfalfa variety. The difference between the two fields

Fig. 1. Installing drip tape on May 11, 2012 at the Colorado State University Western Colorado Research Center at Fruita.

was the second field was furrow-irrigated with gated pipe. Seedbed preparation, planting date and commencement of irrigation was the same for both the SDI plot and the furrow-irrigated plot.

Round-up Ready® alfalfa variety “Denali” was planted at a ¼ to ½ inch depth 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.

We began applying water through the SDI system on May 16, 2013 (Fig. 3). The soil near the soil surface was challenging to wet. To completely wet the soil surface and the seed a short surface irrigation with gated pipe was required.

Water use was monitored at a CoAgMet weather station located on station at the Western Colorado Research Center near the study site. Water use was also monitored using an atmometer (ETgage Company, Loveland, CO). Irrigation water application was determined with a gated pipe flow meter (McCrometer Model MO300 flow meter, Hemet, CA installed in gated pipe section, MCCrometer Great Plains, Model MD306, Aurora, NE) and tailwater was determined using a broad-crested flume fitted with a water level sensor (Global Water, Model WL16U-03,25ft, College Station, TX).

Soil moisture was monitored using data loggers (M. K. Hanson, model no. AM400-02A, Wenatchee, WA). Soil moisture sensors (Watermark, model no. 200SS, Irrometer Co., Riverside, CA) were buried at 8, 16, and 32-inch depths. Sensors were installed approximately 30 feet from the top and bottom of the field, at approximately the middle of the 16-inch and 8-inch zones. In the furrow irrigation field, soil moisture sensors were installed in the middle of the field from side to side and at approximately ¼ of the way down from the top and at approximately ¼ of the distance up from the bottom of the field.

Fig. 2. Two subsurface drip zones with flush valves and drip lines exiting the main lines at the Colorado State University Western Colorado Research Center at Fruita.

Irrigation water with the SDI system was applied at 0.11 inch per hour. We irrigated 6 hrs/zone on April 12, 13, 14, and 15, 2013. We irrigated 4 hrs/zone on May 9, 15, 23, and 27, 2013. After first cutting we applied at 4 hrs/zone twice a week. The SDI irrigation system was shut down on June 24, 2013 for second cutting. The SDI system was restarted on June 27, 2013 at 4 hrs/zone 3 days/week. The SDI system was shut off on July 26, 2013 because of rain and for third cutting. The SDI system was turned back on three times per week at 4 hrs/zone until a rainy period occurred in September. The SDI irrigation system did not run much in September and October 2013 because of third and fourth cutting harvests and the considerable rain we experienced during this period.

Results and Discussion

The alfalfa plant stands in the SDI treatments and the furrow irrigation block in 2013 were thick, uniform, and vigorous. All alfalfa was free of weeds (Fig. 4).

On September 26, 2012 the CoAgMet weather station at the Experiment Station logged the cumulative evapotranspiration (ET) for a full stand of alfalfa at 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 45.0 inches for the same period as the CoAgMet weather station in 2012. Seasonal efficiency was estimated at 71 percent or better (Note that 2012 was the establishment year for alfalfa and to become experienced with the operation of the SDI system).

Precipitation in western Colorado is sporadic and only provides a small contribution to crop production (Fig. 5). During May, July, August, and September 2013 there were 5, 8, 10, and 11 rain events, respectively (Fig. 5). No rain occurred during June 2013. The total amount of precipitation that occurred from May through September was 5.23 inches.

In 2013, there was excellent agreement in the seasonal ET derived from the CoAgMet weather station and the atmometer that was located at the top of the SDI alfalfa field. The seasonal ET from the weather station was 41.3 inches while the seasonal ET determined by the atmometer during the same time period was 41.1 inches (Fig. 6).

The cumulative irrigation water applied using the SDI system along with the four cutting dates are shown in Fig. 7. During the 2013 growing season 18.5 inches of water was applied using SDI to produce the alfalfa crop. Certainly, some of the 5.23 inches of precipitation that occurred during May through September would have contributed to crop production. Also, the antecedent moisture that occurred during winter 2012-13 would have also been available for crop growth.

The irrigation data presented in Fig. 8 indicate the irrigation efficiency that can be achieved with SDI at the 8-inch drip line depth over an entire cropping season the year following alfalfa stand establishment and with the SDI system operating under field conditions. The soil surface was not wetted during the growing season and thus evaporation from the soil surface was minimized. Additionally, the response of Sensor #3 positioned at a 32-inch depth indicate that the soil is quite dry at the deeper depths and thus deep percolation did not occur. Low Watermark sensor readings indicate greater soil water contents while high readings indicate low soil water contents. The response of Sensor #2 shows that irrigation water was being concentrated at the 16-inch depth at a location that was readily available to the alfalfa root system, thus, providing irrigation water to the alfalfa plant without applying water that is lost to 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 #2 and as shown in Fig. 8.

The data presented in Fig. 9 also indicate the irrigation efficiency that can be achieved with SDI when the drip lines were installed at 16-inch depths. More of the upper portion of the soil profile was drier during the growing season than at the 8-inch depth; thus, evaporation at the soil surface was further limited compared to SDI at the 8-inch depth. The response of all three sensors was quite similar at the 16-inch depth and was closer to each other than those in the 8-inch depth. This readily indicates that soil moisture is being concentrated in the soil profile where alfalfa roots can readily obtain soil moisture without losses occurring to evaporation or deep percolation. Again, we had considerable rain events during the month of September and this is indicated by the response shown from Sensors #1 and #2. The response of the 16-inch depth was similar to the 8-inch depth, except the soil moisture among the three depths were similar but concentrated lower down in the soil profile compared to the 8-inch depth.

Fig. 3. Pumping and filter station for the subsurface drip irrigation system at the Colorado State University Western Colorado Research Center at Fruita.

The data in Figs. 8 and 9 illustrate there are a range of soil moistures that are acceptable to obtain high efficiency irrigations using SDI that result in the production of high alfalfa yields without causing soil moisture losses to evaporation or deep percolation.

The responses of the sensors located at the three soil depths at the top end of the furrow-irrigated alfalfa field readily show the variations that occur under furrow irrigation (Fig. 10). Furrow irrigation wets the entire soil profile increasing the potential for deep percolation and increasing evaporation at the soil surface. Thus, more irrigation water is needed to accommodate significant water losses to evaporation and deep percolation in order to maintain high crop yields.

The response of the sensors at the three soil depths of alfalfa grown under furrow irrigation at the bottom end of the field (Fig. 11) is quite similar to the responses at the top end of the field (Fig. 10).

The first year of alfalfa is an establishment period. Two cuttings were obtained from both SDI and furrow plots during 2012. The two alfalfa cuttings were obtained on July 27, 2012 and September 23, 2012 with the SDI plots averaging 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 alfalfa averaged an annual total of 3.62 tons/acre of dry matter in 2012.

Fig. 4. Alfalfa field grown with the subsurface drip irrigation system in 2013 at the Colorado State University Western Colorado Research Center at Fruita.

In 2013, detailed yield data were obtained from four cuttings (Tables 1, 2), with water applied per ton of dry matter produced presented in Table 3.

There were no significant differences in alfalfa forage yields between irrigation treatments in the first, third, fourth, and total 2013 forage yields (Table 1). The forage yield of the furrow irrigation treatment in the second cutting was significantly lower that the SDI treatments.

Moisture concentrations of alfalfa were determined at harvest. There were no significant differences in harvested alfalfa moisture concentrations between irrigation treatments in the first, third, fourth, and total 2013 forage yields (Table 2). The harvested moisture concentration of alfalfa at the 16-inch depth was significantly higher than the 8-inch depth or the furrow irrigation treatment in the second cutting.

In 2013, 18.6 inches of water were applied to both SDI treatments, and under furrow irrigation 71.0 inches of water was applied to the field with 39.8 inches of tailwater (runoff) and 31.2 inches of infiltration water. Thus, the furrow irrigation used 1.68 times more water than the SDI to produce the same amount of alfalfa hay. In other words, compared to furrow irrigation, 12.6 inches less water was required under SDI to produce the same amount of alfalfa hay. When the total amount of applied irrigation water (71.0 inches) is considered, furrow irrigation used 3.8 times more water than the SDI to produce the same amount of alfalfa hay. However, much of the tailwater eventually flows back into the Colorado River for use by downstream users.

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 2013. There were no significant differences among the three irrigation treatments for any of the forage quality factors evaluated (Table 4).

Clearly, SDI uses irrigation water more efficiently than furrow irrigation and the data in this report indicate SDI can significantly reduce the amount of water needed to produce high alfalfa yields and high quality hay. Subsurface drip irrigation has been used successfully to produce alfalfa at other locations (Alam et al., 2002).

SDI offers advantages over furrow irrigation including increased efficiency, potentially fewer weeds, less disease, improved downstream water flow and quality, and more flexibility for field operations because the soil surface is not wetted. However, SDI has some disadvantages. It is expensive to install and maintenance costs may be higher. Irrigation water must be clean and thus water with sediment must be filtered. Pumps may be needed to provide the pressure required to operate an SDI system, thus, operating costs may be higher than furrow irrigation. Germinating shallow-planted seeds with SDI can be problematic and an additional irrigation system may be needed to provide surface moisture for a germination irrigation.

Acknowledgments

Appreciation is extended to Fred Judson and Kevin Gobbo (Western Colorado Research Center staff), Anna Mudd (summer hourly employee), and Evan Cunningham (summer intern) who assisted with this research. Funding support of this project was provided by the Colorado Water Conservation Board and the Colorado River District.

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Table 1. Alfalfa forage yields in the subsurface drip irrigation study at Colorado State University, Western Colorado Research Center, Fruita, CO during 2013.

Treatment	First cutting May 21	Second cutting June 25	Third cutting Aug. 13	Fourth cutting Sept. 28	Total 2013 forage yield
	Dry matter (tons/acre)				
16-inch drip line depth	3.32	2.72 A	2.39	1.44	9.88
8-inch drip line depth	3.61	2.82 A	2.15	1.46	10.04
Furrow irrigation comparison	3.64	2.44 B	2.45	1.34	9.87
Ave	3.52	2.66	2.33	1.41	9.93
CV (%)	6.4	5.8	7.8	6.4	5.2
LSD (0.05)	NS	0.27	NS	NS	NS

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

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 2013.

Treatment	First cutting	Second cutting	Third cutting	Fourth cutting
	Moisture content (%)			
16-inch drip line depth	23.6	26.1 A	24.7	22.3
8-inch drip line depth	23.1	24.8 B	25.6	21.7
Furrow irrigation comparison	22.9	24.3 B	24.5	22.6
Ave	23.2	25.0	25.0	22.2
CV (%)	4.4	2.9	3.2	2.8
LSD (0.05)	NS	1.2	NS	NS

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

Treatment	Inches of irrigation water applied per dry ton of alfalfa
16-inch drip line depth	1.88
8-inch drip line depth	1.85
Furrow irrigation	3.16

Table 4. Forage quality analysis for dry matter, crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), dNDF48, ash, fat, lignin, and calcium in subsurface drip and furrow-irrigation alfalfa at the Colorado State University, Western Colorado Research Center at Fruita during the 2013 growing season.

Treatment	Dry matter	Crude protein	ADF	NDF	dNDF48†	Ash	Fat	Lignin	Ca
	%	%	%	%	%	%	%	%	%
First cutting									
16-inch depth	96.9	20.4	31.4	38.0	18.0	9.6	1.80	7.30	1.29
8-inch depth	97.1	21.8	30.0	37.0	18.0	9.3	1.78	6.60	1.20
Furrow	97.0	21.6	31.0	37.9	18.2	8.8	1.78	6.88	1.14
Second cutting									
16-inch depth	96.6	21.6	35.7	42.3	17.8	8.9	1.58	6.70	1.20
8-inch depth	96.6	22.6	34.0	40.1	17.7	9.2	1.58	6.25	1.25
Furrow	96.8	21.4	35.4	42.4	18.3	9.4	1.68	6.80	1.27
Third cutting									
16-inch depth	97.2	20.2	35.0	41.9	18.8	8.4	1.88	6.92	1.39
8-inch depth	97.2	21.3	32.8	39.7	17.7	8.6	1.95	9.42	1.47
Furrow	97.2	18.8	36.2	44.0	19.4	8.4	1.85	7.40	1.28
Fourth cutting									
16-inch depth	95.4	22.4	30.8	36.6	16.4	10.9	1.72	6.80	1.54
8-inch depth	94.9	21.6	32.5	39.2	17.4	11.0	1.62	7.00	1.47
Furrow	94.6	21.8	32.4	39.0	17.4	11.0	1.58	7.05	1.46

†Denotes digestible NDF at 48 hours of incubation.

Table 4 (continued). Forage quality analysis for phosphorus, potassium, and magnesium in subsurface drip and furrow-irrigation alfalfa at the Colorado State University, Western Colorado Research Center at Fruita during the 2013 growing season.

Treatment	P	K	Mg
	%	%	%
First cutting			
16-inch depth	0.32	2.82	0.26
8-inch depth	0.32	2.68	0.28
Furrow	0.32	2.53	0.27
Second cutting			
16-inch depth	0.30	2.46	0.25
8-inch depth	0.31	2.52	0.28
Furrow	0.32	2.37	0.27
Third cutting			
16-inch depth	0.30	2.12	0.25
8-inch depth	0.30	1.96	0.28
Furrow	0.28	1.98	0.24
Fourth cutting			
16-inch depth	0.32	2.62	0.30
8-inch depth	0.33	2.60	0.30
Furrow	0.33	2.70	0.30

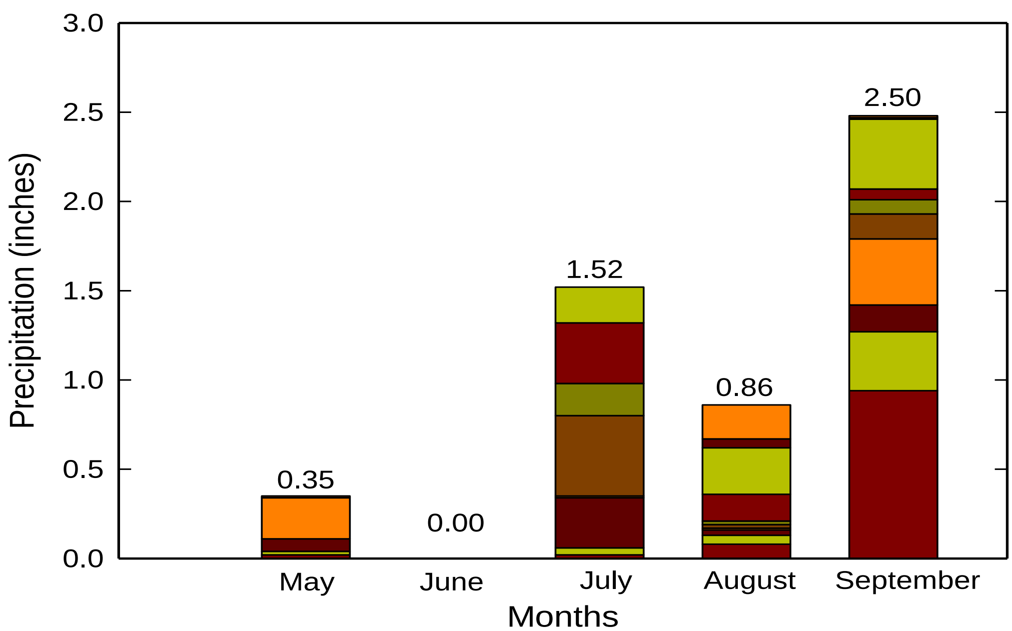

Fig. 5. Monthly precipitation at the Western Colorado Research Center at Fruita that occurred during the 2013 growing season. Rain events that occurred during the month are shown by the stacked bars.

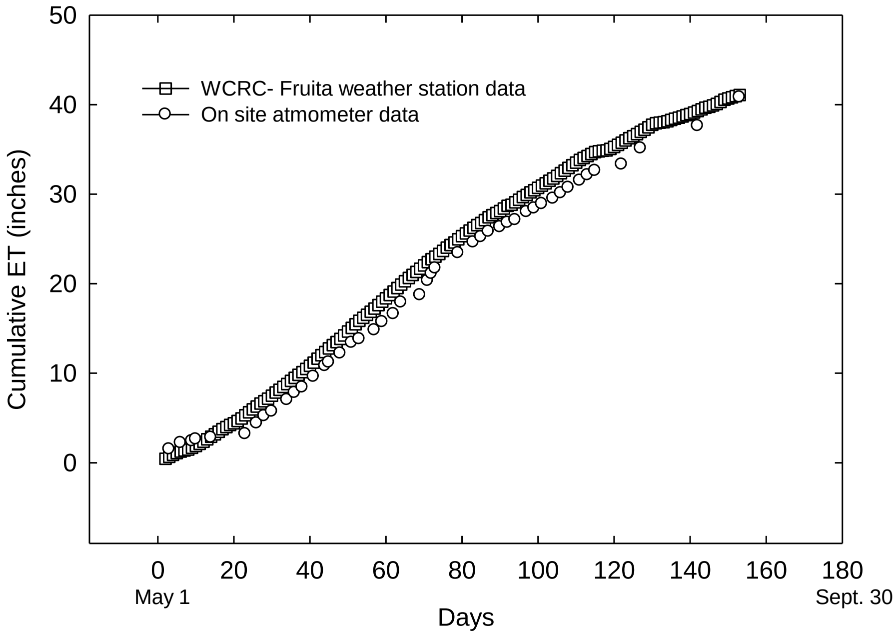

Fig. 6. Seasonal ET estimated by the research center CoAgMet station and with an atmometer located at the top of the SDI field. Note the agreement in ET between the automated weather station and the data from the atmometer.

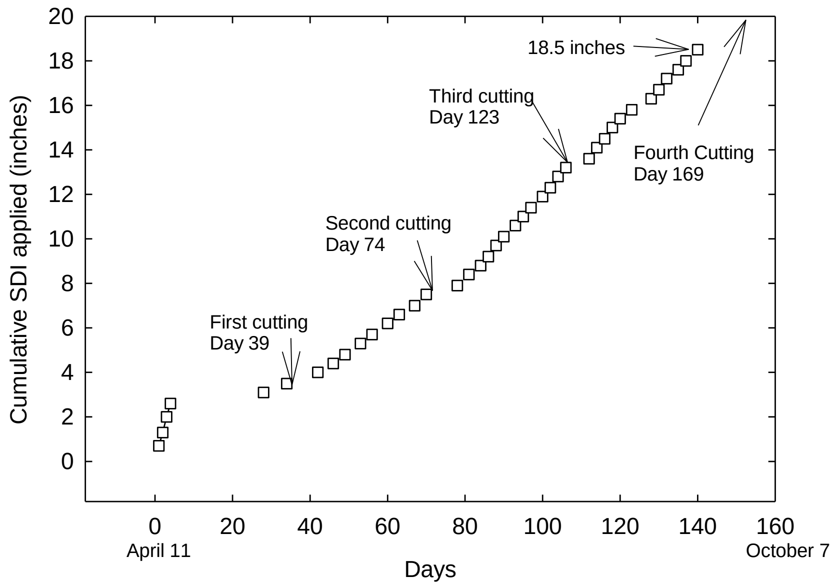

Fig. 7. Calculated cumulative irrigation water applied to alfalfa using a subsurface drip system Colorado State University, Western Colorado Research Center at Fruita during 2013.

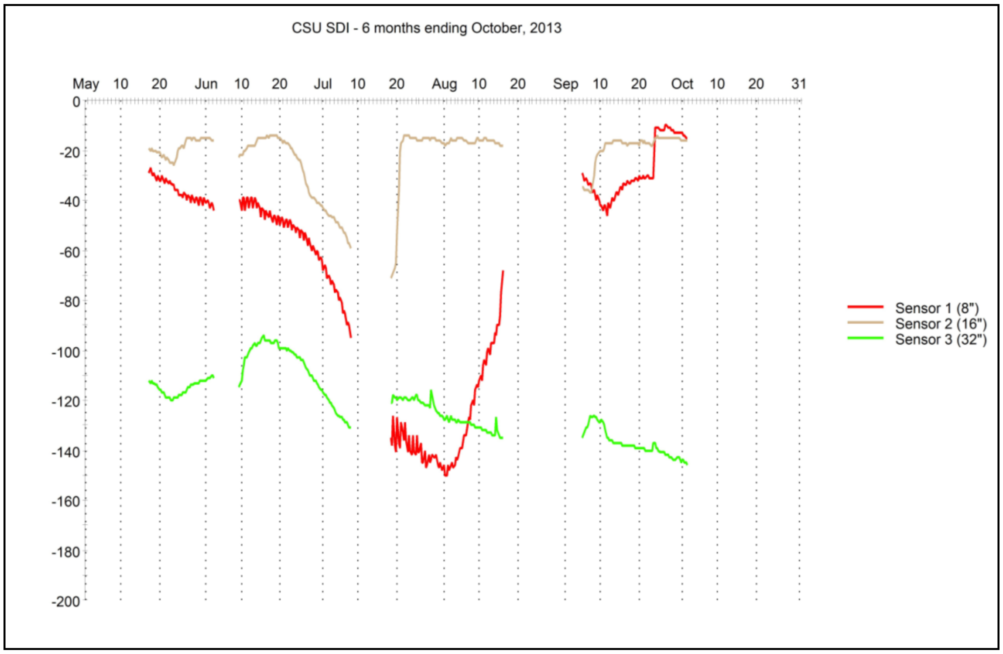

Fig. 8. Watermark sensor readings, which correlate with soil moisture contents, of alfalfa grown with subsurface drip irrigation (SDI) with drip lines installed at an 8-inch depth. Calendar date is the x-axis and the units on the y-axis are centibars.

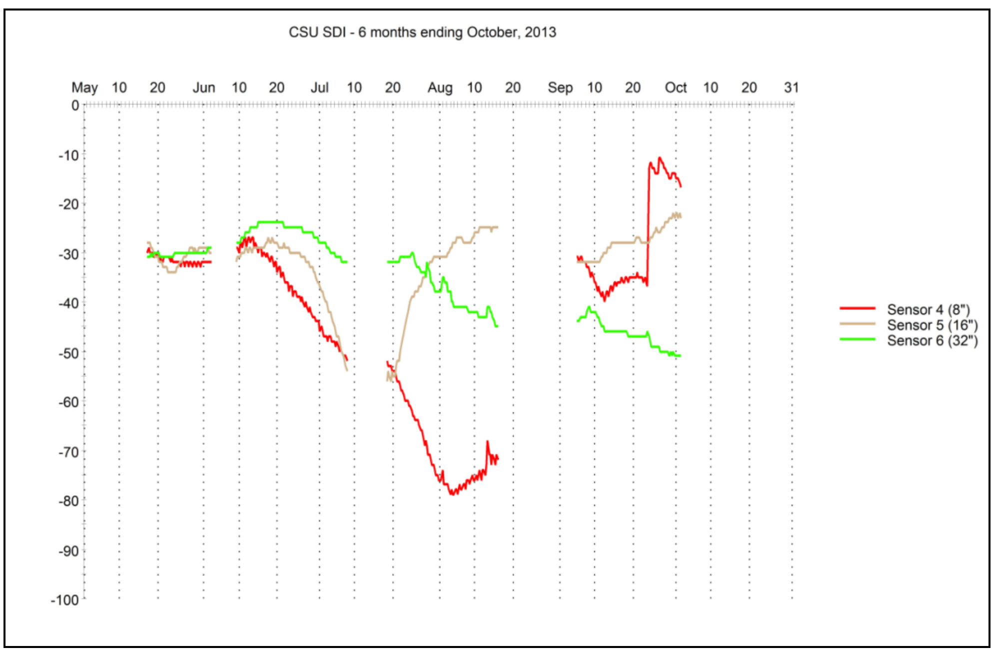

Fig. 9. Watermark sensor readings, which correlate with soil moisture contents, of alfalfa grown with subsurface drip irrigation (SDI) with drip lines installed at a 16-inch depth. Calendar date is the x-axis and the units on the y-axis are centibars.

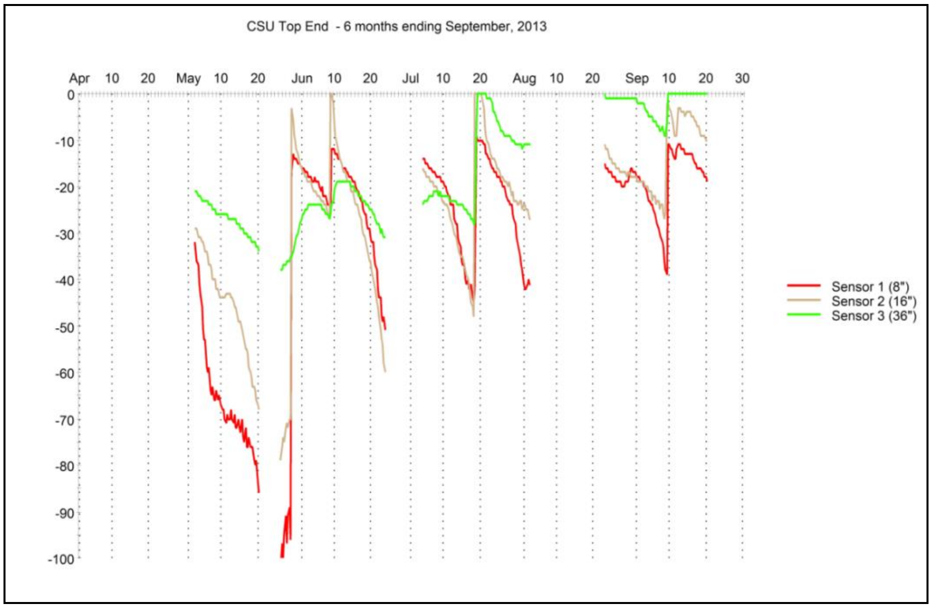

Fig. 10. Watermark sensor readings, which correlate with soil moisture contents, at the top end of the field in alfalfa grown with furrow irrigation. Calendar date is the x-axis and the units on the y-axis are centibars.

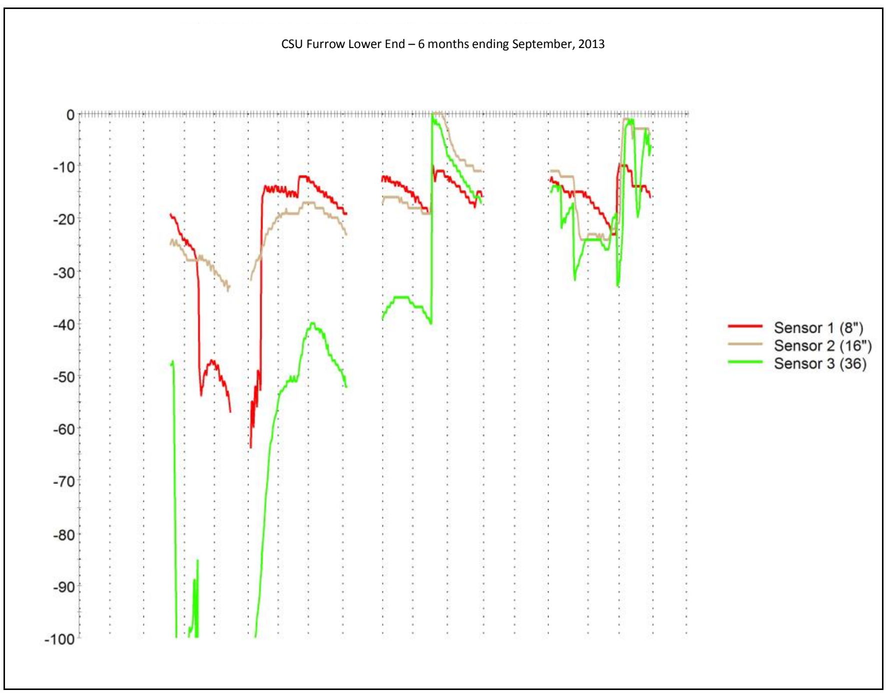

Fig. 11. Watermark sensor readings, which correlate with soil moisture contents, towards the bottom end of the field in alfalfa grown with furrow irrigation. Calendar date is the x-axis and the units on the y-axis are centibars.

Enhancing Sustainability of Alfalfa Production Using Biological Products

Calvin H. Pearson[1,2]

Summary

As costs for crop production inputs continue to increase, producers are increasingly interested in finding alternative technologies that reduce input costs while bolstering yields and product quality. Recently, crop production products have become commercially available to agriculture that are "biostimulants." These products are designed to stimulate beneficial microbes, balance soil pH to release soil nutrients, and provide essential micronutrients, among other things. The objective of this research was to evaluate FoliarBlend by Agri-Gro marketed by Bio-Tec Solutions for the performance of FoliarBlend in alfalfa grown for forage (hay) at Fruita, Colorado during the 2012-2013 growing seasons. Applying FoliarBlend increased forage yields significantly in the third and fourth cuttings in 2012 and FoliarBlend increased forage yield significantly in all four cuttings in 2013 when compared to the non-treated control. Total 2012 yield of alfalfa in the FoliarBlend treatment was 13% higher than in the control while the total 2013 yield of alfalfa in the FoliarBlend treatment was 52% higher than in the control. Application of FoliarBlend affected some forage quality factors and some plant nutrients in some cuttings, but a consistent response did not occur within years or across years. The results of the two years of the Biostimulant Study indicate that applying FoliarBlend in alfalfa may increase total growing season forage yields significantly. The 2013 yield increases that were achieved when FoliarBlend was applied in each cutting were impressive. This study has been conducted at only one location. Additional years of data from multiple locations are needed to determine how FoliarBlend will perform under a wide range of conditions and if application recommendations can be extrapolated to a multitude of environments and crop conditions.

Introduction

As costs for crop production inputs continue to increase, producers are increasingly interested in finding alternative technologies that reduce input costs while bolstering yields and product quality. Recently, crop production products have become commercially available to agriculture that are "biostimulants."

These proprietary products are designed to stimulate beneficial microbes, balance soil pH to release soil nutrients, and provide essential micronutrients, among other things.

The objective of this research was to evaluate FoliarBlend by Agri-Gro marketed by Bio-Tec Solutions for the performance of FoliarBlend in alfalfa grown for forage (hay) at Fruita,

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Colorado during the 2012-2013 growing seasons.

Materials and Methods

The study was conducted at the Colorado State University, Agricultural Experiment Station, Western Colorado Research Center at Fruita during the 2012-2013 growing seasons.

A new seeding of Roundup-Ready alfalfa (Forage Genetics 4R200) was planted on August 30, 2011 at a rate of approximately 20 lbs seed/acre. Alfalfa was planted following winter wheat. The soil type was a Fruita sandy clay loam. Prior to planting, an application of 300 lbs P_2O_5/acre and 63 lbs N/acre was broadcast as 11-52-0 on August 10, 2011. Alfalfa was produced using best management practices as described by Pearson et al. (2011).

Treatments

Treatment #1 – Seed of the Roundup-Ready alfalfa was not treated with FoliarBlend by Agri-Gro prior to planting. Roundup was applied in the fall as per the herbicide label (32 oz/acre of Roundup Power Max, which is specifically formulated for Roundup-Ready crops) and 16 oz/acre of FoliarBlend by Agri-Gro was included in the fall Roundup application (Table 1).

Roundup was applied in the spring each year as per the herbicide label at 32 oz/acre and 16 oz/acre of FoliarBlend by Agri-Gro was included in the spring Roundup application, FoliarBlend only was applied after each cutting at a 16 oz/acre rate (Table 1). Applications following each cutting were made within 7-10 days when alfalfa was approximately 4 inches tall.

Treatment #2 – Control (no products applied, Roundup was applied for weed control, no FoliarBlend was applied in Treatment #2).

Roundup and FoliarBlend products were applied using a CO_2 backpack sprayer and were applied in 50 gallon/acre water at 30 psi. Distilled water was used in all applications.

The two treatments were separated by 135 feet. Plot size was 10 feet wide x 15 feet long with six replications per treatment. Plots were harvested using the automated forage harvesting system as described by Pearson (2007). Immediately following harvest, a subsample of alfalfa was collected in a paper bag, weighed, dried in a drying oven at 50°C, and reweighed to determine plant moisture content at harvest.

Forty-eight hay samples were collected over the growing season (12 samples at each cutting – 2 treatments x 6 replications) to determine hay quality. Hay quality analyses were performed by Weld Laboratories in Greeley (www.weldlabs.com, phone #970-353-8118). Weld Laboratories is certified by the National Forage Testing Association in both NIRS and wet chemistry.

Data were analyzed statistically using Statistix 9 software (Analytical Software, 2008) to determine treatment effects. Treatment comparisons were considered significantly different at the 10% or higher level of probability.

Results and Discussion

A soil sample was collected in the field prior to planting in August 2011, air dried, and analyzed at the Colorado State University Soil, Water, and Plant Testing Laboratory. Soil samples were also collected on December 2, 2013 to determine the effect FoliarBlend had on soil characteristics over the two years of the trial. Three soil cores were sampled and bulked in each plot and sampling depth was 8 inches. The results of the soil tests are shown in Tables 2, 3. The only elements in the soil that were affected by the application of FoliarBlend in alfalfa was P, K, and Zn (Table 3). The application of FoliarBlend in alfalfa at 16 oz/acre resulted in soil P, K, and Zn that was 2.3 times higher, 14% lower, and

1.5 times higher, respectively, than the soil in the control.

The 2012 growing season was very favorable for alfalfa production. The last spring frost occurred on April 16, 2012 and the first fall frost occurred on October 7, 2012, thus, the frost-free days in 2012 was 174 days (28°F base).

The 2013 growing season was also very favorable for alfalfa production. The last spring frost occurred on April 19, 2013 and the first fall frost occurred on October 16, 2013, thus, the frost-free days in 2013 was 180 days (28°F base).

The yield differences between the FoliarBlend treatment and the control in the first and second cuttings in 2012 were not significant (Table 4, Fig. 1). Alfalfa yield in the FoliarBlend treatment in the third cutting was 13% higher than in the control. Alfalfa yield in the FoliarBlend treatment in the fourth cutting was 51% higher than in the control. Total alfalfa yield for 2012 in the FoliarBlend treatment was 13% higher than in the control (Table 4, Fig. 1).

Yield differences were significant between the FoliarBlend treatment and the control in all four cuttings in 2013 and the total 2013 yield (Table 4, Fig. 2). Alfalfa yield in the FoliarBlend treatment in the first, second, third, and fourth cuttings and the total 2013 yield were 51, 45, 64, 42, and 52% higher than in the control, respectively.

Application of FoliarBlend in alfalfa in 2012 did not affect crude protein, ash content, calcium, potassium, sodium, or copper in any of the four cuttings (Table 5).

In 2012, dry matter was significantly higher in the non-treated control in the first and second cuttings compared to alfalfa in the FoliarBlend treatment (Table 5). Dry matter content of alfalfa was significantly higher in the FoliarBlend treatment in the third and fourth cuttings. In all cases, the differences between the two treatments, while significant, were biologically small.

Application of FoliarBlend affected ADF and NDF in only the first cutting in 2012. ADF was 6% and NDF was 5% greater in the control compared to the FoliarBlend treatment (Table 5). dNDF48 in the FoliarBlend treatment in the fourth cutting was 6% higher than in the control.

Fat content of alfalfa was affected by FoliarBlend application in the second and fourth cuttings (Table 5). In the second cutting, fat content was 3% higher in the FoliarBlend treatment than in the control. In the fourth cutting the response was reversed, fat content was 5% higher in the control than in the FoliarBlend treatment.

Lignin content of alfalfa was affected by FoliarBlend application in the first and fourth cuttings (Table 5). In the first cutting, lignin content was 7% higher in the control than in the FoliarBlend treatment. In the fourth cutting the response was reversed, lignin content was 8% higher in the FoliarBlend treatment than in the control.

Phosphorus content of alfalfa was affected by FoliarBlend application in the second and fourth cuttings in 2012 (Table 5). In the second cutting, phosphorus content was 5% higher in the FoliarBlend treatment than in the control. In the fourth cutting, phosphorus content was 10% higher in the FoliarBlend treatment than in the control. Magnesium in the FoliarBlend treatment in the second cutting was 8% higher than in the control. Zinc content of alfalfa was affected by FoliarBlend application in the third and fourth cuttings (Table 5). In the third cutting, zinc content was 21% higher in the control than in the FoliarBlend treatment. In the fourth cutting, zinc content was 13% higher in control than in the FoliarBlend treatment.

Of the factors evaluated in this study in 2012, iron was the element most affected by the application of FoliarBlend. The differences between the iron content of the FoliarBlend treatment and the control were significant in all four cuttings (Table 5). The iron content of alfalfa in the FoliarBlend treatment was consistently lower than in the control. In the first cutting, the iron content was 55% lower in the FoliarBlend than in the control. In the second, third, and fourth cutting iron content were 46%, 30%, and 62% lower in the FoliarBlend than in the control, respectively. The sufficiency range for iron in alfalfa is 45-60 ppm (Jim Self, personal communication, CSU Soil, Plant, and Water Testing Laboratory), which is much lower than those in this trial. High levels of iron in plants are not considered to be toxic (Jim Self, personal communication, CSU Soil, Plant, and Water Testing Laboratory). Plant tissue concentrations of less than 40 ppm are considered to be deficient.

Manganese in the FoliarBlend treatment in 2012 was 51% higher in the first cutting and 108% higher in the second cutting than in the control, respectively (Table 5).

Application of FoliarBlend in alfalfa in 2013 did not affect dry matter, ash content, calcium, sodium, or iron in any of the four cuttings (Table 6).

The application of FoliarBlend in the fourth cutting in 2013 resulted in a 7% decrease in crude protein compared to the control.

ADF in the second, third, and fourth cuttings when FoliarBlend was applied was 6, 6, and 9% higher, respectively, than in the control in 2013 (Table 6). NDF in the second, third, and fourth cuttings when FoliarBlend was applied was 4, 6, and 10% higher, respectively, than in the control in 2013. dNDF48 in the first, third, and fourth cuttings when FoliarBlend was applied was 5, 11, and 8% higher, respectively, than in the control in 2013.

The application of FoliarBlend in the fourth cutting resulted in a 10% decrease in fat compared to the control (Table 6). The application of FoliarBlend in the fourth cutting resulted in an 11% increase in lignin compared to the control (Table 6).
The application of FoliarBlend in the first, second, and third cuttings resulted in a 8, 13, and 22% increase, respectively, in P than in the control in 2013 (Table 6).

The application of FoliarBlend in the fourth cutting resulted in a 10% decrease in K compared to the control (Table 6).

The application of FoliarBlend in the second and third cuttings resulted in a 14 and 16% decrease, respectively, in Mg compared to the control (Table 6).

Zinc content of alfalfa in the first, second, and fourth cuttings was 6, 10, and 13% higher, respectively, in the control than in the FoliarBlend treatment in 2013 (Table 6).

Manganese content of alfalfa in the first, second, and fourth cuttings was 21% higher, 8% lower, and 14% lower, respectively, in the FoliarBlend treatment than in the control in 2013 (Table 6).

The application of FoliarBlend in the first cutting resulted in a 10% decrease in Cu compared to the control (Table 6).

Conclusion

Applying FoliarBlend increased forage yields in the third and fourth cuttings in 2012 and FoliarBlend increased forage yield in all four cuttings in 2013 when compared to the non-treated control. Total 2012 yield of alfalfa in the FoliarBlend treatment was 13% higher than in the control (Fig. 1) while the total 2013 yield of alfalfa in the FoliarBlend treatment was 52% higher than in the control (Fig. 2).

Application of FoliarBlend affected some forage quality factors and some plant nutrients in some cuttings, but a consistent response did not occur within years or across years.

The results of the two-year of the Biostimulant Study indicate that applying FoliarBlend in alfalfa may increase total growing season forage yields. The 2013 yield increases that were achieved when FoliarBlend was applied in each cutting were impressive. Readers of this report are cautioned that these results are for one location. Additional years of data from multiple locations are needed to determine how FoliarBlend will perform under a wide range of conditions and if application recommendations can be extrapolated to a multitude of environments and crop conditions.

Acknowledgments

Appreciation is extended to Fred Judson and Kevin Gobbo (Western Colorado Research Center staff), and Calvin Rock and Anna Mudd (summer hourly employees) who assisted with this research. Thanks to Bio-Tec Solutions, LLC Dennis G. Miller – Founder, phone: 620-778-8582, dennis@bio-tecsolutions.com, www.bio-tecsolutions.com for supporting this research project.

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Table 1. Dates when product applications were performed in alfalfa at the Colorado State University Western Colorado Research Center at Fruita during 2011-12 and 2013.

Treatment	Application Nov. 3, 2011	Application April 16, 2012 April 4, 2013	Application June 1, 2012 June 3, 2013	Application July 3, 2012 July 8, 2013	Application August 17, 2012 August 23, 2013
FoliarBlend	FoliarBlend with Roundup	FoliarBlend with Roundup	FoliarBlend only	FoliarBlend only	FoliarBlend only
Control	Roundup only	Distilled water only	Distilled water only	Distilled water only	Distilled water only

Table 2. Soil test results from soil sampled in the alfalfa field prior to planting in fall 2011at the Colorado State University, Western Colorado Research Center at Fruita, CO.

Treatment	O.M.	pH	Salts	N	P	K
	%		mmhos/cm	ppm	ppm	ppm
Soil test results at planting	1.3	7.7	0.4	3.3	8.1	111

Table 2 (continued). Soil test results from soil sampled in the alfalfa field prior to planting in fall 2011at the Colorado State University, Western Colorado Research Center at Fruita, CO.

Treatment	Zn	Mn	Fe	Cu
	ppm	ppm	ppm	ppm
Soil test results at planting	3.3	4.3	13.9	2.8

Table 3. Soil test results from soil sampled (Dec. 2, 2013) in the alfalfa field in fall 2013 at the Colorado State University, Western Colorado Research Center at Fruita, CO.

Treatment	O.M.	pH	Salts	N	P	K	Mg
	%		mmhos/cm	ppm	ppm	ppm	ppm
16 oz/acre	1.95	7.6	0.95	2.53	9.0*	107*	1.93
Control	1.87	7.5	0.82	2.57	3.9	124	1.55

*, significantly different at the 0.05 level of probability .

Table 3 (continued). Soil test results from soil sampled (Dec. 2, 2013) in the alfalfa field in fall 2013 at the Colorado State University, Western Colorado Research Center at Fruita, CO.

Treatment	Zn	Mn	Fe	Cu	Na	SAR
	ppm	ppm	ppm	ppm	ppm	
16 oz/acre	4.3*	1.94	19.4	2.82	6.12	3.62
Control	2.8	2.06	20.3	3.16	5.28	3.60

Table 4. Alfalfa yields of four cuttings and total alfalfa yield of FoliarBlend compared to a non-treated control at the Colorado State University Western Colorado Research Center at Fruita during 2012.

Treatment	First cutting May 21, 2012	Second cutting June 25, 2012	Third cutting Aug. 9, 2012	Fourth cutting Sept. 24, 2012	Total yield
FoliarBlend	1.57	2.31	3.06*	2.14***	9.08***
Control	1.58	2.30	2.70	1.42	8.01
	NS	NS			

NS, not significant.
*, *** significantly different at the 0.10, and 0.01 levels of probability, respectively.

Table 4 (continued). Alfalfa yields of four cuttings and total alfalfa yield of FoliarBlend compared to a non-treated control at the Colorado State University Western Colorado Research Center at Fruita during 2013.

Treatment	First cutting May 21, 2013	Second cutting July 1, 2013	Third cutting Aug. 13, 2013	Fourth cutting Sept. 29, 2013	Total yield
FoliarBlend	4.41***	2.69***	3.28***	2.04***	12.44***
Control	2.91	1.85	2.00	1.44	8.21

*** significantly different at the 0.01 level of probability, respectively.

Table 5. Alfalfa quality analysis for dry matter, crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), dNDF48, ash, fat, lignin, and calcium from a biological study at the Colorado State University, Western Colorado Research Center at Fruita during the 2012 growing season.

Treatment	Dry matter	Crude protein	ADF	NDF	dNDF48[†]	Ash	Fat	Lignin	Ca
	%	%	%	%	%	%	%	%	%
First cutting									
FoliarBlend	95.6b	23.0	26.9b	31.6b	15.8	10.7	1.91	6.10b	1.79
Control	95.8a	22.5	28.5a	33.2a	16.0	10.9	1.90	6.52a	1.76
Second cutting									
FoliarBlend	94.4b	21.6	32.2	37.9	17.1	10.1	1.94a	6.46	1.55
Control	94.6a	22.4	31.8	37.2	17.2	10.3	1.88b	6.43	1.59
Third cutting									
FoliarBlend	94.8a	19.5	36.1	42.0	17.9	9.7	1.86	7.25	1.60
Control	94.4b	20.7	34.8	40.4	17.8	9.8	1.94	7.03	1.65
Fourth cutting									
FoliarBlend	94.8a	22.9	30.8	36.2	16.8a	11.4	1.70b	7.27a	1.78
Control	95.4b	22.6	29.4	35.0	15.9b	11.1	1.79a	6.72b	1.69

[†]Denotes digestible NDF at 48 hours of incubation.
Numbers within a cutting followed by a different letter are significantly different at P < 0.10 level of probability.

Table 5 (continued). Alfalfa quality analysis for phosphorus, potassium, magnesium, sodium, zinc, iron, manganese, and copper from a biological study at the Colorado State University, Western Colorado Research Center at Fruita during the 2012 growing season.

Treatment	P	K	Mg	Na	Zn	Fe	Mn	Cu
	%	%	%	%	ppm	ppm	ppm	ppm
First cutting								
FoliarBlend	0.18	1.70	0.25	0.18	22.0	190.2b	18.0a	45.0
Control	0.18	1.62	0.25	0.16	22.2	426.5a	11.9b	25.8
Second cutting								
FoliarBlend	0.21a	1.74	0.27a	0.19	21.5	202.8b	13.8	22.7
Control	0.20b	1.75	0.25b	0.19	22.8	378.3a	11.5	27.3
Third cutting								
FoliarBlend	0.17	1.72	0.26	0.20	18.8b	274.2b	15.8a	27.0
Control	0.17	1.71	0.25	0.19	22.8a	390.8a	7.6b	32.3
Fourth cutting								
FoliarBlend	0.22a	2.06	0.26	0.26	21.7b	265.5b	10.6	25.2
Control	0.20b	1.98	0.24	0.24	24.5a	703.8a	7.1	31.3

Numbers within a cutting followed by a different letter are significantly different at P < 0.10 level of probability.

Table 6. Alfalfa quality analysis for dry matter, crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), dNDF48, ash, fat, lignin, and calcium from a biological study at the Colorado State University, Western Colorado Research Center at Fruita during the 2013 growing season.

Treatment	Dry matter	Crude protein	ADF	NDF	dNDF48†	Ash	Fat	Lignin	Ca
	%	%	%	%	%	%	%	%	%
First cutting									
FoliarBlend 16 oz	96.0	22.2	30.7	37.8	19.0a	8.5	1.98	6.96	1.43
Control	96.1	21.8	30.1	36.7	18.1b	8.7	2.03	7.06	1.50
Second cutting									
FoliarBlend 16 oz	95.5	22.6	30.8a	36.9a	16.4	9.0	1.89	6.61	1.80
Control	95.4	22.7	29.1b	35.4b	15.8	9.3	1.80	6.76	1.86
Third cutting									
FoliarBlend 16 oz	95.9	20.0	34.1a	40.5a	17.6a	8.6	2.03	7.65	1.82
Control	95.7	20.6	32.2b	38.2b	15.9b	8.4	2.12	7.36	1.73
Fourth cutting									
FoliarBlend 16 oz	89.9	21.8b	30.1a	37.2a	16.6a	10.2	1.89b	6.79a	1.62
Control	90.4	23.4a	27.6b	33.9b	15.4b	10.4	2.11a	6.12b	1.51

†Denotes digestible NDF at 48 hours of incubation.
Numbers within a cutting followed by a different letter are significantly different at P < 0.10 level of probability.

Table 6 (continued). Alfalfa quality analysis for phosphorus, potassium, magnesium, sodium, zinc, iron, manganese, and copper from a biological study at the Colorado State University, Western Colorado Research Center at Fruita during the 2013 growing season.

Treatment	P	K	Mg	Na	Zn	Fe	Mn	Cu
	%	%	%	%	ppm	ppm	ppm	ppm
First cutting								
FoliarBlend 16 oz	0.27a	2.02	0.39	0.24	34.9b	195.5	26.1a	9.5 b
Control	0.25b	1.87	0.42	0.22	37.3a	193.8	21.5b	10.6a
Second cutting								
FoliarBlend 16 oz	0.26a	1.58	0.47b	0.25	38.8b	240.0	21.3b	9.4
Control	0.23b	1.72	0.55a	0.25	43.3a	202.7	23.3a	9.1
Third cutting								
FoliarBlend 16 oz	0.22a	1.33	0.37b	0.25	37.3	211.3	20.4	9.2
Control	0.18b	1.49	0.44a	0.26	26.8	199.0	21.3	9.3
Fourth cutting								
FoliarBlend 16 oz	0.23	1.68b	0.45	0.36	26.5b	116.5	17.0b	12.2
Control	0.24	1.86a	0.45	0.30	30.5a	135.0	19.7a	12.7

Numbers within a cutting followed by a different letter are significantly different at P < 0.10 level of probability.

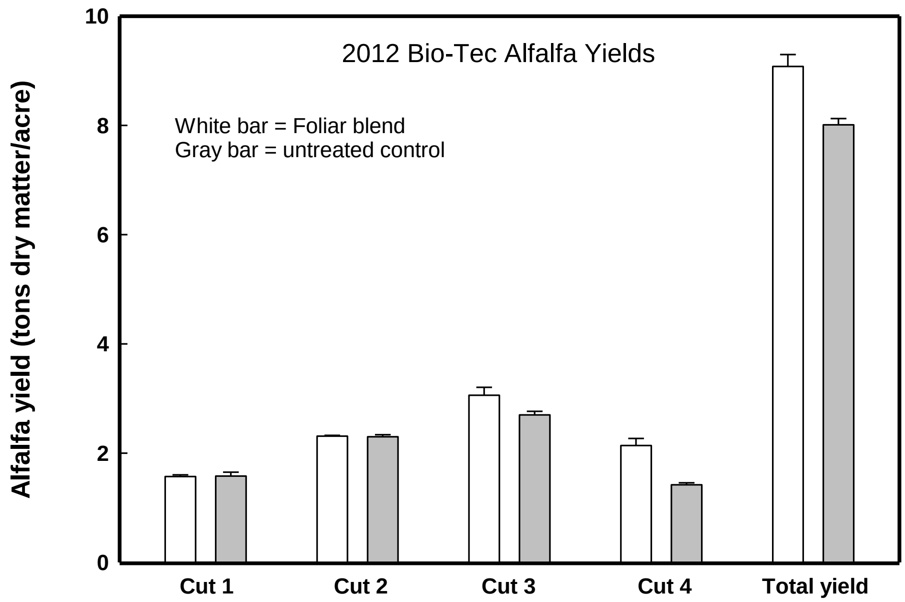

Fig. 1. Alfalfa yields of four cuttings and the total yield of alfalfa treated with and without FoliarBlend product by Agri-Gro at the CSU Western Colorado Research Center at Fruita during the 2012 growing season. Standard errors of the six replications are shown above each bar.

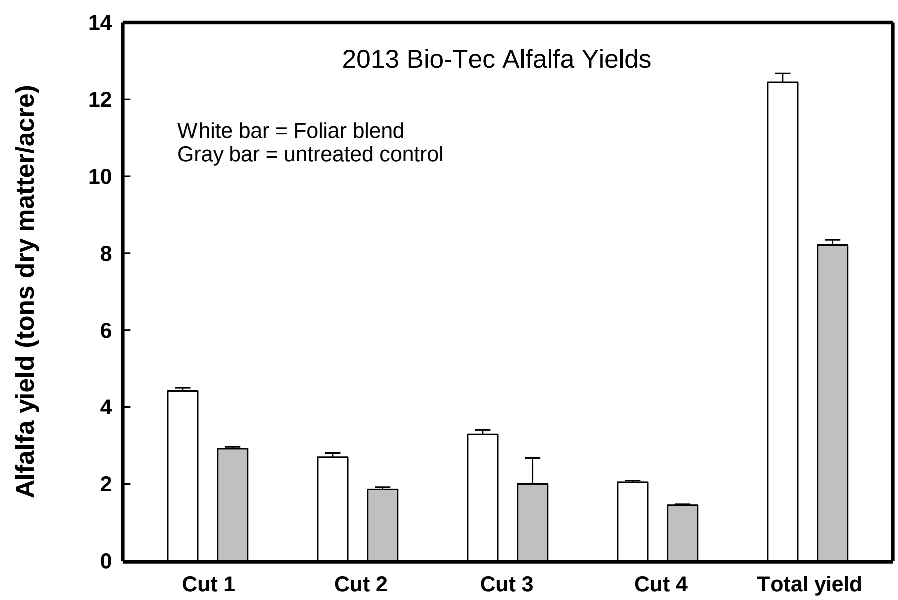

Fig. 2. Alfalfa yields of four cuttings and the total yield of alfalfa treated with and without FoliarBlend product by Agri-Gro at the CSU Western Colorado Research Center at Fruita during the 2013 growing season. Standard errors of the six replications are shown above each bar.

Research Projects/Publications - 2013

Dr. Amaya Atucha

2013-2014 Research Projects

Fine-root dynamics of Peach rootstocks under replant condition.
Effects of biochar on Peach replant disease - Greenhouse bioassay.
Effects of biochar soil amendments on tree growth, yield, and soil nutrient and water availability on a newly planted peach orchard.
Alternative soil amendments to reduce pathogen pressure in a replant site.
NC-140 2010 Honeycrisp Apple Rootstock Trial
NC-140 2009 Redhaven Peach Rootstock Trial

2013-2014 Publications

Atucha, A., Merwin, I.A., Brown, M.G., Gardiazabal, F., Mena, F., Adriazola, C., Goebel, M., and Bauerle, T., 2013. Root distribution and demography in an avocado (Persea americana) orchard under groundcover management systems. Functional Plant Biology (40): 507-515.

Atucha, A., Merwin, I.A., Brown, M.G., Gardiazabal, F., Mena, F., Adriazola, C., and Lehmann, J., 2013. Soil erosion, runoff and nutrient losses in an avocado (Persea americana Mill) hillside orchard under different groundcover management systems. Plant and Soil (368): 393-406.

Atucha, A., Emmett, B. and Bauerle, T., 2014. Growth rate of fine root systems influences rootstock tolerance to replant disease. Plant and Soil (376): 337-346.

Reighard, G., W. Bridges, Jr., D. Archbold, **A. Atucha**, W. Autio, T. Beckman, B. Black, E. Coneva, K. Day, M. Kushad, R. Pokharel, R.S. Johnson, T. Lindstrom, M. Parker, T. Robinson, J. Schupp, M. Warmund, and D. Wolfe. 2013. NC-140 peach rootstock testing in 13 U.S. states. VIII Int. Peach Symposium: Program and Abstracts p. 18.

Dr. Horst W. Caspari

2013 Research Projects*

Viticulture and enology programs for the Colorado wine industry (Colorado Wine Industry Development Board; S. Menke & R. Pokharel, CSU)*

Coordinated wine grape variety evaluations in the western US (Colorado Association for Viticulture and Enology)

*Sponsors/Cooperators are noted in parentheses.

2013 Publications

Non-Refereed WEB Publications:

Caspari, H. 2013. 2012 Grower Survey. http://webdoc.agsci.colostate.edu/aes/wcrc/techbulletins/survey2012.pdf

Caspari, H. 2013. Performance of cool-climate grape varieties in Delta County. http://webdoc.agsci.colostate.edu/aes/wcrc/techbulletins/Grape variety evaluation at Rogers Mesa, 2004-2013.pdf

Caspari, H. and A. Montano. 2013. Cold hardiness of grapevine buds grown at the Western Colorado Research Center - Rogers Mesa near Hotchkiss, Colorado, 2012/13. http://webdoc.agsci.colostate.edu/aes/wcrc/publications/coldhardinessrm13.pdf

Caspari, H. and A. Montano. 2013. Cold hardiness of grapevine buds grown at the Western Colorado Research Center - Orchard Mesa near Grand Junction, Colorado, 2012/13. http://webdoc.agsci.colostate.edu/aes/wcrc/publications/coldhardiness13.pdf

Caspari, H. and C. Lumpkin. 2013. Cold hardiness of grapevine buds grown at the Western Colorado Research Center - Rogers Mesa near Hotchkiss, Colorado, 2013/14. http://webdoc.agsci.colostate.edu/aes/wcrc/techbulletins/coldhardinessrm13-14.pdf

Caspari, H. and C. Lumpkin. 2013. Cold hardiness of grapevine buds grown at the Western Colorado Research Center - Orchard Mesa near Grand Junction, Colorado, 2013/14. http://webdoc.agsci.colostate.edu/aes/wcrc/techbulletins/coldhardiness13-14.pdf

Caspari, H., A. Montano, E. Neubauer, and R. Pokharel. 2013. Fruit bud cold hardiness, western Colorado, 2012/13.

Caspari, H., C. Lumpkin, E. Neubauer, and A. Atucha. 2013. Fruit bud cold hardiness, western Colorado, 2013/14. http://webdoc.agsci.colostate.edu/aes/wcrc/techbulletins/fruit bud cold hardiness 2013-2014.pdf

Sharp, R., H. Caspari, and A. Atucha. 2013. The cost of growing peaches in Western Colorado. http://webdoc.agsci.colostate.edu/aes/wcrc/techbulletins/costofgrowingpeaches[1].pdf

Dr. Stephen D. Menke

2013 Research Projects

Production of novel Colorado wines with several cultivars, with consumer focus group testing (D. Caskey and D. Thilmany/Colorado Department of Agriculture Specialty Block Grant Program/Colorado Wine Industry Development Board, CSU Department of Agricultural and Resource Economics

Comparison of aroma profiles of wines made from Syrah under several trellising systems (H. Caspari/College of Agricultural Sciences/Department of Horticulture and Landscape Architecture, Colorado Wine Industry Development Board, Colorado Association for Viticulture and Enology)

Comparison of aroma chemical profiles from wines made from several NE-1020 vineyard locations, (H. Caspari/College of Agricultural Sciences/Department of Horticulture and Landscape Architecture, Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology)

Development of industry-shared internship program for Ram's Point Winery, and educational Winery, housed at WCRC-OM (L. Sommers, F. Johnson, R. Abbott, J. Steiner, D. Iovanni/C. Beyrouty/S. Wallner /WCRC/College of Agricultural Sciences/Department of Horticulture and Landscape Architecture, Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology)

Production of varietal and blended experimental wines from WCRC grapes (H. Caspari/Western Colorado Research Center, Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture

Comparison of methodologies for GC/MS analysis for aroma profiles of several Colorado varietal wines (H. Caspari, J. Weinke/ Western Colorado Research Center/Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture)

Comparison of scoring for two types of wine quality assurance panels with a derived composite score of both panels, a joint quality assurance evaluation of Colorado and Nebraska wines (J. Reiling and P. Read/University of Nebraska-Lincoln, Colorado Wine Industry Development Board, Nebraska Grape and Winery Board, Nebraska Winery and Grape Growers Association, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture)

2013 Technical Publications

"A novel two panel evaluation system for commercial wines", S. Menke and J. Reiling, ASEV-ES Abstracts, American Journal of Enology and Viticulture Volume 64 Number 3 pp. 423A, ed. Linda F. Bisson

"Comparison of GC/MS Aroma Chemical Profiles from Colorado Cultivars", S. Menke and J. Weinke, 64th ASEV National Conference Technical Abstracts

“A Sustainable Colorado Wine Community”, S. Menke, Phytoworks, Spring 2013, pp. 4-6

2014 Continuing Research Projects

Production of novel Colorado wines with several cultivars, with consumer focus group testing (D. Caskey and D. Thilmany/Colorado Department of Agriculture Specialty Block Grant Program/Colorado Wine Industry Development Board, CSU Department of Agricultural and Resource Economics

Comparison of aroma chemical profiles from wines made from several NE-1020 vineyard locations, (H. Caspari/College of Agricultural Sciences/Department of Horticulture and Landscape Architecture, Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology)

Production of varietal and blended experimental wines from WCRC grapes (H. Caspari/Western Colorado Research Center, Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture

Comparison of scoring for two types of wine quality assurance panels with a derived composite score of both panels, a joint quality assurance evaluation of Colorado and Nebraska wines (J. Reiling and P. Read/University of Nebraska-Lincoln, Colorado Wine Industry Development Board, Nebraska Grape and Winery Board, Nebraska Winery and Grape Growers Association, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture)

Dr. Calvin H. Pearson

2013 Research Projects*

Winter wheat cultivar performance test – Hayden (Mike Williams, Dr. Scott Haley, and the Colorado Wheat Administrative Committee)
Alfalfa variety performance test (2012-2014) – Fruita (seed companies, breeding companies, private industry)
Evaluation of alfalfa genetic material 2011-2013 – Fruita (Dr. Peter Reisen, Forage Genetics)
Evaluation of RR alfalfa genetic material 2012-2014 – Fruita (Dr. Peter Reisen, Forage Genetics)
Evaluation of seed treatments in alfalfa – Fruita (BASF)
Application of FoliarBlend by Agri-Gro in alfalfa on alfalfa yield and hay quality – Fruita (Bio-Tec Solutions)
Evaluation of perennial plant species and production input for sustainable biomass and bioenergy production in Western Colorado – (Sun Grant - Fruita, Rifle, and Carbondale)
Evaluation of basin wildrye and basin x creeping wildrye hybrids as a biomass resource – Fruita (Dr. Steven Larson and Dr. Kevin Jensen, USDA-ARS, Logan, UT)
Evaluation of corn hybrid breeding material for grain and silage – Fruita (DOW AgroSciences)
Evaluation of canola varieties – Fruita (Dr. Mike Stamm, Kansas State University)
Evaluation of Optunia cactus for potential source of biomass for biofuel – Fruita
Performance of subsurface drip irrigation in alfalfa for improved irrigation efficiency and environmental enhancement – Fruita (Colorado Water Conservation Board)
Water banking in alfalfa – Fruita (Dr. Joe Brummer)

2014 Research Projects* (Continuing, New, or Planned)

Winter wheat cultivar performance test – Hayden (Wayne Counts, Dr. Scott Haley, and the Colorado Wheat Administrative Committee)
Alfalfa variety performance test (2012-2014) – Fruita (seed companies, breeding companies, private industry)
Evaluation of RR alfalfa genetic material 2014-2016 – Fruita (Dr. Peter Reisen, Forage Genetics)
Evaluation of RR alfalfa genetic material 2013-2015 – Fruita (Dr. Peter Reisen, Forage Genetics)
Evaluation of RR alfalfa genetic material 2012-2014 – Fruita (Dr. Peter Reisen, Forage Genetics)
Evaluation of seed treatments in alfalfa – Fruita (BASF)
Application of FoliarBlend by Agri-Gro in alfalfa on alfalfa yield and hay quality – Fruita (Bio-Tec Solutions)
Evaluation of perennial plant species and production input for sustainable biomass and bioenergy production in Western Colorado – (Fruita, Rifle, and Carbondale)
Evaluation of basin wildrye and basin x creeping wildrye hybrids as a biomass resource – Fruita (Dr. Steven Larson and Dr. Kevin Jensen, USDA-ARS, Logan, UT)
Evaluation of corn hybrid breeding material for grain and silage – Fruita (DOW AgroSciences)
Evaluation of canola varieties – Fruita (Dr. Mike Stamm, Kansas State University)
Performance of sub-surface drip irrigation in alfalfa for improved irrigation efficiency and environmental enhancement – Fruita (Colorado Water Conservation Board)
Water banking in alfalfa – Fruita (Dr. Joe Brummer)

*Cooperators/collaborators/sponsors are noted in parentheses.

2013 Publications

Pearson, Calvin H., Fred M. Judson, and Calvin B. Rock. 2013. A versatile, low-cost weighing hopper for small-plot field research. Agron. J. 105: 619-622.

Pearson, C.H., D.J. Rath, and K. Cornish. 2013. How pressure and filter material affect extraction of sunflower latex rubber. Ind. Crop Prod. 47:102-105.

Pearson, C.H., K. Cornish, and D.J. Rath. 2013. Extraction of natural rubber and resin from guayule using an accelerated solvent extractor. Ind. Crop Prod. 41:506-510.

Cornish, K., C.H. Pearson, and D.J. Rath. 2013. Accurate quantification guayule resin and rubber requires sample drying below a critical temperature threshold. Ind. Crop Prod. 43:158-164.

Pearson, C. H. Roundup-ready soybean variety performance trial and number of seed rows on a bed at Fruita, Colorado 2012. pps. 36-45. In: Western Colorado Research Center 2012 Research Report. Colorado State University, Agricultural Experiment Station and Extension, Technical Report TR13-05. Fort Collins, Colorado.

Pearson, Calvin. 2013. Research plots combines donated to the Western Colorado Research Center at Fruita. p. 6-7. *In*: Western PhytoWorks (Calvin H. Pearson, ed.). Spring 2013. Newsletter of the Western Colorado Research Center, Agricultural Experiment Station, Colorado State University.

Pearson, Calvin H. and Scott Haley. 2013. Winter Wheat Variety Performance Trial at Hayden, Colorado 2013. http://www.csucrops.com. (accessed 19 March 2014).

Pearson, Calvin H. 2013. Western Colorado Alfalfa Variety Performance Test at Fruita 2013. http://www.csucrops.com. (accessed 19 March 2014).

Pearson, Calvin. 2013. How do I decide what research to conduct? p. 3-4. *In*: Western PhytoWorks (Calvin H. Pearson, ed.). Winter 2013. Newsletter of the Western Colorado Research Center, Agricultural Experiment Station, Colorado State University.

Jones, Lyndsay, Joe Brummer, Calvin Pearson, and Abdel Berrada. 2013. Agronomic responses to partial and full season fallowing of alfalfa and grass hayfields. p. 2. *In*: Western PhytoWorks (Calvin H. Pearson, ed.). Winter 2013. Newsletter of the Western Colorado Research Center, Agricultural Experiment Station, Colorado State University.