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Agricultural Experiment Station

College of Agricultural Sciences

Department of Soil and Crop Sciences

Southwestern Colorado Research Center

Colorado State University Extension

2014-2018 Research Results

Colorado State University
Agricultural Experiment Station
Southwestern Colorado Research Center

2014-2018 Results

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Yellow Jacket, Colorado

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Cover photo shows the 2014 Cover Crop Trial at the Southwestern Colorado Research Center. Photo taken on June 23, 2014 by Abdel Berrada.

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Disclaimer

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Soil & Climate at the Southwestern Colorado Research Center

A.F. Berrada

Soil

The principal soil type at the Research Center is Wetherill loam (fine-silty, mixed, superactive, mesic Aridic Haplustalfs). The Wetherill series is made up of generally deep well drained soils, located on mesas and hills. These soils were formed from sandstone material transported by wind from the Southwest. They tend to be reddish on the surface and generally have low organic matter (around 1.0%). Their water holding capacity ranges from approximately 1.8 to 2.0 inches/ft. Soil pH at the SWCRC is around 7.5. The terrain in southwestern Colorado is generally rolling. Slopes vary from one to 12% and the elevation from less than 6,000 ft to above 7,000 ft. The potential exists for significant wind and water erosion on bare ground, especially in the spring.

Precipitation & temperature

The 30-year (1981-2010, NOAA) average annual precipitation at Yellow Jacket is 15.9 inches of water (Figure 1). Annual precipitation at the CoAgMet (Colorado Agricultural Meteorology, http://www.*coagmet*.colostate.edu) weather station in Yellow Jacket averaged only 11.6 inches from 1992 when the station became operational through 2017. This amount may not account for all the moisture from snow, since CoAgMet uses a simple tipping bucket rain gauge. The 1971-2000 average snowfall average at Yellow Jacket is 68.1 inches. June is the driest month and August through October is the rainiest period. The 2014 season was drier than normal with a precipitation total of 11.0 inches (Figure 1). Total precipitation in 2015 was 14.3 inches. May and June 2015 were unusually wet. Precipitation in 2016 was below normal based on CoAgMet and about normal based on CoCoRaHs (Table 1). March, April, June, and October were dry. In 2017, CoCoRaHs showed nearly 4.0 in. more precipitation than CoAgMet. This confirmed what we suspected all along, i.e., that CoAgMet underestimates precipitation, particularly from snowfall. We joined the CoCoRaHs network in November 2015. The spring and the fall of 2017 were dry as was August. Minimum temperature was generally higher than the 1981-2010 average, except in April and May, while maximum temperature was generally lower, with some exceptions (Figure 2). The frost-free period is 100 to 120 days. The Research Center lies at an elevation of 6900 ft, latitude 37°32’ N and longitude 108°44’ W.

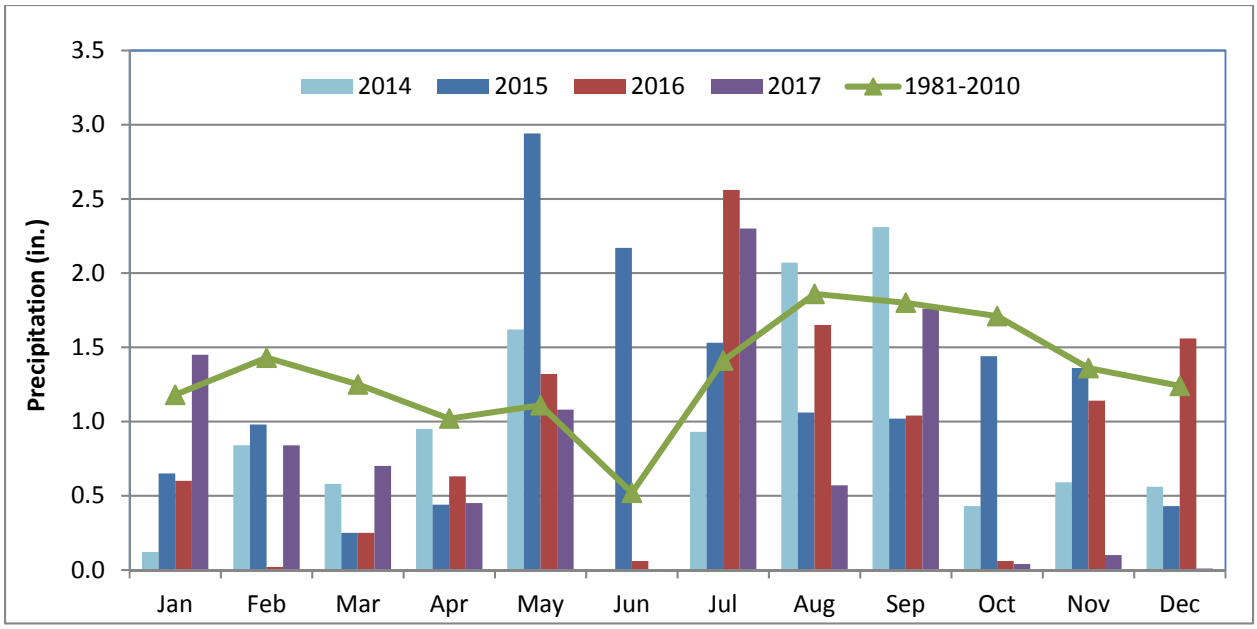

Figure 1. Monthly precipitation at Yellow Jacket, CO in 2014-2017, and 1981-2010.

Table 1. Comparison of monthly precipitation at the Southwestern Colorado Research Center in Yellow Jacket as measured by CoAgMet & CoCoRaHs.

Year	1981-2010 Normal (in.)	2016			2017		
Weather Station/Month		CoAgmet (in.)	CoCoRaHs (in.	Difference (in.)	CoAgmet (in.)	CoCoRaHs (in.	Difference (in.)
January	1.18	0.60	2.47	1.87	1.45	3.55	2.10
February	1.43	0.02	1.11	1.09	0.84	1.49	0.65
March	1.25	0.25	0.38	0.13	0.70	0.93	0.23
April	1.02	0.63	0.61	-0.02	0.45	0.65	0.20
May	1.11	1.32	1.48	0.16	1.08	1.25	0.17
June	0.52	0.06	0.06	0.00	0.00	0.02	0.02
July	1.41	2.56	2.6	0.04	2.30	2.56	0.26
August	1.86	1.65	1.87	0.22	0.57	0.68	0.11
September	1.80	1.04	1.14	0.10	1.76	1.95	0.19
October	1.71	0.06	0.07	0.01	0.04	0.08	0.04
November	1.36	1.14	1.65	0.51	0.10	0.02	-0.08
December	1.24	1.56	2.32	0.76	0.01	0.09	0.08
Total	15.89	10.89	15.76	4.87	9.30	13.26	3.96

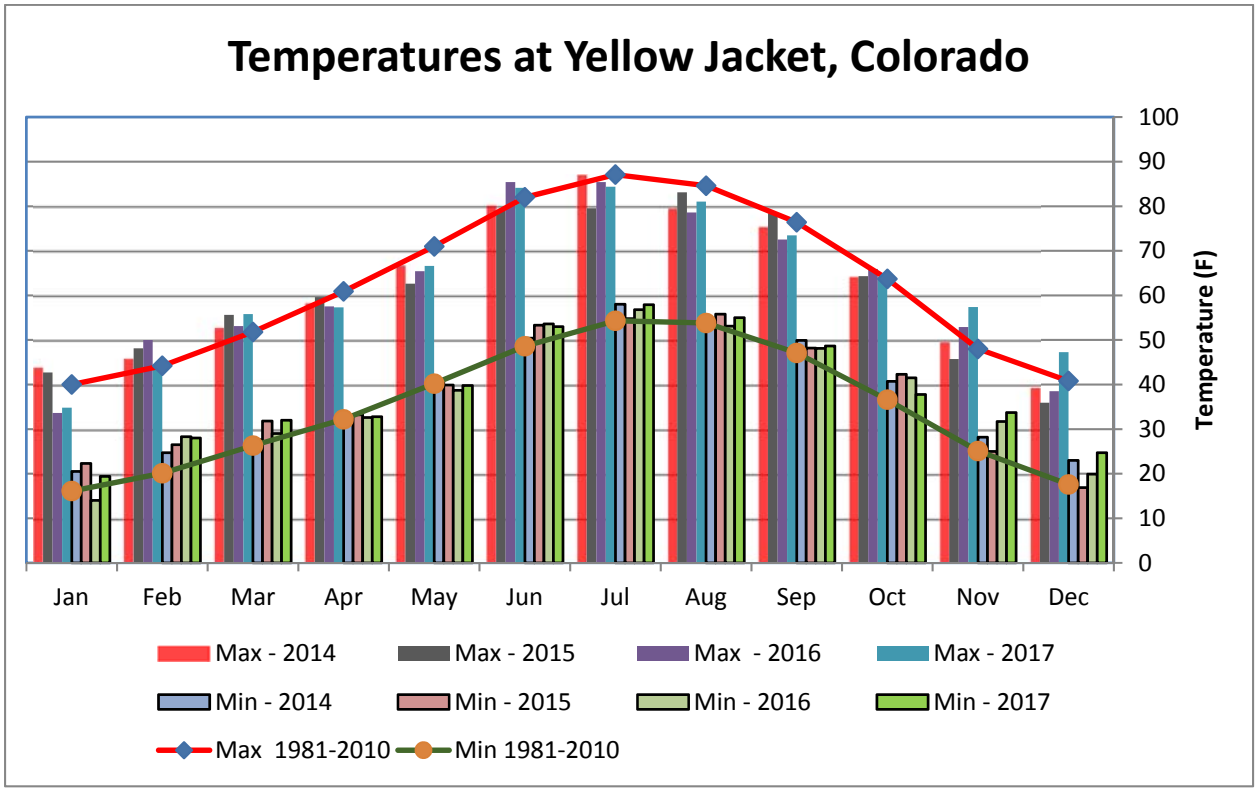

Figure 2. Monthly maximum and minimum temperatures at Yellow Jacket, CO.

Results Highlights

A.F. Berrada

Variety Trials

Winter wheat

The 2014 winter wheat yields were low (22.9 bu/ac on average) due to low winter and late spring precipitation. Colorado varieties and experimental lines performed the best. In 2014-2015, we compared four of the top performing CSU varieties Antero, Brawl CL Plus, Byrd, and Denali to the more widely grown varieties in SW Colorado, Deloris (Utah release) and Juniper (Idaho release). The latter two varieties are resistant to Dwarf bunt while the CSU varieties are not. Hence, we tested all six varieties with and without seed treatment to control dwarf bunt. We conducted the trial at the SWCRC and on two farmers' fields. There was no noticeable dwarf bunt at any of the test sites, which may explain the lack of response to seed treatment. Byrd and Antero did significantly better than Delores at the SWCRC while Byrd, Antero, and Denali outperformed Juniper and Brawl CL Plus at one of the two on-farm trials. Grain yield and protein content were much higher at the SWCRC (52.4 bu/ac, 17.2% protein) than at the other test sites due to greater N and P availability and earlier planting.

Wheat yields were unusually high in 2016, probably due to good soil moisture at planting and above normal precipitation in January and May 2016. Grain yields ranged from 48 to 64 bu/acre with four CSU experimental lines and six CSU-released varieties among the top performers. Fairview and Deloris had similar yields of 50 to 54 bu/acre. Grain protein averaged 15.8% with Washington State University's experimental line HRW080032-12sw having the highest protein concentration (18.3%) and the newly released CSU variety Langin having the lowest concentration (14.1%).

Spring wheat

Irrigated spring wheat did better in 2015 (avg. 110 bu/ac) than in 2014 (avg. 75 bu/ac) due to better weed control, nutrient management, and above normal precipitation in May and June 2015. Unlike any of the varieties tested in 2014 or 2015, the soft white variety Diva experienced significant lodging (30%) in 2015 and had the lowest yield of 92 bu/ac. The varieties UI Stone and Glee had the highest yield of around 125 bu/ac in 2015. Grain protein content ranged from 12.8 to 16.6% in 2015 and 11.6 to 16.0% in 2015.

Malting barley

We tested malting barley at the SWCRC from 2013 through 2016, in partnership with MillerCoors, which was seeking to expand its production area following water shortages in the San Luis Valley. Malting barley is similar to common barley and spring wheat in terms of cultivation, but it has to meet strict malting quality standards. Unlike in 2013 when drought resulted in low yields, grain yields averaged 145 bu/acre in 2014, 144 bu/acre in 2015, and 110 bu/acre in 2016. The highest yield was 162 bu/acre in 2015 and the lowest was 101 bu/acre in 2016. The newer varieties developed by MillerCoors generally outperformed the check, Moravian 069. Test weights varied from 50 to 55 lb/bu depending on the year and the variety. Grain plumpness, grain protein content, and other quality indicators were within the required standards for malting.

Grain sorghum

We tested grain sorghum at the SWCRC for the first time in 2015. Despite a longer than usual growing season, only the earliest maturing varieties (e.g., 251 and AG1101) reached full maturity. Earlier planting may have helped. More testing is needed before making recommendations as to the feasibility of grain sorghum in SW Colorado.

Winter Canola

The 2013-2014 trial was terminated due to heavy damage by army cutworm. In 2014-2015, winter canola averaged 3,355 lb/ac, which was the highest yield produced to date at the SWCRC without irrigation. Most of the varieties had a good fall stand and all varieties had 100% winter survival. Harvest maturity dates ranged from July 9 to July 26. Oil content was less than normal, which could be due to low soil fertility.

Winter Camelina and Winter Safflower

Spring biotypes of camelina and safflower are more common than winter biotypes. However, winter biotypes may be more adapted to rainfed cropping systems in our environment. Only three germplasm of winter safflower were available for testing in 2013-2014. In contrast, we tested 12 varieties of winter camelina in 2012-2014. Winter safflower had a poor stand and poor winter survival. We terminated it in March 2014. Similarly, camelina had a poor fall stand, but it was better than that of safflower, even though moisture conditions were favorable at planting and following planting. It is possible that camelina plants were damaged by insects (aphids, fleas, cutworms) or frost prior to stand evaluation on November 7. Rainfall in August and September 2013 was twice that of the 30-year average. In contrast, winter and spring 2014 precipitation was below average except in May. Seed yields were low but the potential for higher yields exits as was the case in 2012 (TR14-13, http://webdoc.agsci.colostate.edu/aes/SWCRC/pdf/TR14-13.pdf).

Dryland Safflower (planted spring 2014)

Seed yields were much lower in 2014 than in previous years. The average yield was 1015 lb/acre in 2008-2013 compared to 145 lb/acre in 2014. The lower yields in 2014 were due to dry conditions in early winter through April and in June and July, and substantial damage from deer and ravens.

Irrigated Dry Bean (2015)

Seed yield averaged 2,422 lb/acre with no significant differences between the seven entries at the 95% probability level, despite a 346 lb/acre spread between the highest (2,569 lb/acre) and lowest yields (2,223 lb/acre).

Potatoes (2015)

Potato yields ranged from 14.8 to 21.8 tons/acre with an average of 19.1 tons/acre. The variety Midnight Moon had the highest yield but 52% (by weight) of its tubers were under four ounces. Red Luna had similar yield, lower percentage (32%) of tubers under 4 ounces and 15% of these tubers had misshapes, compared to 4% on average for all six entries. Mesa Russet had the lowest yield and a low percentage (27%) of tubers under 4 ounces. Only Fortress Russet had a lower number (25%) of tubers under 4 ounces. It also had the earliest flowering (bloom) date of July 9.

Industrial Hemp

Due to interest in industrial hemp in Colorado, we conducted hemp trials at SWCRC in 2015-2017 and at the Agricultural Research, Development, and Education Center (CSU-ARDEC) in 2017 and 2018.

2015 Hemp Variety Trial

Seed yield averaged 114 lb/acre and ranged from 26 to 506 lb/acre. The seeds ripened over a long period of time and because of the late planting date and other factors, more than half of the varieties hadn't turned a mature color by October 19, 2015. Hemp was harvested shortly after the first fall frost on October 29. As a result, many of the seeds had either fallen to the ground or were eaten by birds. There was also substantial lodging and a hailstorm on September 8, which caused more seed shattering.

Dried biomass yield averaged 3,775 lb/acre and ranged from 2,489 to 5,533 lb/acre. This includes the stems, leaves, seeds, and flowers. The yield of dried stems averaged 3,298 lb/acre and ranged from 2,204 to 4,905 lb/acre. Stalk diameter (measured at the base of the plant) averaged 0.23 inches (0.19 to 0.31") and plant height averaged 58 inches (44" to 77"). Peak growth occurred at 33 to 49 days after planting depending on the hemp variety.

2016 Hemp Variety Trial

Seed yields ranged from 240 to 1,041 lb/acre. There was high variability in seed yield (CV[4] of 46%). Bialobrzeskie, Diana, USO 31, and Santhica produced less than 500 lb/acre. The tallest varieties (≥ 70 in.) tended to have the highest above ground DM yield, except for Diana. Plant population at harvest averaged only 29% of the number of planted seeds. It would be useful to determine the optimum planting dates and seeding rates for hemp cultivation in SW Colorado.

2017 Hemp Seeding Rate Trial at SWCRC

In this trial, hemp variety Helena was planted at four seeding rates (500,000; 750,000; 1,000,000; and 1,250,000 seeds/acre). Seed yield, total dry matter yield, and stem diameter were not significantly different among the seeding rates. There was a heavy weed infestation early in the season, which may have affected plant population, seed and biomass yields.

Plant population at harvest averaged 22% of the seeding rate, which was low, but consistent with previous results. Hence, lower seeding rates than what we adopted in 2015 and 2016 (*952,205 seeds/acre*) may be feasible and would reduce seed cost.

2016 Hemp Deficit Irrigation Trial at SWCRC

The hemp variety Futura 75 was grown at three irrigation amounts: 100 % corn ET (21.7 in. gross), 60% corn ET (12.5 in. gross), and a low amount of 4.2 inches (Check). Rainfall totaled 4.8 in. There was high variability in seed yield and no significant difference among treatments. There was much less variability in total above ground DM and in Stem DM. Both were significantly higher at 100% and 60% ET compared to the Check.

2017 Hemp Irrigation Trial at ARDEC South

The hemp variety Helena was subjected to five irrigation treatments, I-1 (no supplemental irrigation), I-2 (7.5 in. gross), I-3 (12 in. gross), I-4 (16.5 in. gross), and I-5 (23.0 in. gross). Irrigation scheduling was based on corn ET, with I-4 representing 100% ET.

Seed yield, above ground dry matter yield, stem dry matter yield, and stem diameter were

[4] CV: Coefficient of Variation

significantly affected by irrigation amount. Irrigation treatment I-5 produced the highest seed yield (2,312 lb/ac) and total dry matter (13,749 lb/ac), followed by I-4 (1,511 and 9,801 lb/ac, respectively). I-5 also had the highest THC level but it was well below the legal limit of 0.3%. CBD averaged 1.3% and was lowest at I-1.

Treatment I-5 closely matched alfalfa ET and produced the highest seed and dry matter yields. Assuming an 85% irrigation application efficiency, with drip tapes on the soil surface, then the net irrigation amount at I-5 would be 19.5 in. Assuming a net rainfall amount of 3.5 in. (80% efficiency) and a similar soil water balance at planting and at harvest (zero storage gain!), hemp net water use would be around 23.0 in. (27.3" gross) in conditions that are similar to those of 2017 at ARDEC South. At I-4, the net water requirement amount would be 17.5 in. or 20.8 in. gross. This amount may vary with the hemp variety and other factors such GDD[5].

2018 Hemp Irrigation Trial at ARDEC South

This trial was similar to the 2017 trial at ARDEC South. However, the total (gross) applied irrigation amounts were 0.9, 4.1, 10.4, 15.1, and 19.5 in., at I-1, I-2, I-3, I-4, and I-5, respectively. There were three hemp varieties (Fedora 17, Felina 32, and Helena) instead of one. Seed yield was highest at irrigation I-4 and I-5 ($P>0.05$) and lowest at I-1 & I-2. Fedora 17 had the highest seed yield (1,388 lb/ac) at irrigation level 4. Total DM and stem yields increased with increasing irrigation amounts up to level 3. Felina 32 and Helena produced significantly more stem than Fedora 32, but all three varieties had similar stem plus leaves DM. Irrigation levels 3-5 produced the tallest plants compared to levels 1 &2. The same was true for stem diameter, although irrigation levels 2 & 3 were not significantly different. Fedora 17 was the shortest of the three varieties and had the smallest stem diameter. Helena had the tallest plants in numeral value and at $P > F = 0.10$.

Based on these results, 18 to 19 inches of total (rain + irrigation) water amount would be enough to produce around 1,000 lb/acre of seed yield. It is conceivable that greater seed yields would have been obtained had we applied more N fertilizer. Two hailstorms may have reduced seed yield and total biomass as well.

CBD averaged 1.8 to 2.2%, with irrigation levels 3 & 4 outperforming irrigation levels 1 & 2. The CBD concentration of Fedora 17 and Felina 32 averaged 2.12 %, which was significantly greater than that of Helena (1.68%). THC levels were well below the legal limit of 0.3%. Fedora 17 and Felina 32 had slightly more THC than Helena.

The average stand on June 6, 2018 was 511,286 plants/acre. The final stand at harvest averaged 422,314 plants/acre, which was less than half the seeding rate of 915,195 seeds/acre.

Response of sunflower to deficit irrigation in 2012 & 2014

In this study, a standard height sunflower hybrid, Mycogen 8H449CLDM, and a short stature hybrid, Syngenta 8H570CL, formerly known as Triumph s870CL were tested under four irrigation regimes: Pre-Plant (Pre-P) irrigation only, irrigation at growth stages R4 to R6 (R4-6), irrigation at R1 to R6 (R1-6), and full season irrigation (Full Season). All the treatments received around 2.0 inches of irrigation water before planting. Water use efficiency (lb. of grain per inch of water received from irrigation and rainfall) was highest at R1-6 in 2012 and at R4-6 in 2014.

[5] GDD: Growing Degree Days

The Full Season treatment had the lowest water use efficiency in both years.

Seed yield was greater in 2012 than in 2014 possibly due to earlier planting, less bird damage, and slightly warmer weather in 2012. The full season irrigation treatment had the highest seed yield in both years while Pre-P had the lowest yield. Mycogen 8H449CLDM outperformed Syngenta 8H570CL, but the difference between the two hybrids was small at Full Season in 2012 and at Pre-P in 2014. Short-stature hybrids such as 8H570CL may be suitable for irrigation with side rolls, which are common in SW Colorado. Increased irrigation amounts generally led to higher seed oil content.

Fertilizer application of up to 90 lb N/acre in 2012 and 60 lb N/acre in 2014 had no significant impact on sunflower seed yield, % oil content or test weight despite soil test recommendations that would indicate otherwise. Yield loss due mostly to bird damage was greater in 2014 (13%) than in 2012 (4%). Growing sunflower and other oilseed crops at the SWCRC tended to attract a lot of birds since there was no sunflower grown within miles of the Research Center.

Evaluation of Corn Hybrid for Drought Tolerance in 2014

Six corn hybrids, some of which had the so-called drought tolerance genes, were tested in 2014 at the SWCRC for their response to water stress. The irrigation treatments were: 33%, 67%, and 100% of corn evapotranspiration (ET). Grain yield of 67% (163 bu/acre) and 100% ET (173 bu/acre) were not statistically different. The 33% ET treatment averaged 68 bu/ac. At 33% ET the corn hybrid P9690HR had the highest yield. At 67% ET, DKC-52-04 had the highest yield followed closely by 199-00DGVT2PRIB. At 100% ET, P9690HR had the highest yield followed by 199-00DGVT2PRIB and DKC52-04.

Irrigation Water Requirements at the Full-Service Area (FSA) of the Dolores Project

For the period of record (2000-2009), our analysis indicates that more water (1,714 ac-ft with analysis 1b and 7,718 ac-ft with analysis 2) may be needed to meet crop water demand in the FSA than the current allocation of 56,490 acre-feet. Improvements in farming practices will have to be made to maximize water use efficiency and take advantage of all the water that is currently available or may become available to the FSA irrigators in the future. Improvements include the judicious choice of crops and crop varieties, optimum planting dates, sound irrigation scheduling, and adequate nutrient soil, crop (e.g. pest control), and nutrient management. Upgrading the irrigation equipment to more efficient systems or components would help as well. In years with limited water supplies, farmers may have to irrigate fewer acres than they normally would, reduce the number of acres in alfalfa or apply water during the most sensitive crop growth stages e.g., flowering and grain formation for small grains.

Cover Crops

2014 Trial

In 2014, above ground dry matter (DM) yields ranged from 172 lb/ac for a hairy vetch /yellow sweet clover mix, up to 4,057 lb/ac for spring barley, with no supplemental irrigation. Spring forage barley in monoculture and barley mixtures had the highest yield. When spring forage barley was included, it tended to dominate the mixture. The other cover crops in the mixture were sparse and stunted or leggy. This situation could probably be improved by reducing the

planting rate of spring forage barley. Single cover crops and cover crop mixtures that included only legumes had the lowest yield, except for spring forage peas. Spring barley was much taller and has better canopy coverage than the hairy vetch /yellow sweet clover mix. If the cover crops had been allowed to grow for more time before harvest, the differences in biomass yield probably may not have been as large. However, in a situation where cover crops are grown during part of the fallow period to reduce soil erosion, suppress weeds, fix nitrogen or provide other benefits, terminating the cover crops at the right time and with the right method can be critical to the sustainability of the overall cropping system.

2015-2018 Dryland Cover Crops Project

The objectives of this project were to (1) evaluate the performance of several cover crop mixtures (CCMs), (2) assess the impacts of cover crops on soil health and quality, soil moisture, cash crop, and profitability; and (3) disseminate project results and contribute to improved soil health management in the region. To date, we conducted 10 field trials and tested 19 CCMs. These trials encompassed two crop rotations (winter wheat-fallow and winter wheat-safflower-fallow), two tillage practices (conventional tillage and no-till), and conventional and organic crop production. CCMs were planted in late summer or in the spring and consisted of three to ten species of legumes, grasses, brassicas, and other plants. Two of the three growing seasons had below average precipitation. The 2017-2018 season was especially dry (42% of normal) and resulted in crop failure at six of the nine sites that had a cover or cash crop. The results are not conclusive yet, but some trends have emerged.

Late summer-planted cover crops produced significantly more biomass than the spring-planted ones. In general, the greater the biomass, the less soil moisture and soil NO_3-N was available to the cash crop. When cover crops were planted too early after wheat harvest, volunteer wheat tended to dominate plant canopy and biomass. This can be mitigated somewhat with no-till and timely rainfall, and by minimizing wheat harvest losses. Some cover crop species performed poorly (e.g. teff, flax, sunn hemp, balansa clover) and the notion that the more species (i.e., greater diversity) in the mix, the better may not hold true in the project area due primarily to water limitations. The climate in the region (semi-arid with short growing season), in addition to seed cost and proper management (i.e., planting date, seeding depth, inoculation) are key considerations for developing high performance cover crop mixtures. Winter wheat yields were lower following cover crops than after fallow and this is likely due to temporary immobilization of soil nitrogen and reduced soil moisture at planting.

Dryland Crop Rotation Trial

From 2011 through 2014, the only crop rotation that did not show a loss was winter wheat-fallow. Winter wheat was profitable in 2015, due to favorable growing conditions, which resulted in a high grain yield of 42.1 bu/acre.

Wheat Varieties Performance Trials

A.F. Berrada, S. D. Haley[6], J.J. Johnson[7], and A.Y. Berrada[8]

Introduction

Wheat is an important crop in SW Colorado. In 2012, there was a total of 22,900 acres of wheat in Dolores, Montezuma, and La Plata counties (USDA-NASS 2012 Census of Agriculture). Grain yield averaged 24.2 bu/acre. Most of the wheat acreage is winter wheat and most of it is non-irrigated. Spring wheat is a minor crop in SW Colorado and it is usually irrigated. Non-irrigated spring cereals such as wheat, barley, and oats generally do not perform well in SW Colorado, except in years with above average fall-winter precipitation.

The Southwestern Colorado Research Center has been conducting wheat variety trials for several years to evaluate the performance of newly released varieties as well as experimental lines from Colorado State University, Utah State University, the University of Idaho, Washington State University, and private companies such as WestBred. Wheat varieties commonly grown in SW Colorado include: Deloris and Juniper winter wheat; and Jerome and Jefferson spring wheat. They were released by Idaho and Utah and possess resistance to dwarf bunt (*Tilletia controversa*), which is a concern in SW Colorado. According to Cook and Veseth (1991)[9], dwarf bunt is "limited to areas with prolonged snow cover on unfrozen ground". In contrast, most of the wheat varieties released by CSU are not resistant to dwarf bunt since it is not a concern in eastern Colorado where the bulk of Colorado wheat is grown. The two exceptions are Fairview hard red winter wheat and Sylvan hard red spring wheat. Unfortunately, certified seeds of these two varieties are no longer available.

The wheat variety trials were planted with a Kincaid spinner planter with double disks, in six-row, 6 ft. wide by 40 ft. long plots. The middle four rows were harvested with a Hege plot combine for yield estimates. The treatments (varieties) were arranged in a randomized complete block design with four replications. Agronomic traits that are measured in the wheat and other crop variety trials include grain yield and protein content, heading date, plant height, and percent lodging. Some elevators pay a premium for protein content in wheat grain that is above a certain level, usually 12%. Protein content and structure affect grain nutritional quality and its properties for making dough and other cereal products. Plant height can impact lodging, grain yield, and total biomass. Moreover, varieties of certain height may be more suited to some environments (e.g., shorter varieties may do better under water stress), cultural practices (e.g., side roll vs. center pivot) or uses (e.g., grain vs. forage) than others. Heading date was measured to give an indication of how quickly a variety can reach maturity.

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[6] Professor and Wheat breeder, Colorado State University.
[7] Professor and Crop Testing Leader, Colorado State University
[8] Former Research Associate at the Southwestern Colorado Research Center
[9] Cook, R.J., and R.J. Veseth. 1991. Wheat Health Management, p. 5777: Diseases of the Heads. APS Press, St. Paul, MN.

2013-2014 Dryland Winter Wheat Variety Trial[10]

Table 2. Results of the 2013-2014 dryland winter wheat variety trial.

Entry	Type[11]	Grain Yield (bu/acre)[12]	Grain Moisture (%)	Test Weight (lb/bu)	Plant Height (in)	50% Heading Date	Grain Protein[13] (%)
CO11D446	HRW	29.9	9.9	57.8	19.3	5/31	16.0
CO11D174	HRW	27.2	9.7	54.9	20.5	6/2	16.9
CO09W009	HWW	26.4	10.1	58.5	17.9	6/2	16.1
Denali	HRW	26.3	10.1	58.3	20.3	6/2	15.9
Snowmass	HWW	25.7	9.5	54.9	20.8	6/2	17.3
Brawl CL Plus	HRW CL2	24.8	9.7	59.5	20.9	5/30	16.7
CO11D346	HRW	24.8	9.8	55.2	21.9	6/2	16.0
Byrd	HRW	24.5	9.9	56.0	20.6	6/2	16.0
Antero	HWW	24.4	9.7	57.2	20.3	6/2	17.0
Ripper	HRW	24.0	9.4	56.2	15.9	5/29	17.6
Curlew	HRW	23.9	9.5	55.4	22.9	6/2	17.8
Hatcher	HRW	22.8	9.6	55.0	18.0	6/2	16.2
CO09W040-F1	HWW	22.5	9.7	53.7	20.5	5/30	14.7
UI SRG	HRW	22.5	9.5	52.1	20.8	6/5	17.6
Fairview	HRW	20.3	9.3	51.7	22.6	6/7	16.4
IDO1215	HWW	19.7	8.5	51.0	17.5	6/11[14]	18.0
Juniper	HRW	19.5	9.1	55.1	23.9	6/5	18.3
IDO1213	HWW	19.2	8.8	50.7	16.5	6/9	17.8
Deloris	HRW	18.9	9.3	53.4	21.1	6/4	17.6
Farnum	HRW	16.3	9.4	52.9	18.1	6/16[10]	17.8
IDO1103	HRW	16.1	9.2	50.3	16.4	6/9	17.8
Mean		22.9	9.5	54.7	19.8		16.9
CV (%)		14.8	2.2	1.5	9.2		3.4
$LSD_{.05}$		4.7	0.3	1.2	2.6		1.2
$LSD_{.3}$		2.5	0.2	0.6	1.4		

[10] The trial was conducted at CSU's Southwestern Colorado Research Center in a RCB design with four replications. Plot size was 6 ft x 40 ft.
[11] HRW: Hard Red Wheat; HWW: Hard White Wheat; CL: Clearfield (resistant to 'Beyond' herbicide)
[12] Adjusted to 12 % moisture and 60 lb/bu.
[13] 12% moisture basis
[14] Most of the heads never completely emerged from the flag leaf.

Trial Information

Previous crop	Summer fallow
Planting date	10/01/13
Seeding rate	700,000 seeds/ac
Harvest date	7/18/13
Precipitation (planting to harvest)	8.1 inches

Results Summary

Moisture at and following planting was adequate resulting in a good stand. December through April precipitation was below normal (2.7 vs. 6.1 inches). Above-normal precipitation in May helped head setting but grain-filling and seed size were negatively affected by the lack of precipitation in June. Consequently, the trial only averaged 22.9 bu/acre. Three Colorado experimental lines and Colorado varieties Denali and Snowmass performed the best. Test weights were generally in the low to mid 50s. Wheat yields were lower in 2013-2014 than in 2012-2013 (22.9 vs 30.5 bu/acre on average) despite greater precipitation in the summer and fall of 2013 and in February, April, and May 2014 (CSU-AES Technical Report 14-13, http://webdoc.agsci.colostate.edu/aes/SWCRC/pdf/TR14-13.pdf). Only December and January had greater precipitation (2.80 vs 0.36 in) in 2012-2013 than in 2013-2014. Precipitation from October 2012 through June 2013 was 5.5 inches. It was 7.22 inches during the same period in 2013-2014. As noted in “Soil & Climate at the Southwestern Colorado Research Center”, CoAgmet underestimates water from snow.

Table 3. 2012-2016 winter wheat results summary.

Entry	Type[15]	Grain Yield (bu/acre)[16]				
		2012	2013	2014	2015	2016
CO11D446 (Langin)	HRW			29.9		61.3
CO11D174 (Avery)	HRW			27.2		56.8
Denali	HRW	29.4	30.2	26.3	41.7	60.9
Snowmass	HWW	27.8	30.9	25.7		59.8
Brawl CL Plus	HRW	30.6	32.2	24.8	52.6	59.1
Byrd	HRW	28.2	33.3	24.5	76.9	60.1
Antero	HWW			24.4	55.1	60.2
Ripper	HRW	24.3	33.3	24		
Curlew	HRW	29.9	28.9	23.9		59.3
Hatcher	HRW	25.1	30.9	22.8		
UI SRG	HWW	26.5	31.2	22.5		
Fairview	HRW	26.0	24.7	20.3		54.0
Juniper	HWW		31.9	19.5	46.1	57.4
Deloris	HRW	25.7		18.9	41.8	50.2
Farnum	HRW			16.3		50.1
Average		27.4	30.8	23.4	52.4	57.4

[15] HRW: Hard Red Wheat; HWW: Hard White Wheat; CL: Clearfield (resistant to 'Beyond' herbicide)
[16] Adjusted to 12 % moisture and 60 lb/bu.

2014-2015 Winter Wheat Variety by Seed Treatment Trials

Introduction

Dryland winter wheat is the main grain crop in SW Colorado, but county averages are low (around 20 bu/acre) due to low and erratic precipitation and low production inputs. Several winter wheat varieties developed by Colorado State University's wheat breeding program have performed well at the Southwestern Colorado Research Center (SWCRC) but they do not possess resistance to dwarf bunt (*Tilletia controversa*). Dwarf bunt is more of a concern in western Colorado than in eastern Colorado where most CSU varieties are grown. One exception is 'Fairview', which was released in 1991 by USDA-ARS in cooperation with the Colorado and Idaho Agricultural Experiment Stations. Fairview is no longer the dominant winter variety in SW Colorado. It has been replaced by 'Delores'[17] and 'Juniper'[18] which are also resistant to dwarf bunt. Planting resistant varieties remains the best defense against dwarf bunt, but fungicide seed treatments such as "Dividend" or "Cruiser Maxx" (active ingredient difenoconazole) provide excellent control of both soil-borne and seed-borne dwarf bunt (http://www.agf.gov.bc.ca/cropprot/dbunt.htm).

Four CSU-released varieties, 'Deloris' and 'Juniper' were grown on two farmers' fields and at SWCRC in 2014-2015, to test the varieties performance and response to seed treatment. The hypothesis was that the CSU varieties will outperform Deloris or Juniper and not be affected by dwarf bunt due to the seed treatment.

Materials & Methods

The winter wheat trial was conducted at three locations: The Southwestern Colorado Research Center (SWCRC) in Yellow Jacket, and Garchar and Fisher farms in Dolores County. The design of the trial was a split-plot randomized complete block with four replications at each of the trial locations. Wheat varieties were assigned to the main plots and seed treatment to the sub-plots. There were six winter wheat varieties and two seed treatments (untreated and treated). Four of the wheat varieties ('Antero', 'Brawl CL Plus', 'Byrd', and 'Denali') were released by CSU and the other two varieties ('Deloris' and 'Juniper') were released by Utah and Idaho, respectively. Deloris and Juniper were used as checks. The treated seeds were coated with Dividend XL RTA at 10 fluid oz per 100 lb of seed. Planting dates at each location were as follows: SWCRC – September 18, 2014; Garchar – September 25, 2014; and Fisher – October 23, 2014. The planting rate was 700,000 seeds/acre. Each plot was 40 feet long by 6 feet wide with a row spacing of 12 inches. Soil samples were collected at about the same time as planting. The soil test results as well as fertilizer recommendations are shown in Table 1. Harvest dates were as follows: SWCRC – July 27, 2015; Garchar – August 24, 2015; Fisher – August 10, 2015. Precipitation between planting and harvest at the Research Center was 11.9 inches. Precipitation from October 2014 through April 2015 was 42% of normal. However, May plus June 2015 rainfall was approximately three times the 1981-2010 average.

[17] Delores was released by Utah State University's Agricultural Experiment Station in 2002.
[18] Juniper was released by Idaho University's Agricultural Experiment Station in 2006.

Table 4. Soil test results and fertilizer recommendations.

Field	Sample Depth (in)	Soil Test Results						Yield Goal bu/ac	Fertilizer Recommendations (lb/ac)		
		Soil pH	O.M. (%)	NO3-N (ppm)	NO3-N (lb/ac)	P (ppm)	K (ppm)		**N**	**P_2O_5**	**K_2O**
Fisher	0 to 12	7.9	0.9	5	18	16	233	40	35	40	0
Fisher	12 to 24			5	18	6					
Garchar	0 to 12	7.8	0.9	4	14	19	206	40	40	35	0
Garchar	12 to 24			4	14	8					
SWCRC	0 to 12	6.9	1.3	35	126	64	173	40	0	0	0
SWCRC	12 to 24	6.7	1.1	38	137	23	155				

Results

Table 5. Winter wheat results at the Southwestern Colorado Research Center (SWCRC).

Variety and Seed Treatment	Yield[19] (bu/ac)	50% Heading Date	Plant Height (in)	Moisture (%)	Test Weight (lb/bu)	Protein (%)[20]
Byrd	76.9	5/30	30.9	9.9	57.5	16.0
Dividend	75.3	5/30	31.3	10.0	57.4	16.2
Untreated	78.4	5/31	30.5	9.9	57.6	15.8
Antero	55.1	6/3	29.3	10.3	59.0	17.2
Dividend	52.6	6/4	28.8	10.2	58.8	17.6
Untreated	57.6	6/2	29.8	10.3	59.2	16.8
Brawl CL Plus	52.6	5/31	31.5	10.0	58.4	17.0
Dividend	53.9	5/31	32.3	10.0	58.6	16.9
Untreated	51.3	6/1	30.8	10.1	58.2	17.2
Juniper	46.1	6/6	33.8	9.5	57.1	18.8
Dividend	43.9	6/7	32.5	9.6	57.4	19.0
Untreated	48.3	6/6	35.0	9.4	56.7	18.6
Deloris	41.8	6/7	29.5	10.1	58.5	16.5
Dividend	41.2	6/7	29.0	10.1	58.2	16.3
Untreated	42.4	6/7	30.0	10.0	58.8	16.7
Denali	41.7	6/6	25.5	10.1	57.5	17.8
Dividend	38.5	6/6	25.0	10.1	57.3	17.8
Untreated	44.9	6/6	26.0	10.0	57.7	17.8
Average	52.4	6/4	30.1	10.0	58.0	17.2
CV (%)	21.9		9.6	2.6	1.4	4.4
$LSD_{.05}$	12.0		3.0	0.3	NS	1.3

[19] Adjusted to 12% moisture and 60 lb/bu.
[20] 12% moisture basis.

Table 6. Winter wheat results at Garchar.

Variety and Seed Treatment	Yield[21] (bu/ac)	Grain Moisture (%)	Test Weight (lb/bu)	Protein (%)[22]
Byrd	30.1	9.5	57.8	7.6
Dividend	30.6	9.4	57.9	7.5
Untreated	29.6	9.6	57.8	7.7
Deloris	28.2	9.0	58.8	8.1
Dividend	28.3	8.9	58.9	8.3
Untreated	28.0	9.2	58.8	7.9
Denali	28.1	9.5	59.5	7.8
Dividend	28.1	9.5	59.3	8.0
Untreated	28.1	9.4	59.7	7.6
Juniper	27.3	8.9	58.0	8.0
Dividend	27.5	8.9	57.9	8.0
Untreated	27.1	9.0	58.1	8.0
Antero	27.2	9.4	59.3	7.8
Dividend	26.9	9.4	59.1	7.9
Untreated	27.6	9.5	59.5	7.7
Brawl CL Plus	21.0	9.1	58.9	9.6
Dividend	21.4	9.1	59.1	9.7
Untreated	20.5	9.1	58.6	9.4
Average	27.0	9.2	58.7	8.1
CV (%)	4.3	2.7	1.1	2.7
$LSD_{.05}$	1.2	0.3	0.7	0.4

Table 7. Protein levels of treated and untreated winter wheat at Garchar.

Seed Treatment	Protein (%)[23]
Untreated	8.0
Treated	8.2
$LSD_{.05}$	0.2

[21] Adjusted to 12% moisture and 60 lb/bu.
[22] 12% moisture basis.
[23] 12% moisture basis.

Table 8. Winter wheat results at Fisher.

Variety and Seed Treatment	Yield[24] (bu/ac)	Moisture (%)	Test Weight (lb/bu)	Plant Height (in)	Protein (%)[25]
Byrd	43.4	10.8	58.7	26.5	11.3
Dividend	42.5	10.9	58.9	25.7	11.2
Untreated	44.3	10.8	58.5	27.3	11.4
Antero	39.9	10.8	58.8	27.2	12.1
Dividend	39.2	10.8	59.0	27.0	12.2
Untreated	40.6	10.8	58.6	27.3	12.0
Denali	38.9	10.7	59.5	29.3	12.3
Dividend	38.8	10.7	59.4	29.3	12.6
Untreated	39.0	10.8	59.7	29.3	12.1
Deloris	36.6	10.2	57.2	35.0	13.8
Dividend	36.1	10.1	57.8	34.3	13.1
Untreated	37.2	10.2	56.7	35.7	14.4
Juniper	34.8	9.7	57.2	39.5	14.4
Dividend	34.6	9.7	57.2	39.3	14.2
Untreated	35.0	9.7	57.2	39.7	14.6
Brawl CL Plus	28.6	10.3	58.4	28.3	13.8
Dividend	27.3	10.2	58.0	28.0	12.9
Untreated	30.0	10.3	58.7	28.7	14.7
Average	37.1	10.4	58.3	31.0	12.9
CV (%)	5.3	1.5	1.1	2.4	5.1
LSD.05	2.1	0.2	0.7	0.9	1.1

Table 9. Yield of treated and untreated winter wheat at Fisher.

Seed Treatment	Yield (bu/ac)
Untreated	37.7
Treated	36.4
LSD.05	1.2

Summary

Wheat grain yield was highest at SWCRC (52.4 bu/ac), followed by Fisher (37.1 bu/ac), and Garchar (27.0 bu/ac). Protein content was also highest at SWCRC (17.2%), well ahead of Fisher (12.9%), and Garchar (8.1%). The higher grain yield at SWCRC was likely due to more nitrogen and phosphorus availability (Table 1) than at the other two test sites. The greater soil nitrate nitrogen may also explain the higher grain protein content at SWCRC. No fertilizer was applied

[24] Adjusted to 12% moisture and 60 lb/bu.
[25] 12% moisture basis.

to the wheat crop at any of the test sites. Other factors that may have contributed to differences in wheat yields among the three sites include planting date, soil condition at planting, weed control, wildlife damage, lodging, and shattering. We did not measure precipitation at the farmers' sites, but spatial variations in snowfall or rainfall are common in SW Colorado.

Grain test weight averaged around 58 lb/bu at all three sites. There was no significant difference in grain yield due to seed treatment at SWCRC and at Garchar. The difference was small at Fisher (1.3 bu/ac), but it was significant and in favor of the untreated seed. The lack of benefit from seed treatment may be because no dwarf bunt infestation was observed at any of the test sites.

Byrd outperformed all the other varieties at SWCRC. Byrd and Antero performed significantly better than Delores. Delores and Denali had the lowest yields but were statistically similar to Juniper and Brawl CL Plus. All CSU varieties except Brawl CL Plus outperformed Delores and Juniper at Fisher's. At the Fisher farm test site, Byrd had the highest yield (43.4 bu/ac) followed by Antero (39.9 bu/ac) and Denali (38.9 bu/ac). Brawl CL Plus had the lowest yield of 28.6 bu/ac. Byrd had the highest grain yield at Garchar (30.1 bu/ac), closely followed by Deloris, Denali, Juniper, and Antero (27 to 28 bu/ac). Brawl CL Plus was far behind with 21 bu/ac.

In conclusion, at least one CSU winter wheat variety outperformed the more commonly grown varieties Deloris or Juniper, with or without seed treatment. Nutrient availability contributed to the greater yield at the SWCRC. More years of testing are needed to prove the hypothesis that CSU-released varieties are a viable alternative to dwarf-bunt resistant varieties in SW Colorado.

Acknowledgements

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2015-2016 Winter Wheat Variety Performance Trial

Results

Table 10. 2015-2016 Winter Wheat Variety Trial Results.

Entry	Source	Type	Plant Height (in)	Adjusted Grain Yield (bu/ac)[26]	Grain Protein (%)[27]	Grain Test Weight (lb/bu)	Grain Moisture (%)
CO12D2011	CSU	HWW	30.8	64.0	15.5	59.6	8.3
CO11D1539	CSU	HRW	32.2	62.0	15.3	55.6	7.9
Langin (CO11D446)	CSU	HRW	27.5	61.3	14.1	58.9	8.5
Denali	CSU	HRW	28.8	60.9	15.2	60.5	8.3
Antero	CSU	HWW	29.0	60.2	15.5	58.3	8.2
Byrd	CSU	HRW	29.0	60.1	15.0	57.9	8.2
CO12D2010	CSU	HWW	31.5	59.8	14.5	57.3	8.1
Snowmass	CSU	HWW	31.7	59.8	15.2	57.5	8.1
CO12D922	CSU	HWW	29.7	59.6	15.1	57.0	8.0
Curlew	USU	HRW	32.8	59.3	16.2	56.9	7.6
Brawl CL Plus	CSU	HRW	29.7	59.1	16.2	60.5	8.4
ARS09200-3H	WSU	?	28.2	58.2	15.3	57.2	8.3
Juniper	UI	HRW	39.3	57.4	16.4	59.5	7.9
Avery (CO11D174)	CSU	HRW	29.3	56.8	15.0	56.7	8.0

[26] Yield adjusted to 12% moisture and 60 lb/bu.
[27] Protein adjusted to 12% moisture.

Entry	Source	Type	Plant Height (in)	Adjusted Grain Yield (bu/ac)[26]	Grain Protein (%)[27]	Grain Test Weight (lb/bu)	Grain Moisture (%)
CO12D906	CSU	HWW	30.3	56.4	16.6	57.4	8.0
CO12D1028	CSU	HWW	31.5	54.9	15.1	58.2	8.5
HRW080032-12sw	WSU	HRW	28.0	54.8	18.3	55.6	7.7
Fairview	CSU	HRW	32.8	54.0	16.5	58.1	7.9
ARS070146-15H	WSU	?	30.0	52.8	16.1	55.3	7.7
Deloris	USU	HRW	31.3	50.2	16.8	57.5	8.0
Farnum	WSU	HRW	28.0	50.1	17.6	56.0	8.0
CO11D1767	CSU	HRW	26.0	49.3	15.5	57.1	7.9
ARS090199-4H	WSU	?	27.2	48.2	15.8	55.8	7.9
Average			30.2	56.9	15.8	57.6	8.1
LSD.05			3.8	8.6	1.8	1.9	0.4
CV (%)			7.6	10.7	5.5	2.3	3.7

Randomized Complete Block Design with 4 reps. Planted on 09/24/2015 & harvested on 07/18/2016, Previous crop: Summer fallow. No fertilizer or pesticide was applied.

Summary

Winter wheat yields were relatively high in 2015-2016 due to good soil moisture storage during summer fallow, good stand establishment, above average winter precipitation (CoCoRaHS records), and average to above average rainfall during flowering and early seed fill (May 2016). Grain yields ranged from 48 to 64 bu/acre with four CSU experimental lines and six CSU varieties among the top performers. Fairview and 'Deloris' had similar yields of 50 to 54 bu/acre. Grain protein averaged 15.8% with Washington State University's experimental line HRW080032-12sw having the highest protein concentration (18.3%) and the newly released CSU variety 'Langin' having the lowest concentration (14.1%).

2014 Irrigated Spring Wheat Variety Trial

A.F. Berrada and S.D. Haley

Trial Information

Harvest date	August 20
Irrigation	Irrigated with side roll
Number of replications	4
Fertilizer application	41.5 lb N + 59.3 lb P_2O_5/acre on 03/18/14
Pest control	May 17: 2,4-D at ~1.4 pt/ac
Planting date	March 25
Planting rate	1,200,000 seeds/acre at 12-inch row spacing
Plot size	6 ft by 40 ft
Rainfall	4.76 inches (planting to harvest)
Trial design	Randomized complete block

Results

Table 11. Results of the 2014 spring wheat variety trial.

Variety	Type[28]	Yield[29] (bu/ac)	50% Heading Date	Grain Moisture (%)	Height (in)	Protein (%)	Test Weight (lb/bu)
IDO694C-A	HWS	82.4	June 16	10.7	27.3	12.8	58.0
IGUACU	HRS	80.8	June 20	11.5	32.8	13.7	59.6
IDO862E	HRS	77.3	June 16	10.7	30.5	13.7	59.1
Jerome	HRS	75.7	June 17	10.6	31.5	14.3	56.2
IDO862T	HRS	74.9	June 18	10.6	33.0	15.7	58.0
IDO1202S	HWS	73.8	June 24	10.9	32.3	14.1	58.5
BREAKAWAY	HRS	72.9	June 19	10.8	32.8	14.6	59.2
Jefferson	HRS	71.1	June 20	10.5	32.8	16.6	56.8
Sylvan	HRS	69.9	June 27	10.8	32.3	14.8	55.8
Average		75.1	June 20	10.8	31.8	14.5	57.8
CV (%)		7.2		1.7	3.5	5.7	2.1
LSD.05		8.0		2.1	1.7	1.8	1.9

[28] HRS: Hard Red Spring Wheat; HWS: Hard White Spring Wheat
[29] Adjusted to 12% moisture & 60 lb/bu.

Summary

Spring wheat yield averaged 75 bu/ac in 2014, which was less than expected, due to poor weed control and low soil N availability. Applied N and P were based on the soil test results for an adjacent malting barley trial and the desire to not exceed 14% protein content for malting barley. Protein content for spring wheat averaged 14.5%, with 'Sylvan' topping 16%. Currently, 'Jefferson' is probably the most commonly planted spring wheat variety in southwestern Colorado, followed by 'Jerome'. Sylvan was released by The Colorado and Utah Experiment Stations in 1994 for its superior yield and bread-making quality compared to spring wheat varieties grown at the time such as 'Oslo'. However, Sylvan has lost its purity and is no longer available for sale as registered or certified seed.

2015 Irrigated Spring Wheat Variety Trial

F. Berrada and S. D. Haley

Experimental Procedure

There were 23 varieties of spring wheat in this trial. The design of the trial was a randomized block with four replications. The soil was sampled and analyzed, and fertilizer was applied before planting at a rate of approximately 115 lb N/acre + 54 lb P_2O_5/acre. The planting rate was 1.2 million seeds/acre. Each plot was 40 feet long by 6 feet wide with a row spacing of 12 inches. The spring wheat was planted on April 1 and harvested on August 31. For weed control, the trial was sprayed with 2,4-D Amine at 1.25 pt/acre on May 23. Irrigation water was applied with a side roll. Rainfall between planting and harvest totaled 8.15 inches. Protein content of the harvested spring wheat was obtained for two replications.

Results Summary

Spring wheat yield in this trial averaged 110 bu/ac and the average grain protein content was 14.1% (Table 12). The top performers were the varieties from UI Stone to 11SB0096 (the difference in yield among these varieties is not statistically significant). UI Stone was tested at the SWCRC in 2010-2012 as IDO599. It was released by the University of Idaho in 2013. Jefferson averaged 109 bu/ac. There was no noticeable lodging except for the variety Diva, which experienced 30% lodging and had the lowest yield of 92 bu/ac.

Table 12. Results of the 2015 spring wheat variety trial.

Variety	Type[30]	Yield (bu/ac)[31]	50% Heading date[32]	Grain Moisture (%)	Height (in)	Protein (%)[33]	Test Weight (lb/bu)
UI Stone	SWS	126.0	June 21	10.3	30.0	11.6	59.8
Glee	HRS	124.9	June 19	9.7	32.5	14.3	59.3
WB7618	HWS	119.4	June 22	9.2	25.8	14.5	58.9
Whit	SWS	119.1	June 20	9.3	30.3	12.9	57.8
LCS Iguacu	HRS	117.5	June 23	10.1	33.5	14.3	59.5
Otis	HWS	117.2	June 28	9.6	36.3	14.0	59.4
11SB0096	SWS	115.7	June 22	9.3	29.3	14.4	58.1
WB7328	HWS	112.0	June 18	9.6	26.5	14.0	59.2
WB9653	HRS	111.9	June 23	9.1	29.5	14.0	57.2
WB9377	HRS	110.4	June 22	9.6	26.8	14.1	59.6
UI Platinum	HWS	109.4	June 19	9.7	28.0	13.5	59.3
Jefferson	HRS	108.8	June 20	9.7	31.5	13.9	59.6
IDO862E	HRS	108.3	June 17	9.8	32.8	14.6	60.2
IDO1202 S	HWS	108.2	June 23	10.0	30.5	14.2	60.6
LCS Atomo	HRS	108.2	June 19	9.2	25.8	13.7	58.3
WB9668	HRS	107.9	June 19	9.5	26.8	15.0	59.2
IDO862T	HRS	104.7	June 20	9.9	33.0	14.5	60.5
Macon	HWS	103.7	June 20	9.4	29.5	14.7	57.9
Alum	HRS	102.6	June 23	9.8	30.8	14.9	59.4
LCS Pro	HRS	100.4	June 22	9.6	35.5	14.5	58.6
Tara 2002	HRS	98.6	June 19	10.0	31.3	14.0	59.6
Kelse	HRS	98.5	June 22	9.2	32.3	16.0	57.8
Diva	SWS	91.6	June 25	9.7	33.0	12.7	58.4
Average		109.8	June 21	9.6	30.5	14.1	59.0
CV (%)		8.7		2.1	5.4	4.8	1.3
LSD.05		13.6		0.3	2.3	1.4	1.1

[30] HRS: Hard Red Spring Wheat; HWS: Hard White Spring Wheat; SWS: Soft White Spring Wheat
[31] Adjusted to 12% moisture & 60 lb/bu
[32] Feekes scale 10.5
[33] 12% moisture basis

2014-2016 Irrigated Malting Barley Trials

A.F Berrada and A.Y. Berrada

Introduction

Research was initiated in 2013 to test the performance of several malting barley (MB) varieties, in collaboration with MillerCoors. MB in Colorado is mostly grown in the San Luis Valley, commonly in rotation with potatoes. It may be a good alternative to spring wheat in southwestern Colorado but requires supplemental irrigation to perform well, as indicated by the 2013 results (TR 14-13[34]). Further testing showed the potential to produce MB grain yields in excess of 150 bu/acre. Challenges to growing MB in SW Colorado include securing a contract with MillerCoors and meeting quality standards such as: grain plumpness ≥ 70%, grain germination at 72 hours ≥92%, grain protein ≥ 7.5% and ≤14%, and damaged or diseased kernels ≤ 5%.

In these trials, we tested several Moravian varieties developed by MillerCoors. We measured grain yield, plumpness, density (test weight), protein, and moisture, plant height, and other characteristics.

Trial Information

Year	2014	2015	2016
Planting date	March 21	March 31	April 7
Planting rate (seeds/ac)[35]	834,500	833,000	751,000
Harvest date	August 11	August 25	September 6
Irrigation type	Sprinkler (side roll)	Sprinkler (side roll)	Sprinkler (side roll)
Number of reps	3	3	3
Fertilizer application	41.5 lb N + 59.3 lb P_2O_5/ac on March 18	56 lb N + 45 lb P_2O_5/ac on March 30	140 lb N + 37 lb P_2O_5/ac on April 6
Pest control	2,4-D @ ~1.4 pt/ac on May 17	2,4-D @ 1.25 pt/ac on May 23	2,4-D @ 1.0 pt/ac on May 30
Plot size	200 ft. by 6 ft.	200 ft. by 6 ft.	160 ft. by 6 ft.
Rainfall (planting to harvest)	3.62 in.	8.06 in.	5.38 in.
Trial design	Randomized Complete Block		

Results Summary

MB grain yields averaged 145 bu/acre in 2014, 144 bu/acre in 2015, and 110 bu/acre in 2016 (Table 13). The highest yield was 162 bu/acre in 2015 and the lowest was 101 bu/acre in 2016. The newer varieties developed by MillerCoors generally outperformed the check. Test weights varied from 50 to 55 lb/bu depending on the year and the variety (data not shown). Grain

[34] Berrada, A. (ed.). 2014. Southwestern Colorado Research Center 2013 Results. CSU-AES Technical Report TR 14-13. Ft. Collins, CO.

[35] 12-in row spacing

plumpness, grain protein content, and other quality indicators were within the required standards for MB.

Table 13. Malting barley variety trial results.

Variety #	2014 Bu/acre	2015 Bu/acre	2016 Bu/acre	2014 % Plump	2015 % Plump	2016 % Plump	2014 % Protein	2015% Protein	2016 % Protein
1 (Check)	141.6	144.5	100.9	80.4	97.6	94.6	13.0	9.8	11.3
2	154.7	161.6	121.6	84.8	98.5	97.0	12.9	9.6	11.4
3	NA	139.5	104.9	NA	96.8	94.6	NA	9.9	10.5
4	150.4	155.9	NA*	89.6	98.3	NA	12.0	10.7	NA
5	143.2	NA	NA	90.7	NA	NA	12.8	NA	NA
6	148.4	153.0	NA	92.4	99.3	NA	11.7	9.7	NA
7	134.5	108.9	111.7	86.7	97.6	96.2	13.9	11.9	10.9
Mean	145.2	143.9	109.8	87.0	98.0	95.6	12.7	10.3	11.0
St. Dev.	7.9	21.6	13.5	5.3	1.1	1.4	0.9	1.1	0.7
$PLSD_{0.05}$	13.5	22.9	NS**	6.6	NS	NS	1.4	NS	NS
CV%	5.6	15.0	12.3	5.8	1.1	1.5	6.9	10.9	6.3

**NA: Not Available*

***NS: Not significant at Pr > F = 0.05.*

2015 Dryland Grain Sorghum Variety Trial

A. F. Berrada, J. Rizza[36], J. Cook[37], and A. Y. Berrada

This trial was conducted at Southwestern Colorado Research Center (SWCRC) in 2015 to:

1. Determine if grain sorghum can fully mature at this relatively high elevation of approximately 7000 ft. Because of the short growing season at the SWCRC, only varieties with early- to medium-maturity rating were selected for this trial.
2. Test food-grade varieties 'NUS310', 'AG1301', 'AG1401', 'SP3303', and '12GS0106'. The seeds for these varieties were supplied by CSU Extension Small Acreage Management (SAM). According to SAM, "food-grade sorghum produces a white or cream seed that can be used for livestock feed, milled to make a gluten-free flour, malted for gluten-free beer, or popped for eating."

Procedure

Eleven varieties of grain sorghum were tested in a RCB design with four replications. Plot size was 40 feet long by 10 feet wide and row spacing was 30 inches. The sorghum was planted on June 19 at a rate of approximately 45,000 seeds per acre. It was cultivated between rows on July 22 to control weeds. Additional weeding was achieved with hand hoeing. A hailstorm occurred on September 8 and caused moderate damage (leaf shredding) to the sorghum plants. On October 27, we harvested all the seed heads in the middle two rows by 6.0-ft. length in each plot. Most of the varieties had not reached the black layer growth stage at harvest. The first killing frost occurred on October 29. We dried the seed samples for several weeks then cleaned and weighed the seeds. There were still a lot of hulls left after cleaning. Total rainfall from planting to harvest was 7.2 inches. Rainfall in May plus June (5.1") was substantially above the 30-year average of 1.6 inches.

Comments about data measured

Data measured	Comments
Yield	Adjusted to 14% moisture.
Days to 50% heading	Days after planting until 50% of the plants in a plot have one or more panicles that have fully emerged. Recorded twice a week.
Moisture	Grain moisture measured after the harvested grain had been oven-dried and air-dried.
Days to emergence	Days after planting to reach 25% or greater emergence. Two outlier data points were removed.

Results

[36] Small Acreage Specialist, CSU Extension & USDA-NRCS in Grand Junction, CO.
[37] Small Acreage Management Coordinator, CSU Extension & USDA-NRCS in Brighton, CO.

Table 14. Results of the 2015 grain sorghum trial.

Variety	Company [38]	Maturity Category	Yield (lb/ac) [39]	Yield (bu/ac) [40]	Days to 50% heading	Days to emergence	Moisture (%)	Plant Height (in)
AG1101	A	Early	5,257	105.1	62.1	10.3	7.4	29.5
12GS0106	C	Early	5,146	102.9	65.6	10.0	6.0	36.5
AG1201	A	Early	5,145	102.9	67.8	10.5	7.5	31.0
SPX11814	C	Medium	5,072	101.4	65.6	10.3	5.1	32.0
NUS310	R	Medium	5,056	101.1	66.3	10.0	6.0	33.0
SP3303	C	Early	4,848	97.0	67.3	10.0	5.1	31.0
AG1301	A	Early to medium	4,683	93.7	71.3	10.0	6.9	32.3
251	C	Early	4,590	91.8	60.3	10.7	6.4	30.0
SPX12214	C	Early	4,484	89.7	69.8	10.0	5.4	29.5
AG1401	A	Early to medium	3,689	73.8	74.6	10.0	5.4	30.3
AG1203	A	Medium	3,021	60.4	79.3	10.0	5.3	32.8
Average			4,636	92.7	68.2	10.1	6.0	31.6
$LSD_{0.05}$			NS	NS	4.5	0.5	1.7	2.3
$LSD_{\mathbf{0.1}}$			1,229	24.6	3.8	0.4	1.4	1.9

Grain yields were comparable to yields obtained in eastern Colorado. However, only the earliest maturing varieties (i.e., 251 and AG1101) reached the black layer growth stage at harvest time. The other varieties ranged from soft dough (e.g., AG1401) to hard dough (e.g., AG1201). Earlier planting may have helped, although soil temperature did not reach and stay above 60 degrees F. until June 16[41]. Moreover, the 2015 growing season was longer than normal. The first frost occurred on October 28, while on average, the first fall freeze (28.5 deg. F.) happens on October 16 at the 50% probability level. Even though this first year of testing showed promise, only the earliest maturing grain sorghum varieties should be planted at this elevation until more data is available.

[38] A = Alta Seeds. C = Chromatin-Sorghum Partners. R = Richardson Seeds, Inc.
[39] Adjusted to 14% moisture.
[40] Based on an average test weight of 50 lb/bu.
[41] It is recommended to plant grain sorghum after soil temperature reaches and stays above 60 degrees for three consecutive days. In some years (e.g., 2013 or 2014) this happens by early June.

Oilseed Crops

A.F. Berrada

Introduction

Sunflower regained interest in SW Colorado after the passage of the Energy Policy Act in 2005, which provided incentives for the production of renewable energy, among other things. A company was formed in 2005 and a plant was built in Dove Creek, CO in 2007-2008 to extract oil from safflower and sunflower and eventually blend it with diesel to produce biodiesel. Sunflower acreage peaked in 2008, then dropped substantially after the Dove Creek plant ceased operation in 2010. Niche markets for safflower and sunflower grown in SW Colorado or SE Utah include birdseed, high oleic sunflower, and organic safflower and sunflower. Safflower, sunflower, camelina, and canola have been tested at SWCRC to evaluate their adaptation to SW Colorado, their performance, and their response to N rate, planting date and rate, crop rotation, or limited irrigation. More information and results on these crops can be found in CSU-AES Technical Reports TR10-06, TR11-04, TR12-7, and TR14-13.

Canola is a registered trademark of the Canadian Canola Association and refers to cultivars of rapeseed with low erucic acid content[42]. Both winter and spring canola have performed well at SWCRC. However, winter canola is less prone to damage by hail, insects or birds due to its earlier harvest. Moreover, winter canola generally requires less irrigation water to maximize production since it is grown during the cooler part of the year and benefits from fall and winter precipitation. It is generally planted in late August to early September and harvested by mid-July, similar to winter wheat.

Camelina is native of Europe where it has been grown for a long time. It has been referred to as 'gold-of-pleasure', false flax, wild flax, linseed dodder, etc. It is a member of the mustard family which includes rapeseed, cabbage, cauliflower, radish, and turnip. Camelina's short growing season (85-100 days) and relatively low water and nutrient requirements make it a good candidate for dryland cropping systems. As with canola, there are winter and spring varieties of camelina. Both camelina and canola can be grown in rotation with winter wheat, whereby a crop is grown each year but the feasibility of such a crop rotation has not been evaluated in SW Colorado. Volunteer camelina or canola can be an issue in any cropping system due to the small size of camelina and canola seeds and challenges with volunteer control, especially with Roundup Ready and Clearfield varieties of canola. Canola is mostly grown for oil, while camelina is prized for its high omega-3 fatty acid content (35 to 39%). Camelina acreage in the US is minuscule compared to that of canola or sunflower. Currently there is no commercial production of camelina or canola in SW Colorado.

Like winter canola and winter wheat, winter hardy varieties of camelina and safflower may be more suitable to SW Colorado than spring varieties. They will be planted in late summer-early fall and benefit from fall and winter precipitation, and harvested by mid-July, which would reduce heat stress and bird damage (camelina).

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[42] Southwestern Colorado Research Center 2005-2009 Results. Technical Report TR10-06, CSU-AES, Ft. Collins, CO.

2013-2014 National Winter Canola Variety Trial

A.F. Berrada, M.J. Stamm[43], J.J Johnson, and A.Y. Berrada

This trial is part of the National Winter Canola Variety Trial program managed by Kansas State University. Data collected or measured include fall stand, winter survival, bloom date, plant height, seed maturity date, seed moisture, seed test weight, and seed yield and oil content.

Trial Information

Fertilizer application	None
Harvest date	Not harvested
Irrigation	None
Number of replications	3
Planting date	September 6, 2013
Planting rate	5 lb/acre at 12-inch row spacing
Plot size	6 ft by 40 ft
Pre-emergent herbicide	September 3, 2013: Cornbelt Trifluralin @ 1.54 pt/ac
Precipitation[44]	8.43 inches (planting to termination)
Trial design	Randomized block

By March 3, 2014 the winter canola was pretty much gone, having been eaten by army cutworms. The trial was terminated on March 18. Fall stand averaged 4.5 over 10 and ranged from 1.8 to 6.6 (Table 7).

Table 15. Results of the 2013-2014 National Winter Canola Variety Trial.

Variety	Fall Stand (0-10)[45]	Variety	Fall Stand (0-10)
MH10G11	6.6	46W94	4.5
Raffiness	6.1	Claremore	4.4
DKW46-15	5.9	KSR07352S	4.4
Hornet	5.8	Sitro	4.4
CHH2311	5.7	KSR07363	4.3
X13W029C	5.7	X10W665C	4.3
Argos	5.6	CHROME	4.2
Dimension	5.4	Garou	4.1

[43] Canola breeder, Kansas State University.

[44] The actual amount of precipitation may have been higher because snow measurements at the automated weather station tend to be inaccurate.

[45] 0 = no stand, 10 = excellent.

Variety	Fall Stand (0-10)[45]	Variety	Fall Stand (0-10)
EdimaxCL	5.2	MH09E3	4.1
Popular	5.2	MH10L23	4
X12W377C	5	Wichita	4
X12W447C	5	Riley	3.9
Mercedes	4.9	Inspiration	3.3
DKW41-10	4.8	Safran	3.3
X10W443C	4.7	46W99	2.8
PT211	4.7	Visby	2.4
HyCLASS115W	4.6	DKW44-10	1.9
DKW47-15	4.5	HyCLASS125W	1.8
Average	4.5		
CV (%)	31		
LSD.05	2.3		

2014-2015 Dryland National Winter Canola Variety Trial

Abdel Berrada, Michael Stamm[46], Jerry Johnson, and Amin Berrada

Trial Information

There were 36 varieties of winter canola in this trial. The design of the trial was a randomized complete block with three replications. Each plot was 40 feet long by 6 feet wide. On August 26, 2014 the trial area was sprayed with Treflan (a pre-emergent herbicide) at a rate of 1.75 pints/acre. The canola was planted on September 2, 2014 at a rate of 5 lb/acre. The trial received no irrigation. Harvest was completed on July 29, 2015. Between planting and harvest the research center received 12.74 inches of precipitation. However, the actual amount of precipitation is probably higher because moisture from snow is not measured accurately by CoAgmet. Seed from two replications of each variety was analyzed for oil content.

Table 16. Measured Data.

Data measured	Comments
Yield	Canola seed yield adjusted to 9% moisture.
Bloom date	Date on which 50% of the plants have one or more open flowers.
Density	The harvested seed density, also known as “test weight”.
Fall stand	A rating from 0 to 10 where 0 = no stand, 10 = perfect stand. A four-foot section of row in each plot was measured. Gaps of three or more inches between plants were recorded. Measured on October 13, 2014.
Harvest maturity date	The date when 90% or more of the plants have turned a mature color.
Height	The height to the tallest part of an average plant in the plot.
Moisture	Seed moisture after harvest.
Winter survival	The percentage of plants that survived the winter. Twenty plants per plot were checked. Measured on March 19, 2015.

Results

[46] Canola breeder, Kansas State University.

Table 17. Results of the 2014-2015 National Winter Canola Variety Trial.

Variety	Yield (lb/ac)[47]	Bloom Date	Density (lb/bu)	Fall Stand	Harvest Maturity Date	Height (in)	Moisture (%)	Oil (%)
DK IMISTAR CL	3,985	4/30	53.7	10.0	7/19	43.0	5.2	32.5
Hornet	3,884	5/4	51.8	9.0	7/17	46.7	5.2	32.9
Mercedes	3,779	4/30	52.9	9.7	7/18	43.7	5.4	34.1
Einstein	3,688	4/30	52.6	9.7	7/20	36.0	5.7	34.6
DK SENSEI	3,667	5/4	53.3	10.0	7/20	39.7	5.1	31.1
CHROME	3,628	5/3	52.7	7.2	7/18	42.0	5.3	33.6
SY Marten	3,579	4/30	52.5	10.0	7/26	47.0	5.8	33.6
SY Harnas	3,559	4/30	53.2	9.0	7/18	41.3	5.5	32.6
HEKIP	3,554	4/28	53.3	10.0	7/20	44.7	5.6	32.0
Popular	3,544	4/30	53.0	9.7	7/21	44.7	5.5	34.1
NK Technic	3,527	4/30	53.8	10.0	7/18	41.3	5.6	32.0
Inspiration	3,523	5/1	53.3	7.5	7/18	44.0	5.2	33.4
Safran	3,507	5/3	53.1	9.2	7/22	44.7	5.7	32.7
Garou	3,504	4/30	52.7	9.2	7/21	40.7	5.4	33.1
KSUR21	3,430	5/4	53.4	9.4	7/17	47.3	5.4	33.6
DK IMIRON CL	3,418	5/4	53.7	9.5	7/16	43.7	5.2	30.2
Sitro	3,388	4/30	53.0	8.1	7/15	44.3	5.3	33.6
NK Petrol	3,367	4/30	53.8	9.4	7/16	47.0	5.6	32.3
MH11J41	3,351	4/30	52.8	9.1	7/14	44.7	5.4	33.6
MH11M16	3,319	5/4	52.6	9.6	7/18	49.7	5.4	33.1
Edimax CL	3,303	4/30	53.2	9.3	7/18	42.0	5.5	33.5
KS4549	3,288	5/4	52.6	9.5	7/13	47.0	5.2	32.1
MH12AX37	3,270	5/3	51.7	9.4	7/23	48.7	5.7	33.2
Virginia	3,269	4/30	52.2	10.0	7/17	38.3	5.2	30.3

[47] Yield is adjusted to 9% moisture. Yields in bold text are in the top performing group and are not significantly different from each other.

Variety	Yield (lb/ac)[47]	Bloom Date	Density (lb/bu)	Fall Stand	Harvest Maturity Date	Height (in)	Moisture (%)	Oil (%)
KS4506	3,246	5/3	52.9	9.5	7/15	42.3	5.4	32.0
SY Fighter	3,201	4/30	51.8	9.0	7/26	41.7	6.0	34.9
DK SEVERNYL	3,196	5/4	53.4	9.4	7/20	39.7	5.1	31.4
Riley	3,168	4/30	52.5	7.7	7/10	43.0	5.1	33.3
VSX-3	3,128	4/30	52.3	10.0	7/15	40.0	5.4	30.4
SY Saveo	3,110	4/30	52.8	6.9	7/22	47.7	6.2	35.0
Wichita	3,022	4/30	53.3	8.8	7/9	44.7	5.2	32.2
Dimension	2,942	4/30	52.6	9.3	7/25	48.3	6.4	34.9
VSX-4	2,941	4/30	52.0	8.2	7/19	44.7	5.9	31.4
Sumner	2,935	4/30	53.0	6.6	7/9	45.0	5.1	32.9
Claremore	2,873	5/4	53.6	9.1	7/13	42.0	5.5	31.6
Raffiness	2,691	4/30	52.5	10.0	7/15	42.0	5.3	33.1
Average	3,355	5/1	52.9	9.1	7/18	43.7	5.5	32.8
CV (%)	8.0		1.1	8.6		11.8	6.1	2.9
LSD.05	438.6		1.0	1.3		NS	0.5	1.9

Summary

Seed yield averaged 3,355 lb/ac. This was the highest winter canola yield produced to date at the SWCRC without irrigation. Most of the varieties had a good fall stand and all varieties had 100% winter survival. Harvest maturity dates ranged from July 9 to July 26. Oil content was less than normal, which was perhaps due to low soil fertility. Soil test results from samples taken before planting showed Organic Matter: 1.1%, Nitrate-N: 38 ppm or 137 lb/acre, P: 23 ppm, and K: 155 ppm in the top foot of soil. No additional N, P or K was recommended based on a yield goal of 1000 lb/acre.

2013-2014 Dryland Winter Camelina Trial

A.F. Berrada and C. L. Rife[48]

Trial Information

Harvest date	July 11, 2014
Irrigation	None
Number of replications	4
Planting date	September 6, 2013
Planting rate	7.5 lb/ac at 12-inch row spacing
Plot size	6 ft by 40 ft
Pre-emergent herbicide	September 3, 2013: Cornbelt Trifluralin @ 1.54 pt/ac
Rainfall	11.3 inches (planting to harvest)
Trial design	Randomized block

[48] Crop breeder, High Plains Crop Development, LLC, Torrington, WY

Table 18. Results of the 2013-2014 winter camelina trial.

Variety	Yield[49] (lb/ac)	Stand on Nov. 7, 2013	Grain Moisture[50] (%)	Test Weight[46] (lb/bu)	50% Bloom Date[51]
HPX-WG1-6	432	24%	7.1	46.2	May 4
Joelle	371	28%	7.2	43.0	May 9
HPX-WG4-1	368	27%	7.2	46.1	May 3
HPX-WG1-29	347	22%	7.2	45.9	May 4
Bison	342	21%	7.1	42.7	May 6
HPX-WG4	336	31%	7.2	47.5	May 7
HPX-WG2	320	28%	7.2	46.9	May 9
HPX-WG1-8	301	33%	7.2	45.2	May 6
HPX-WG1	284	19%	7.3	46.8	May 5
HPX-WG1-35	275	20%	7.1	46.2	May 5
HPX-WG1-33	255	24%	7.2	46.5	May 9
HPX-WG1-24	236	31%	7.3	45.4	May 8
Average	322.0	26%	7.2	45.7	May 6
CV (%)	24.9	43.8	2.6	5.3	
LSD.05	115.2	16	0.3	NA	

Results Summary

The camelina fall stand was poor even though moisture conditions were favorable at planting and following planting. It is possible that camelina plants were damaged by insects (aphids, fleas, cutworms) or frost prior to stand evaluation on November 7. Rainfall in August and September 2013 was twice that of the 30-year average. In contrast, winter and spring 2014 precipitation was below average except in May. Seed yields were low but the potential for higher yields exit as was shown in 2012 (TR14-13, http://webdoc.agsci.colostate.edu/aes/SWCRC/pdf/TR14-13.pdf).

[49] Adjusted to 8.5% moisture
[50] Using the brown mustard setting on the grain analyzer. Test weight could not be determined for several plots.
[51] Date when 50% of stems have 1 or more open flowers. Data was collected from 3 replications.

2013-2014 Dryland Winter Safflower Variety Trial

A.F. Berrada

Table 19. Results of the 2013-2014 winter safflower variety trial.

Entry[52]	Stand on Nov. 8, 2013
PI 651879	21%
PI 651878	16%
PI 651880	12%
Average	16%

Results Summary

Fall stand was poor to begin with and on March 13, 2014 there were only a handful of plants that survived the winter. Consequently, this trial was terminated on March 18, 2014. There were no released varieties of winter safflower that we were aware of when this trial was conducted; only germplasm. The goal was to find out if any of the three entries could survive the winter and perform well enough to warrant further testing. Unfortunately, that did not happen. Like winter wheat, winter canola or winter camelina, winter safflower would benefit from winter and early spring precipitation and potentially outperform spring-planted safflower. Moreover, an earlier harvest e.g., in July rather than in September or October as is usually the case with spring safflower, would allow for more soil water recharge in the summer and the potential to plant a fall crop.

[52] Seeds were obtained from USDA-ARS in Pullman, WA.

2014 Dryland Safflower Variety Trial

A.F Berrada and A.Y. Berrada

Trial Information

Harvest date	September 5
Irrigation	None
Number of replications	5
Planting date	April 8
Planting rate	348,480 seeds/acre at 12-inch row spacing
Plot size	6 ft by 40 ft
Rainfall	5.37 inches (planting to harvest)
Trial design	Randomized block

Results

Table 20. Results of the 2014 dryland safflower variety trial.

Variety	Brand	Yield[53] (lb/ac)	Seed Moisture (%)	Test Weight (lb/bu)	Plant Height (in)	50% Bloom Date
S-351	SeedTec	267	5.9	39.5	15	July 14
3303	SeedTec	190	6.0	39.3	15	July 14
S-333	SeedTec	169	6.0	39.7	15	July 18
9359	SeedTec	166	5.9	39.0	15	July 16
S-719	SeedTec	158	5.9	37.7	15	July 14
S-321	SeedTec	157	5.8	40.5	16	July 15
S-541	SeedTec	147	5.8	37.7	15	July 15
7325	SeedTec	135	6.2	37.6	16	July 14
CW 88-OL	Cal/West Seeds	134	5.9	39.7	15	July 15
6159	SeedTec	131	6.1	38.6	16	July 18
CW 3268-OL	Cal/West Seeds	124	5.9	37.8	15	July 16
CW 99-OL	Cal/West Seeds	121	5.8	36.6	15	July 14
S-208	SeedTec	102	5.8	38.0	15	July 14
CW 1221	Cal/West Seeds	97	5.8	36.8	14	July 15
8231	SeedTec	83	6.0	35.0	15	July 14
Average		145	5.9	38.2	15	July 15
CV (%)		46			6.5	
LSD.05		85			NS	

Note: The yield was low, so the samples for each variety had to be combined in order to measure

[53] Adjusted to 10% moisture

the moisture and test weight. Therefore, statistics for the moisture and test weight are not available.

Summary

Safflower seed yields were much lower than in previous years. The average dryland safflower yield was 1,015 lb/acre in 2008-2013. The lower yields in 2014 were due to dry conditions in early winter through April and in June and July, and substantial damage from deer and ravens. Deer and bird damage increased the variability in seed yield.

2015 Irrigated Dry Bean Variety Trial

A.F Berrada, M. A. Brick[54], J. B. Ogg[55], J.J. Johnson, and A.Y. Berrada

Introduction

Southwestern Colorado is one of the few areas in Colorado that produces dry beans in a low rainfall area without the benefit of irrigation water. The long-term annual average precipitation in the San Juan Basin is 12 to 16 inches. Winter precipitation is critical to recharge the soil profile and provide moisture for seed germination and early plant growth. Dry beans are planted in late May to mid-June. Seed germination and plant development coincides with the driest period of the year. Dry beans are usually harvested by mid-September to avoid the fall freeze.

The variety 'San Juan Select' pinto bean was released in 1946. San Juan Select was the primary pinto variety grown in southwestern Colorado until 1981, when 'Cahone' was released by Colorado State University (Wood et al., 1983)[56]. In 1994, 'Fisher' pinto bean was released by Colorado State University (Fisher et al., 1995)[57]. Fisher is more sensitive to local environmental conditions than Cahone and is not widely planted.

Trial Information

The irrigated dry bean trial included seven varieties of beans. The trial area received approximately 51 lb N/acre and 26 lb P_2O_5/acre on April 7. It was sprayed with Treflan at 1.5 pt/acre on June 16. Trial design was a randomized complete block with four replications. Each plot was 40 feet long by 10 feet wide with a row spacing of 2.5 feet. The beans were planted on June 19 at a rate of about 83,635 seeds/acre. There were problems with the planter in a couple plots, so three rows had to be replanted by hand. An area of 6 ft by 5 ft was harvested from each plot by hand starting on September 30. The beans were air dried, shelled and cleaned, then weighed. Finally, moisture and test weights were recorded. The trial was irrigated with a center pivot. Rainfall between planting and harvest was 3.61 inches.

Results

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[54] Professor, Dry Bean Breeder, and Department Head, Soil & Crop Sciences
[55] Research Associate, Plant Breeding & Genetics, Soil & Crop Sciences
[56] Wood, D.R., A.G. Fisher, and M. Ballarin. 1983. Registration of Cahone bean. Crop Sci. 23:399.
[57] Fisher, A.G., M.A. Brick, D.R. Wood, M. Stack, H.F. Schwartz, J.B. Ogg, C.H. Pearson, J.F. Shanahan, and M. Ballarin. 1995. Registration of 'Fisher' pinto bean. Crop Sci. 35:1511.

Table 21. Results of the 2015 Irrigated Dry Bean Trial.

Variety	Yield (lb/ac)[58]	Moisture (%)	Test Weight (lb/bu)
Croissant	2,569	10.1	58.8
Othello	2,547	10.2	58.6
COSD 3	2,511	10.6	61.3
COSD 25	2,469	10.4	58.4
Long's Peak	2,407	10.4	58.1
COSD 7	2,227	10.5	60.0
Centennial	2,223	10.4	60.8
Average	2,422	10.4	59.4
CV (%)	16	1.1	1.0
LSD.05	NS	0.2	0.9

Results Summary

Seed yield averaged 2,422 lb/acre with no significant differences between the seven entries at the 95% probability level; despite a 346 lb/acre spread between the highest (2,569 lb/acre) and lowest yields (2,223 lb/acre).

[58] Adjusted to 14% moisture

2015 Irrigated Potato Variety Trial

A.F. Berrada, Samuel Y.C. Essah[59], D.G. Holm[60], and A.Y. Berrada

Introduction

Potatoes are not commonly grown in southwestern Colorado, but they are a major crop in the San Luis Valley where there has been a concern about Potato Virus Y infecting seed potatoes. There is potential to grow disease-free seed potatoes in southwestern Colorado and given that potatoes are a high cash crop, this would provide a good source of income for the region, assuming that Potato Virus Y is not present and other conditions are met such as the availability of equipment and facilities to plant, harvest, and store potatoes. In addition to producing disease-free seed potatoes, the goal of this research is to also evaluate specialty potatoes.

Trial Information

There were six varieties of potato in the trial. The trial had four replications in a randomized complete block design. Plots were 30 feet long by 40 inches wide with one row per plot. Spacing between plants was 10 inches. Before planting, the ground was fertilized at a rate of 137.3 lb/acre of nitrogen and 69.3 lb/acre of P_2O_5. Potatoes were planted on May 14 at a depth of 1-3 inches. The seed potatoes were obtained from the San Luis Valley Research Center and were already treated with fungicide. Weeds were controlled by hoeing. The potatoes were hilled on June 24. They were harvested on October 1st through 2nd. For harvest, a six foot by one row area of each plot was dug up. The experiment was irrigated with a side roll. Rainfall between planting and harvest was 7.64 inches.

Bloom date was recorded to give an idea of the maturation speed of the different potato varieties. Size distribution, diameter distribution, and external defects were measured because they affect the marketability of the potatoes and therefore the price a producer can receive. Further details are located in Tables 22-25.

[59] Associate Professor and Potato Agronomist, Colorado State University, Department of Horticulture and Landscape Architecture, San Luis Valley Research Center, Center, Colorado.

[60] Professor and Potato Breeder, Colorado State University, Department of Horticulture and Landscape Architecture, San Luis Valley Research Center, Center, Colorado.

Comments on data that was measured

Data measured	Comments
Bloom date	Date when 50% of the potato stems have had one or more flowers open, even if the flowers have since died back.
Potato size & distribution	This was measured by trying to fit a potato through a metal plate with a circular hole cut into it. If any part of the potato was larger than a given diameter it wouldn't fit through the hole and it would go into the larger diameter category. Diameter was measured only for spherical varieties of potatoes as opposed to oblong varieties. Results were reported as the percentage by weight rather than percentage by number of tubers.
External defects	This was recorded only for potatoes that were four ounces or more in weight. Results were reported as the percentage by weight rather than percentage by number of tubers.

Results

Table 23: Potato yield and other data.

Variety	Yield (tons/acre)	Bloom Date	Size Distribution (%)							
			< 4 oz	4-6 oz	6-8 oz	8-10 oz	10-12 oz	12-14 oz	14-16 oz	> 16 oz
Midnight Moon	21.8	July 22	52	25	12	5	2	3	0	0
Red Luna	21.3	July 17	32	21	17	8	9	6	5	2
CO00291-5R	20.9	July 17	34	32	17	10	5	1	2	0
Masquerade	18.9	July 14	46	28	13	6	4	3	0	0
Fortress Russet	17.0	July 14	25	22	21	13	8	5	2	4
Mesa Russet	14.8	July 9	27	30	20	12	7	3	2	0
Average	19.1	July 16	36	26	17	9	6	3	2	1
CV (%)	17.7									
LSD.05	5.1									

Table 24. Potato external defects.

Variety	External defects			
	Growth Cracks	Knobs	Misshapes	Total
Midnight Moon	0%	0%	0%	0%
Red Luna	14%	0%	1%	15%
CO00291-5R	1%	0%	0%	1%
Masquerade	0%	0%	0%	0%
Fortress Russet	0%	0%	2%	2%
Mesa Russet	3%	0%	4%	7%
Average	3%	0%	1%	4%

Table 25. Potato diameter distribution.

Variety	Diameter			Diameter and Weight	
	< 2 in	2-4 in	> 4 in	> 2 in < 10 oz	> 2 in > 10 oz
Midnight Moon	31%	69%	0%	64%	4%
Red Luna	28%	72%	0%	50%	20%
CO00291-5R	16%	84%	0%	76%	8%
Masquerade	24%	76%	0%	68%	8%
Average	25%	75%	0%	65%	10%

Summary

Potato yield averaged 19.1 tons/acre (4.8 to 21.8) with ‘Mesa Russet’ producing significantly less than ‘Midnight Moon’, ‘Red Luna’ or ‘CO00291-5R’. The variety Midnight Moon had the highest yield but 52% of the tubers were under four ounces. External defects were uncommon except for Red Luna which had growth cracks in 14% of the tubers that were four ounces or larger. No Potato Virus Y was detected in the trial. Mesa Russet and Fortress had the earliest bloom date-- July 9 and July 14, respectively, and the highest percentage (74 and 75%) of tubers that were 4 ounces or higher.

This one-year trial proves the already known fact that potatoes can be grown successfully in SW Colorado. The management of the trial was challenging due to the lack of adequate planting, cultivation, and harvest equipment. Further testing is needed to develop best management practices and a market analysis will be a plus before recommending large-scale production of disease-free seed potatoes or specialty potatoes in SW Colorado.

Industrial Hemp Variety Trials at the Southwestern Colorado Research Center (SWCRC)

A.F. Berrada, A.Y. Berrada[61], J.K. McKay[62], and B. Campbell[63]

Introduction

Due to interest in industrial hemp in SW Colorado, Colorado State University's Southwestern Colorado Research Center (SWCRC) conducted field trials in 2015 and 2016 to test the adaptation and yield potential of this emerging crop. Similar trials were conducted at the Agricultural Research, Development, and Education Center (CSU-ARDEC) near Ft. Collins.

Research on industrial hemp in Colorado was made possible by the Agricultural Act of 2014 ("Farm Bill") and by the Colorado Revised Statute C.R.S. 35-61-109. Under this statute, industrial hemp is defined as "a plant of the genus cannabis and any part of the plant, whether growing or not, containing a delta-9 tetrahydrocannabinol [THC] concentration of no more than three-tenths of one percent on a dry weight basis". The Colorado Industrial Hemp Regulatory Program is administered by the Colorado Department of Agriculture (CDA). It

- "Permits growing and possessing industrial hemp by registered persons for commercial or research and development purposes.
- Establishes an industrial hemp committee to work with the Department of Agriculture to establish an industrial hemp registration program and a seed certification program.
- Establishes an industrial hemp grant research program for state institutions of higher education to conduct research to develop or recreate strains of industrial hemp best suited for industrial applications."

Arrangements were made with CDA to obtain industrial hemp seeds from Europe. The seeds of 28 varieties were ordered in 2015, but only 12 made it to the SWCRC. In 2016, all 13 varieties ordered were received and tested at ARDEC and SWCRC. Below are the results of the variety trials at SWCRC. Some of these results were combined with the results from ARDEC and submitted for publication in 2018[64].

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[61] Former Research Associate, Colorado State University, Southwestern Colorado Research Center

[62] Associate Professor, Colorado State University, Department of Biological Sciences & Pest Management

[63] PhD candidate, Colorado State University, Department of Biological Sciences & Pest Management

[64] Campbell, B., A. Berrada, C. Hudalla, S. Amaducci, and J. McKay. Genotype-by-Environment Interactions of Industrial Hemp (Cannabis sativa, L.) Varieties Highlight Diverse Responses to Environmental Factors. Submitted for publication in Crop Science in September 2018.

Hemp Variety Trial at the SWCRC in 2015

Trial Information

The industrial hemp variety trial was conducted at the Southwestern Colorado Research Center which is located near Yellow Jacket, Colorado. The design of the trial was a randomized complete block with four replications. There were twelve varieties of hemp. Each plot was 30 feet long with six rows per plot and eight inches between rows.

The priority was to plant hemp as soon as the seeds were available, and the soil was dry enough to operate machinery. Soil samples were taken shortly before hemp seeding and were sent to a private laboratory for analysis several weeks later. Rather than waiting for the results, 110 lb N/acre were applied on June 17, which in hindsight was a poor decision. Indeed, soil test analysis (Table 25) shows that no N or K fertilizer was needed but that 30 lb P_2O_5 per acre should have been applied. The recommendations were based on a yield goal of 4.0 tons of dry matter and are not site specific. One publication from Manitoba, Canada states that the rule of thumb is to treat fertility recommendations for industrial hemp "similar to a high yielding and high protein spring wheat production" but that "more research is required to develop a better understanding of hemp fertility recommendations" (http://www.gov.mb.ca/agriculture/crops/production/print,hemp-production.html, accessed on December 30, 2015). The same publication reports nutrient uptake and removal estimates (total for hemp stalks and seeds) of 178 lb N/acre, 96 lb P_2O_5/acre), and 227 lb K/acre, and 12 lb S/acre, but no hemp yield estimate was given.

The hemp trial site was in spring wheat in 2014 and in alfalfa before that, which may explain the high N-NO_3 availability in the top 2.0 feet of soil prior to hemp seeding. The added N may have delayed plant maturity and favored vegetative growth at the expense of seed production.

Hemp was planted on June 18 following 2.18 inches of rain on June 5-12. The seeding rate was approximately 952,205 seeds per acre and the seeding depth was about one inch. Irrigation with the center pivot totaled 6.5 inches. Rainfall from planting to harvest was 5.04 inches. A hailstorm on September 8 caused lodging and loss of leaves. Monthly precipitation at the research center in 2015 is shown in Figure 3[65].

Hemp was harvested starting on October 29, 2015. Hemp plants were cut about six inches above the ground with a push-type sickle-bar mower. The four middle four rows of each plot were harvested to estimate seed yield and plant biomass.

[65] Data for the month of December is not displayed because it was not available at the time this report was written.

Table 26. Test results from soil samples taken on August 10, 2015.

Sample Depth (inches)	Soil pH	Excess Lime	% Organic Matter	Nitrate-Nitrogen (lb N/ac)	Phosphorus (ppm)	Potassium (ppm)	Fertilizer Recommendations (lb/ac)[66]		
							N	P_2O_5	K_2O
0-12	7.6	Lo	1.4	68	13	195	0	30	0
12-24				97	5				

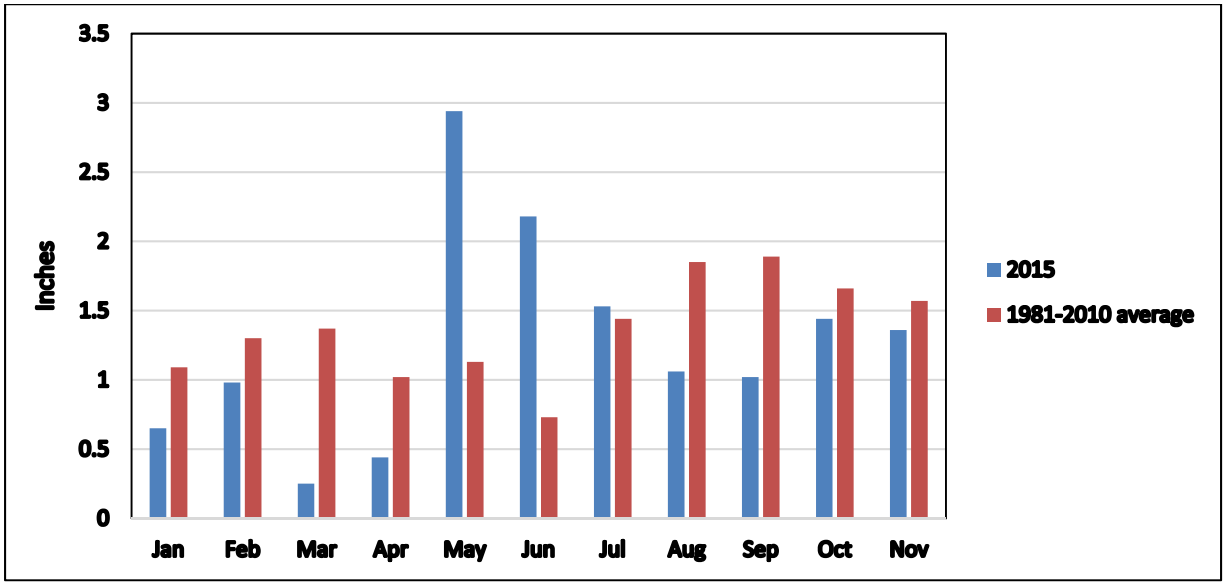

Figure 3. Monthly Precipitation at Yellow Jacket, CO in 2015.

Pests

Weeds were controlled by hoeing. The only other pest problem we noticed was black birds.

Measurements

Hemp emergence was measured on June 30. The number of plants were counted in a three foot by one row area in each plot in two replications. Because of the small area measured and the small number of replications the emergence numbers are only a rough estimate.

Plant height was measured approximately once a week from July 20 until September 29. Measurements were taken for three replications and two plants per plot were measured. The same plants were measured each week. The plants that were chosen were about average height, although as the growing season progressed they may have become shorter or taller than average. If the hemp plant lodged or seriously injured another plant was chosen. The goal of these measurements was to get an idea of how fast the hemp was growing during the season. The final height was calculated by measuring five plants per plot shortly before harvest. These plants were

[66] Servi-Tech Inc. recommendations for a yield goal of 4 tons/acre

also used to get a rough estimate of lodging.

Stem diameter was measured shortly before harvest. A pair of calipers was used to measure the diameter of ten plants per plot at the base of each plant.

Biomass moisture was calculated by picking fifteen plants per plot out of what was harvested and then comparing the weight before and after they were dried. The plants were air dried for several weeks and then oven dried for 24 hours at 80 degrees Celsius which was assumed to bring them to 0% moisture.

Stem, seed, and leaf plus inflorescence yield was calculated by separating out the different plant parts. Leaves and inflorescence could not be separated so they were weighed together. The seeds were very difficult to separate from the leaf and inflorescence, so a much smaller sample was used (several grams per plot) to measure how much seed there was instead of the original 15 plant sample.

Flowering Observations

Dates when the following flowering stages occurred were recorded: beginning of flowering, full flowering, and the end of flowering for both male and female flowers. The characteristics for determining the flowering dates are shown in Table 27.

Flowering observations were recorded for six plants in each plot and were recorded for two replications. It would have been good to record flowering dates for all four replications, but taking flowering observations was by far the most time-consuming part of this experiment so the amount of data collected had to be cut down. The first flowering growth stage data was recorded on July 29. Unfortunately, several hemp plants had reached the beginning of female flowering several days prior to July 29 so the start date had to be estimated. Most plants had both female and male flowers, but some had only one or the other type. Figure 4 shows an example of female hemp flowers while Figure 5 shows male hemp flowers. It was difficult to tell when some flowering stages occurred, so the dates are rough estimates. Observations on flowering dates were taken twice a week until August 24 and were taken once a week after that. Several observations had to be skipped because of other work that needed to be done at the research center.

There were many bees throughout flowering.

Table 27. Procedure used for taking flowering observations.

Growth stage	Procedure that was used	Recommend using this procedure next time
Beginning of female flowering	When the first flower bracts can be seen	
Full female flowering	When flowers from the bottom to the top of the inflorescence (or the area of the inflorescence where female flowers exist) have reached at least the “beginning of female flowering” growth stage.	

Growth stage	Procedure that was used	Recommend using this procedure next time
End of female flowering	When all flower bracts have turned brown or are no longer visible.	
Beginning of male flowering	When the first male flower buds can be clearly identified.	When the first male flowers open.
Full male flowering	When the first male flowers open.	When there are open male flowers from the bottom to the top of the inflorescence (or the area of the inflorescence where male flowers exist).
End of male flowering	When all the male flowers have either dried up or fallen off.	

Figure 4. Photo of hemp female flowers.

Note: The pale green extensions tipped with brownish-purple are the flower bracts. Source: *https://www.minnesotawildflowers.info/flower/hemp*

Figure 5. Photo of male hemp flowers.

Note: Some of the flowers are open while most of them haven't opened yet. Source: *https://www.minnesotawildflowers.info/flower/hemp*

Results

Yield

The varieties in the tables below are sorted in descending order by biomass yield. Yield results are shown in Table 27. Yields were adjusted to 0% moisture. 'Carmagnola' and 'Tisza' had the best above-ground biomass yields at 5,533 and 5,231 lb/ac respectively. The above-ground biomass included everything that was harvested which was the whole plant from about six inches above the ground and upwards. The moisture levels of the biomass averaged 47% at harvest and ranged from 33% to 56%.

Seed yield was low for every variety except Carmagnola, which produced 519 lb/ac of seed. The seeds ripened over a long period of time. As a result, many of the seeds had either fallen to the ground or were eaten by birds by the time the hemp was harvested. Moreover, there was substantial lodging with an average of 31% of plants lodged. Some of the hemp stalks seemed to easily break. Lodging was exacerbated by a hailstorm that occurred on September 8. The hailstorm also caused some loss of seeds. Consequently, seed yields were low to very low for most of the planted varieties.

Carmagnola and Tisza also had the highest stem yields at 4,848 and 4,766 lb/ac respectively. Most of the above-ground hemp biomass was made up of stems (88% on average).

'Dacia', 'Lovrin', and Carmagnola had the highest leaf plus inflorescence yields at 440, 438, and 435 lb/ac respectively. Most of the leaves had dropped off by harvest.

The seeds ripened over a lengthy period. As a result, many of them had either fallen to the ground or were eaten by birds by the time the hemp was harvested. This resulted in a very low seed yield for almost all varieties.

Table 28. Hemp yield in 2015.

Variety	Dry Biomass Yield (lb/ac)[67]	Seed Yield (lb/ac)[68]	Stem Yield (lb/ac)[64]	'Leaf + Inflorescence' Yield (lb/ac)[64]	Biomass Moisture (% of wet weight)
Carmagnola	5,533	519	4,848	435	44%
Tisza	5,231	47	4,766	219	34%
Futura 75	4,541	66	4,119	355	41%
Dacia	4,537	169	3,871	440	53%
Tygra	3,526	132	3,127	266	49%
Félina 32	3,506	71	3,049	275	47%
Santhica 27	3,474	25	3,100	348	49%
Férimon	3,446	70	2,732	386	43%
Monoica	3,086	26	2,818	328	54%
USO 31	3,031	35	2,660	332	56%
Lovrin	2,905	46	2,415	438	56%
Ivory	2,489	105	2,459	180	33%
Average	3,775	107	3,339	333	47%

Height and Stem Diameter

The average hemp stem diameter at the base of the plant was 5.8 mm. 'Lovrin' had the thickest stems with a diameter of 8.0 mm while Tisza had the thinnest stems with an average diameter of 4.8 mm. There was no correlation between stem diameter and biomass yield, although the varieties with the thickest stems tended to have a higher leaf plus inflorescence yield.

The average height for all of the varieties was 58 inches. Carmagnola was the tallest variety at 77 inches followed by Dacia at 74 inches. 'USO 31' was the shortest variety at 44 inches in height. The taller varieties tended to have a higher biomass yield although there were exceptions.

[67] Above-ground biomass only, roots are not included. Yield is adjusted to 0% moisture.
[68] Adjusted to 0% moisture.

Table 29. Stem diameter and plant height.

Variety	Stem Diameter (mm)	Height (in)
Carmagnola	7.1	77
Tisza	4.8	65
Futura 75	5.6	56
Dacia	6.6	74
Tygra	5.4	55
Félina 32	5.0	48
Santhica 27	5.0	55
Férimon	5.0	52
Monoica	6.8	59
Uso 31	5.0	44
Lovrin	8.0	58
Ivory	5.7	53
Average	**5.8**	**58**

Hemp Stand, Lodging, and Maturity Date

Results for the hemp stand, lodging, and maturity are shown in Table 29. When comparing the number of plants per acre between June 30 and harvest there was on average a 37% reduction. At the end of the season Tisza had the best stand while Lovrin and ‘Monoica’ had the worst.

There was substantial lodging with an average of 31% of plants lodged. Part of this was due to a hailstorm that occurred on September 8.

More than half of the plots hadn’t turned a mature color by October 19. ‘Ivory’ reached a mature color by August 28 and was by far the earliest variety.

Table 30. Stand, lodging, and maturity results.

Variety	Emergence on June 30 (plants/acre)	Hemp Stand before harvest (plants/acre)	Lodging	Maturity Date[69]	Number of plots that reached maturity by October 19
Carmagnola	203,280	136,125	10%	Oct 19	3
Tisza	268,620	252,285	40%	Oct 17	4
Futura 75	341,220	207,818	40%	Oct 12	1
Dacia	188,760	126,143	15%		0
Tygra	261,360	164,258	50%	Oct 12	1
Félina 32	333,960	204,188	25%	Oct 12	1
Santhica 27	428,340	193,298	25%	Oct 19	3
Férimon	370,260	194,205	50%	Oct 19	3
Monoica	159,720	83,490	20%		0
Uso 31	304,920	201,465	40%		0
Lovrin	137,940	66,248	15%		0
Ivory	137,940	142,478	45%	Aug 28	4
Average	261,360	164,333	31%	Oct 7	20 out of 48 total plots

Growth Rate

Growth rate results are shown in Figure 6. These results are derived from the plant height measurements that were taken periodically during the growing season. The peak daily growth rate for all varieties was achieved somewhere between days 33 and 49 after planting. Plant height nearly stopped increasing from day 71 forward for most varieties. Carmagnola (which is the tallest variety) didn't have the highest initial growth rate but kept growing rapidly from days 50 to 70. The growth rate of most of the other varieties had greatly fallen off.

[69] Date when 50% of the plants in a plot have changed stem color.

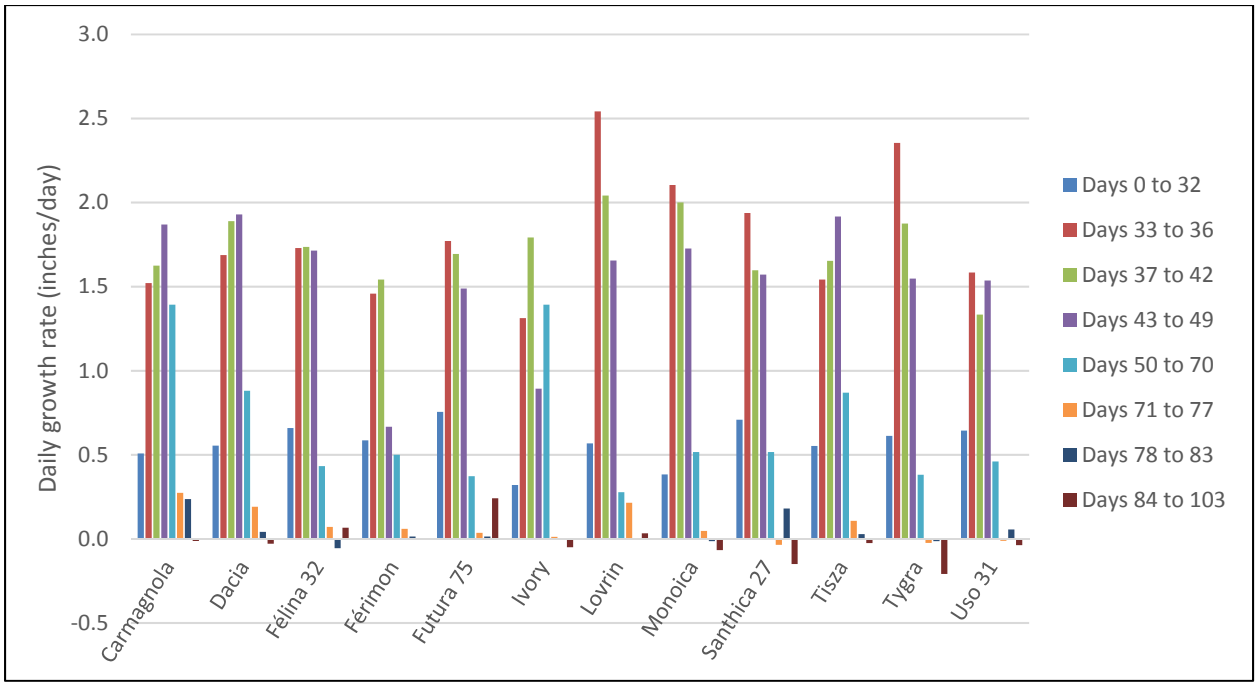

Figure 6. Growth rate.

Flowering

Flowering stage results are shown in Table 30. Varieties with higher biomass yields tended to have later flowering dates. Female flowering dates generally occurred earlier than male flowering dates:

beginning of female flowering - beginning of male flowering = 3 days

full female flowering - full male flowering = 6 days

end of female flowering - end of male flowering = 22 days

The earliest variety to reach the end of male flowering was Ivory at 81 days followed by Tygra at 82 days. The latest variety was Dacia at 105 days.

Table 31. Days since planting to reach various flowering stages.

Variety	Beginning of female flowering	Full female flowering	End of female flowering	Beginning of male flowering	Full male flowering	End of male flowering
Carmagnola	66	70	88	61	71	101
Tisza	57	63	75	57	66	89
Futura 75	53	61	75	59	66	85
Dacia	53	58	78	58	65	105
Tygra	42	47	61	47	56	82
Félina 32	43	49	67	46	55	92
Santhica 27	41	46	63	44	53	91
Férimon	47	51	69	55	62	89
Monoica	46	50	69	47	57	92
Uso 31	39	43	60	39	47	93
Lovrin	40	44	57	41	48	90
Ivory	42	46	66	43	50	81
Average	**47**	**52**	**69**	**50**	**58**	**91**

Results Summary

Because of the late planting date and the diversity in maturity ratings and other plant characteristics, more than half of the varieties hadn't turned a mature color by October 19, 2015. Hemp was harvested shortly after the first fall frost on October 29. Normally, the first fall freeze occurs by late September or early October.

Dried seed yield averaged 114 lb/acre and ranged from 26 to 506 lb/acre. The seeds ripened over a long period of time. As a result, many of the seeds had either fallen to the ground or were eaten by birds by the time the hemp was harvested. Moreover, there was substantial lodging and a hailstorm on September 8, which caused more seed shattering.

Dried biomass yield averaged 3,775 lb/acre and ranged from 2,489 to 5,533 lb/acre. The dried biomass includes the stems, leaves, seeds, and flowers. The yield of dried stems averaged 3,298 lb/acre and ranged from 2,204 to 4,905 lb/acre. Stalk diameter (measured at the base of the plant) averaged 0.23 inches (0.19 to 0.31") and plant height averaged 58 inches (44 to 77"). Peak growth occurred at 33 to 49 days after planting depending on the hemp variety.

Hemp Variety Trial at the SWCRC in 2016

Trial Information

Fertilizer	54 lb N/ac + 35 lb P_2O_5/ac
Irrigation through September 19	8.0 in.
Number of hemp varieties	13
Number of replications	4
Planting date	June 7
Planting rate	952,205 seeds/ac
Plot size	30 ft x 6 ft
Precipitation through September 19	4.76 in.
Row spacing	12 in.

Results

Table 32. Results of the hemp variety trial in 2016.

Variety	Whole Oven Dried Plant (above-ground) Yield (lb/ac)	Oven Dried Stem Yield (lb/ac)	Oven Dried Seed Yield (lb/ac)	Oven Dried Leaf & Hulls & Inflorescence Yield (lb/ac)	Average Height (inches)	Average Stem Diameter (mm)	% Moisture	Number of plants per acre
Tiborszallasi	6,722	4,519	1,041	1,162	72	7	54%	246,840
Eletta Campana	8,283	5,707	1,035	1,541	75	9	60%	250,470
Felina 32	6,474	3,804	937	1,733	54	5	59%	254,100
Ferimon 12	5,354	2,977	928	1,450	48	6	58%	301,290
Futura 75	6,346	4,033	882	1,432	63	7	59%	333,960
Monoica	6,986	4,654	843	1,490	67	7	55%	268,620
Carmaleonte	6,130	3,782	710	1,638	55	7	59%	304,920
CS	7,739	5,759	690	1,290	78	7	57%	304,920
Fedora 17	5,482	3,437	565	1,480	50	7	61%	333,960
Bialobrzeskie	4,538	2,783	463	1,291	44	5	56%	363,000
Diana	5,746	3,712	390	1,644	70	8	62%	152,460
USO 31	4,185	2,577	341	1,267	48	6	57%	196,020
Santhica 27	5,282	3,769	240	1,273	61	6	62%	264,990
Average	6,098	3,962	697	1,438	60	7	59%	275,042
CV (%)	12.4	11.2	45.8	20.1	10.6	19.6		20.3
Pr > F	0.000	0.000	0.006	0.200	0.000	0.001		0.000
$LSD_{.05}$	1087.1	634.7	485.1	NS	9.31	1.86		80154
$LSD_{.01}$	1457.6	851.1	614.2	NS	12.48	2.49		107479

Note: The hemp samples were air dried for several weeks and then oven dried for about 24 hours at 70 degrees C.

Summary

Seed yields ranged from 240 to 1,041 lb/acre. There was high variability in seed yield (CV of 46%). ‘Bialobrzeskie’, ‘Diana’, USO 31, and ‘Santhica’ produced less than 500 lb/acre.

The tallest varieties (≥ 70 in.) tended to have the highest above ground DM yield, except for Diana. There was a weak correlation between plant height and seed yield.

Plant population at harvest averaged only 29% of the number of planted seeds. It would be useful to determine the optimum planting dates and seeding rates for hemp cultivation in SW Colorado.

Hemp Seeding Rate Trial at the SWCRC in 2017

A.F. Berrada

Introduction

In 2015 and 2016, we planted hemp at 952,205 seeds/acre as was recommended by Dr. McKay's research group to ensure a good stand. However, the average plant population at harvest was only 17% of the seeding rate in 2015 and 27% in 2016. The objective of this trial was to test a range of seeding rates and evaluate their impact on seed yield and total aboveground dry matter. Planting hemp at a lower seeding rate than in 2015 or 2016, without significantly affecting production, would lower seed cost. The original plan was to include three hemp varieties, Helena, Beniko, and Tygra. However, Beniko and Tygra had poor germination rates (less than 25%) and were not included in the trial. We also wanted to test 2-3 planting dates (e.g., mid-May, early June, and mid-June) but could not do it due a delay in seed delivery. We planted hemp on June 18 in 2015 and June 7 in 2016, which was one (2016) to three (2015) weeks later than we would have liked. Earlier planting (e.g., mid to late May) would give hemp more time to grow and produce viable seeds before the first killing frost in the fall. Field observations indicate that hemp may be more cold-tolerant than, for example, dry bean, corn or sunflower, which we have planted as early May 20-25.

Helena in this trial was planted on June 1 at four seeding rates, in a randomized complete block design with four replications. Plot size was 6 ft. wide (6 rows) by 40 ft. long. A total of 9.43 in. (gross) was applied with the center pivot. Rainfall from June through September was 4.63 in. based on CoAgmet and 5.21 in. based on CoCoRAHs. There was hardly any precipitation in October. On October 11, we counted all the plants in two 5-ft row sections per plot, cut them at ground level, and weighed them.

Results

Table 33. Results of the seeding rate trial in 2017.

Seeding rate (seeds/ac)	Plant population at harvest (plants/ac)	% of seeding rate	Seed Yield (lb/ac)	Total Dry Matter (lb/ac)	Stem Diameter (mm)
500000	137214b[70]	27.4	806.0	5183.6	8.9
750000	191664ab	25.6	770.0	5597.5	7.8
1000000	179685ab	18.0	755.6	5597.5	8.0
1250000	218889a	17.5	814.4	6076.6	8.1
Average	181863	22.1	786.5	5613.8	8.2
CV (%)	19.1		16.9	11.9	13.2

[70] Means followed by the same letter are not significantly different at $\alpha = 0.05$.

Seeding rate (seeds/ac)	Plant population at harvest (plants/ac)	% of seeding rate	Seed Yield (lb/ac)	Total Dry Matter (lb/ac)	Stem Diameter (mm)
LSD.05	55694		NS[71]	NS	NS

Plant population at harvest averaged 22% of the seeding rate, which is low but consistent with previous results. Seed yield, total dry matter yield, and stem diameter were not significantly different among the seeding rates. These parameters and plant population may have been affected by a heavy weed infestation, mostly pigweed. We started hoeing the plots late (early July) and probably destroyed some of the hemp plants with the hoe or by trampling them.

Although the results of this trial are not conclusive due to the heavy weed infestation, they indicate that lower seeding rates than what we adopted in 2015 and 2016 (952,205 seeds/acre) may be feasible, which would reduce seed cost.

[71] **N**on-**S**ignificant differences among means at $\alpha = 0.05$.

Hemp Deficit Irrigation Trial at the SWCRC in 2016

A.Y. Berrada and A.F. Berrada

Trial Information

Evapotranspiration data source	http://www.coagmet.com/
Fertilizer	97 lb N/ac + 73 lb P_2O_5/ac on June 2nd
Hemp variety	Futura 75 (border plots are different varieties)
Number of replications	3
Planting date	June 7
Planting rate	952,205 seeds/ac
Plot size	40 ft x 12 ft
Reference ET based on	Corn
Reference ET model	Penman-Kimberly
Row spacing	12 in.

Irrigation Treatments

Irrigation treatment	Total sprinkler irrigation from June 7 through June 28 (in.)	Total irrigation received from June 29 to September 18 (in.)	Net irrigation received from June 29 to September 18 (in.)	Total precipitation from June 7 to September 18 (in.)
100% of ET	4.20	17.53	14.02	4.76
60% of ET	4.20	8.27	6.62	4.76
Minimal	4.20	0.00	0.00	4.76

All irrigation treatments received several sprinkler irrigations in order to achieve good emergence. The minimal irrigation treatment also needed irrigation initially because the ground was very dry at planting.

All irrigations from June 29 onwards were with drip irrigation. The minimal irrigation treatment did not receive any further irrigation following this date.

The 100% of ET treatment received enough irrigation to replace 100% of ET from planting until the September 18. ET totaled 18.55 inches during this period. Drip irrigation efficiency was considered when deciding how much to irrigate. Drip irrigation efficiency was assumed to be 80% since the drip tapes were laid on the soil surface. Similarly, the 60% of ET treatment received enough irrigation to replace 60% of ET. ET was based on a corn crop since an ET estimate for hemp was not available.

Results

Table 34. Results of the deficit irrigation trial in 2016.

Irrigation Treatment	Whole Oven Dried Plant (above-ground) Yield (lb/ac)	Oven Dried Stem Yield (lb/ac)	Oven Dried Seed Yield (lb/ac)	Oven Dried Leaf & Hulls & Inflorescence Yield (lb/ac)	% Moisture
100% of ET	5,819	3,877	547	1,395	57%
60% of ET	5,236	3,266	670	1,299	57%
Minimal	3,251	2,225	349	677	51%
Average	4,768	3,123	522	1,124	55%
CV (%)	11.1	12.7	50.3	17.9	
Pr > F	0.009	0.017	0.405	0.023	
$LSD_{.05}$	1203.8	897.1	NS	455.6	

Note: The hemp samples were air-dried for several weeks and then oven dried for about 24 hours at 70 deg. C.

Summary

There was no significant difference in seed yield, which may be due to the high CV. Irrigation application was non-uniform and could explain some of the variability in seed yield. Hemp stand was non-uniform as well.

There was much less variability in total above ground DM and in stem DM. Both were significantly higher at the 100% and 60% ET than the treatment with minimal irrigation application.

Futura 75 averaged 882 lb/ac in the variety trial. The latter was conducted in a more productive soil, under the center pivot.

Hemp Deficit Irrigation Trial at ARDEC South in 2017

A.F. Berrada

Introduction

With limited water supplies and a growing population, managing water is of utmost importance in Colorado. It is believed that agriculture uses 70 to 80% of water resources, although some of the water is recycled into the atmosphere, aquifers, and streams and rivers through evaporation, deep percolation or runoff. Accounting for crop water use is part of a statewide effort to manage water resources wisely. Industrial hemp is an emerging crop in Colorado, but there is little, if any, information about its water requirements. This trial is an attempt to address that by applying different amounts of irrigation water and monitoring its use and effects on crop growth and performance.

'Helena' hemp[72] variety was planted on June 13, 2017 at 952,205 seeds/acre. Plot size was 10 ft by 100 ft, row spacing was 10 inches. Five irrigation treatments were applied in a RCBD with two replications. These treatments varied from the intended rates of 0, 33, 67, 100, and 133% alfalfa ET due to the late start of irrigation and difficulties in scheduling irrigation on time and at the correct amounts. Corn was used as a reference for scheduling irrigation with WISE (Water Irrigation Scheduler for Efficient Application)[73] or ET data from the closest weather station, which was Fort Collins East of Northern Water (http://www.northernwater.org/waterconservation/weatherandetdata.aspx, verified on April 6, 2018).

Water was delivered with a drip system, from July 3 through September 19. Rainfall from planting to harvest was 4.12 in. A similar amount was recorded in May and only 0.29 in. fell from June 1 through July 25. The dry conditions from late May through July resulted in a poor and non-uniform (variable) stand, despite efforts to water the whole plot area with a garden hose after planting.

Neutron probe access tubes were installed in each irrigation treatment and replication and neutron probe readings were made weekly from August 18 through September 22. Campbell Scientific CS655 Water Content Reflectometer Plus sensors were installed in I-4 at 6-, 18-, and 30-in. depths and were connected to Campbell Scientific data logger CR300. The data from the neutron probe or the CR300 are not included in this report due to lack of calibration.

Trial Information

	Rate/Date	Comment
Hemp variety	Helena	
Fertilizer application[74]	65 lb N/acre on April 18, 2017	Week of April 17

[72] We planned to include the French varieties Fedora 17 and Felina 32 based on the results of a field trial at ARDEC North in 2016 but the seeds did not arrive until late July.

[73] http://wise.colostate.edu/

[74] Soil test results are attached.

	Rate/Date	Comment
Planted	6/13/2017	
Initial female flowering	8/9/2017	
Full female flowering	8/23/2017	WISE data below (corn)
Harvested	9/18-22/17	GDD: 1571.81 (I4 & I5)
Rainfall (6/13-9/22), gross	4.34 in.	WISE shows 4.12 in.
ETrs Alfalfa (6/13-9/19)	23.72 in.	Corn WU (I-5): 15.25 in.
ETrs Alfalfa (6/13-9/22)	24.30 in.	Corn WU (I-4): 14.91in.
ETos Grass (6/13-9/22)	18.90 in.	Effective water (I5): 25.314 in.
ETrs Alfalfa (6/13-9/22)	19.35 in.	Effective water (I4): 18.18 in.

Results

Table 35. Results of the irrigation trial at ARDEC South in 2017.

Irrigation Treatment	Gross amount of irrigation (in.)[75]	Plants/ac @ harvest	Stem Diameter (mm)	Seed Yield (lb/ac)	Total Dry Matter (lb/ac)	Stem Dry Matter (lb/ac)	THC[76] (% by wt.)	CBD[72] (% by wt.)
I-1	0.00	492228	5.19d[77]	539.70c	4063.36c	2686.52d	0.021	0.907
I-2	7.54	481338	6.44cd	841.94c	6284.54c	4533.50c	0.038	1.398
I-3	11.99	405108	7.63bc	865.92c	6011.09c	4264.85cd	0.035	1.343
I-4	16.48	503118	8.06ab	1511.17b	9801.00cb	6927.38b	0.036	1.336
I-5	22.98	481338	9.00a	2312.33a	13749.22a	9067.00a	0.091	1.387
Average	11.80	472626	7.26	1214.21	7981.84	5495.85	0.044	1.274
CV (%)		21.4	17.51	28.82	21.97	21.34	NA	NA
$LSD_{.05}$		NS[78]	1.29	530.68	2659.6	1778.6	NA	NA

[75] Approximately a quarter on an inch was applied with a garden hose prior to drip irrigation. Application was not uniform.
[76] Samples were taken from the inflorescence at harvest. Seeds were removed. Each sample was composited from all 4 reps of each treatment.
[77] Means followed by the same letter are not significantly different at $\alpha = 0.05$.
[78] Non-Significant differences among means at $\alpha = 0.05$.

Plant population at harvest averaged 49.6% of the seeding rate, but it was probably lower since we selected the sample areas to represent what the stand would have looked like had germination and emergence been uniform. Seed yield, above ground dry matter yield, stem dry matter yield, and stem diameter were significantly affected by irrigation amount. Irrigation treatment I-5 produced the highest seed yield and Total Dry Matter, followed by I-4. I-5 also had the highest THC level but it was well below the legal limit of 0.3%. CBD averaged 1.3% and was lowest at I-1.

Treatment I-5 closely matched ET alfalfa and produced the highest seed and dry matter yields. If we assume an 85% irrigation application efficiency, since the drip tapes were placed on the soil surface, then the net irrigation amount at I-5 would be 19.5 in. Assuming a net rainfall amount of 3.5 in. (80% efficiency) and a similar soil water balance at planting and at harvest (zero storage gain!), hemp net water use would be around 23.0 in. (27.3" gross) in conditions similar to those of 2017 at ARDEC South. At I-4 the net water requirement amount would be 17.5 in. or 20.8 in. gross. This amount may vary with the hemp variety and other factors such GDD.

Acknowledgments

I would like to thank Casey Gildea for helping me set up the experiment and Loren 'Tugg' Hutchins for assisting with irrigation, weeding, and harvest. Brian Campbell provided valuable advice for hemp research at CSU.

Table 36. Soil test results at ARDEC South in May 2017.

				Modified Walkley Black	AB-DTPA Extract	$NaHCO_3$ Extract	AB-DTPA Extract						
pH	Salts	Excess	Texture Estimate	Organic Matter	Nitrate-N	P	P	K	S	Zn	Fe	Mn	Cu
	mmhos/cm	Lime		%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
7.6	1.8	very high	sandy clay	2.3	27	10.2	5.5	307	62.6	1.1	9.6	1.3	2.0

	Recommendations for dented corn										
Irrigation	Yield Goal bu/ac	N lb/ac	P2O5 lb/ac	K2O lb/ac	S lb/ac	Zn lb/ac	Fe lb/ac	Mn lb/ac	Cu lb/ac	B lb/ac	Gypsum t/ac
Pivot	225-235	65-73	20*	0	0	1[79]	0	0	0	0	N/A

[79] Banded application. For broadcast, add 5 lb Zn/ac.

Hemp Irrigation Trial at ARDEC South in 2018

A.F. Berrada[80]

With limited water supplies and a growing population, managing water is of utmost importance in Colorado. It is believed that agriculture uses 70 to 80% of available water, although some of the water is recycled into the atmosphere, aquifers, and streams and rivers through evaporation, deep percolation or runoff. Accounting for crop water use is part of a statewide effort to manage water resources wisely. Industrial hemp is an emerging crop in Colorado, but there is little, if any, information about its water requirements. This trial is an attempt to address that by applying different amounts of irrigation water and monitoring its use and its effects on crop growth and performance.

Objectives

1. Determine hemp water requirement for optimum growth.
2. Determine the effects of water deficit on hemp performance (e.g., seed yield and total biomass) and on THC and CBD levels.

Materials & Methods

Irrigation treatments

I-1: Check. Minimal irrigation for stand establishment and no irrigation after that.

I-2: 100% ET from emergence to early bloom and no irrigation after that.

I-3: 100% ET from emergence to early bloom and 67% ET from bloom to physiological maturity

I-4: 100% ET from emergence to maturity

I-5: 100% ET from emergence to early bloom and 133% ET from bloom to physiological maturity.

The irrigation amounts were based on corn ET.

Table 37. Irrigation amounts, and water use in 2018.

Irrigation Treatment	Gross Irrigation Amount (in.)	Effective Water (in.)	Crop Water Use (in.)
I-1 (stand establishment)	0.91	4.25	9.37
I-2 (first flower)	4.11	7.03	12.15
I-3 (70% ET)	10.44	12.53	17.31

[80] This trial would not have been possible without the assistance of Brian Mitchell, PhD Candidate in the Department of Horticulture & Landscape Architecture, who provided excellent help in all aspects of this trial.

Irrigation Treatment	Gross Irrigation Amount (in.)	Effective Water (in.)	Crop Water Use (in.)
I-4 (100% ET)	15.05	16.35	20.78
I-5 (130% ET)	19.51	20.43	23.49
ETr @ I-4: 31.31 in.		Rainfall (planting - harvest): 3.53 in.	

Hemp varieties

Table 38. Variety characteristics and seeding rates.

Variety	Origin	Type	Germination rate (%)	Seeding rate (seeds/acre)
Fedora 17	France	Monoecious	87.0	875,591
Felina 32	France	Monoecious	83.0	917,788
Helena	Serbia	Monoecious	80.0	952,205
Average			83.3	915,195

Table 39. Seed yields in 2016 and 2017.

Variety	Dryland	Irrigated	Comments
	Seed yield (lb/ac)		
Fedora 17¶	540	1326	The average yield of 13 varieties was 329 lb/ac with no irrigation and 994 lb/ac with supplemental irrigation.
Felina 32¶	545	2085	
Helena§	540	1511	Average yields with no irrigation and at 100% corn ET

¶ Variety trial at ARDEC in 2016 (Campbell et al.)
§ Irrigation trial at ARDEC South in 2017 (Berrada)

We chose 'Fedora 17' and 'Felina 32' for this trial because they had the highest seed yields in 2016 at ARDEC, with or without irrigation (Table 39). We added Helena to compare the results to 2017 at the same location at ARDEC South. We planted hemp on 5/17/2018 @ 761764 seeds/acre adjusted for germination rate (Table 38). On 5/18/2018, we spread a mix of urea @ 68 lb N/ac and 11-52-0 @ 30 lb P_2O_5/acre uniformly on the whole plot area. Two rain events totaling 0.36" occurred shortly after that and more rainfall (0.65") was recorded on 5/22/2018. We harvested hemp manually on 9/12/2018 in two 10 ft. rows. The rows were selected as to represent a "normal" stand. The harvested plants were air-dried for five weeks, then weighed and separated into seeds and stems. Six of the harvested plants were selected at random and measured for height and stem diameter. All the harvested plants were counted to determine the final stand counts. Earlier stand counts were done in two 6-ft rows in reps 2&4 on June 6, June 21, and September 1, 2018.

1. Experimental design: Split plot RCB design with irrigation treatments assigned to the main plots and varieties to the subplots, with four replications. Irrigation treatments were assigned at random to reps 1&2 (Irrigation Block #1) and reps 3&4 (Irrigation Block #2). Water was applied with a drip system at an estimated efficiency of 87%. Irrigation amounts are shown in Table 37.
2. Measurements & observations:
    a. Soil moisture content with a neutron probe (data not shown)
    b. Stand count
    c. Plant height
    d. Flowering dates
    e. Cannabinoids
    f. Stem diameter
    g. Seed yield
    h. Total dry matter (mostly stem + leaves)
    i. Stem yield

Results

Table 40. Statistical analysis (SAS 9.4 Proc Mixed & GLM).

	Pr > F				
Effect	Seed Yield	Total DM	Stem Yield	CBD	THC
Irrigation	<0.000	<0.000	<0.000	0.130	0.332
Variety	0.199	0.489	0.050	0.000	0.023
Irr. by Var.	0.097	0.644	0.683	0.703	0.533

Effect	Early Stand	Final Stand	Plant Height	Stem Diameter
Irrigation	0.458	0.435	0.000	0.021
Variety	0.655	0.256	0.004	0.003
Irr. by Var.	0.131	0.237	0.482	0.207

Irrigation amount (level) had a significant effect on seed, total DM, and stem yields; and on plant height and stem diameter (Table 40). There were also significant differences among the three varieties in stem yield, plant height, stem diameter, THC, and CBD.

Seed yield was highest at irrigation levels 4 and 5 (P>0.05) and lowest at irrigation levels 1 & 2 (Table 41). Fedora 17 had the highest seed yield (1,388 lb/ac) at irrigation level 4. Based on these results, 18 to 19 inches of total (rain + irrigation) water amount would be enough to produce around 1000 lb/acre of seed yield. It is conceivable that greater seed yields would have been obtained had we applied more N fertilizer. Several of the hemp plants/leaves were yellow throughout most of the growth period, particularly at the irrigation levels 3-5, which may have been caused by N deficiency. There were also two hailstorms that may have reduced seed yield and total biomass.

Total DM and stem yields increased with increasing irrigation amounts up to level 3 (Table 41).

Felina 32 and Helena produced significantly more stem than Fedora 17 but all three varieties had similar stem plus leaves DM. Irrigation levels 3-5 produced the tallest plants compared to levels 1 &2 (Table 43). The same was true for stem diameter, although irrigation levels 2&3 were not significantly different. Fedora 17 was the shortest of the three varieties and had the smallest stem diameter. Helena had the tallest plants in numeral value and at P > F = 0.10.

CBD averaged 1.8 to 2.2%, with irrigation levels 3 & 4 outperforming irrigation levels 1 &2 (Table 41). The CBD concentration of Fedora 17 and Felina 32 averaged 2.12 %, which was significantly greater than that of Helena (1.68%). THC levels were well below the legal limit of 0.3%. Fedora 17 and Felina 32 had slightly more THC than Helena.

Table 41. Average yields and THC and CBD concentration.

Effect	Seed Yield	Total DM	Stem Yield	CBD	THC
	Lb/ac	Lb/ac	Lb/ac	%	%
Irrigation level					
1	191.7 c*	2488.7 b (d)	1581.8 c	1.81 c	0.057
2	297.2 c	3432.7 b (c)	2300.9 b	1.88 c	0.058
3	632.6 b	7318.3 a (b)	5646.5 a	2.20 a	0.069
4	1042.0 a	8276.3 a (a)	6117.0 a	2.01 ab	0.067
5	933.0 a	8177.0 a (a)	6092.2 a	1.96 bc	0.057
Variety					
Fedora 17	701.3	5681.5	3978.9 b	2.07a	0.065 a
Felina 32	589.5	6116.3	4545.9 a	2.17a	0.068 a
Helena	567.1	6018.0	4518.1 a	1.68b	0.053 b
Average	619.3	5938.6	4347.7	1.97	0.062

* Means followed by the same letter are not significantly different at P=0.05 or (P=0.10).

Table 42. Irrigation by variety seed yield.

Irrigation level	Variety	Seed Yield (lb/ac)
1	Fedora 17	253.8 e
1	Felina 32	139.0 e
1	Helena	182.2 e
2	Fedora 17	278.7 de
2	Felina 32	314.8 de
2	Helena	298.2 cde
3	Fedora 17	677.0 c
3	Felina 32	665.5 c
3	Helena	555.3 cd
4	Fedora 17	1387.9 a
4	Felina 32	1012.7 b
4	Helena	725.3 c
5	Fedora 17	909.0 bc
5	Felina 32	815.3 bc
5	Helena	1074.6 b
Average		619.3 (Pr > 0.1)

* Means followed by the same letter are not significantly different at P=0.10.

Table 43. Plant population, plant height, and stem diameter.

Effect	Early Stand	Final Stand	Plant Height	Stem Diameter
	Plants/ac	Plants/ac	Inch	Mm
Irrigation level				
1	481883	428794	41.14 b	4.58 c
2	428340	395307	48.24 b	5.42 bc
3	591690	454658	64.40 a	6.67 ab
4	528165	432878	65.91 a	7.33 a
5	526350	399935	71.47 a	7.58 a
Variety				
Fedora 17	539600	442679	51.21 b	5.15 b
Felina 32	515642	418993	58.31 ab	7.15 a
Helena	478616	405271	65.17 a	6.65 a
Average	511286	422314	58.23	6.32

* Means followed by the same letter are not significantly different at P=0.05 or (P=0.10).

The average stand on June 6, 2018 was 511286 plants/acre. The final stand at harvest averaged 422314 plants/acre, which was less than half the seeding rate of 915195 seeds/acre.

Acknowledgments

I would like to thank Brian Mitchell for his valuable assistance in all aspects of this trial. His dedication to this project and interest in hemp inspired me.

Table 44. Soil test results in 2018.

DATE RECEIVED: 4/10/2018 DATE REPORTED: 4/17/2018 TEXTURE: SANDY CLAY LOAM

METHOD USED:			Estimate	Walkley Black Extract Extract ----------AB-DTPA Extract---------- Water							
Lab No.	pH	EC Salts mmhos/cm	Excess Lime	Organic Matter %	Nitrate N Ppm	Phosphorus P ppm	Phosphorus P ppm	Potassium K ppm	Zinc Zn ppm	Iron Fe ppm	Manganese Mn ppm
F1014a	8.1	0.6	very high	2.4	9	17.4	9	305	1.3	7.9	2.4
F1015b	7.9	0.9	very high	1.8	16	20.1	11.6	403	1	8.1	3.8

FERTILIZER RECOMMENDATIONS FOR YIELD GOAL OF 3000 LB/A										
I. D.			POUNDS OF ACTUAL NUTRIENT PER ACRE							
Lab No.	Irrigation	Proposed Crop	N lb/ac	P2O5 lb/ac	K_2O lb/ac	Zn lb/ac	Fe lb/ac	Mn lb/ac	Cu lb/ac	Boron lb/ac
F1014a	yes	hemp	55	20	0	0	0	0	0	0
F1015b	yes	hemp	35	20	0	0	0	0	0	0

Response of Sunflower to Deficit Irrigation

A.F. Berrada, J.P. Schneekloth[81], and A.Y. Berrada

Sponsor: The National Sunflower Association

Introduction

A common perception is that sunflower uses less water than corn or other field crops for maximum seed production (Meyer et al., 2009). This may be due to the fact that sunflower has a deep root system that can extend as much as 8.0 ft below the soil surface (Stone, 2002), which allows it to extract more water from the soil profile than crops with shallower root systems. Hence, sunflower may withstand longer periods of drought or extract more water from the soil profile than other field crops.

Nielsen (2007) derived the following response of sunflower to water use in Akron, CO:

Yield (lb/acre) = 150.6*(inches water use – 6.9)

Seed production started at 6.9 inches of water consumption. Each additional inch of water produced approximately 151 lb/acre. The threshold amount of water for seed production (6.9 in.) is similar to the long-term average rainfall at the SWCRC during the sunflower growing season (approximately early June to mid-October). Consequently, in the absence of above normal rainfall during the growing season, sunflower seed production in SW Colorado would depend heavily on stored soil moisture or supplemental irrigation.

Sunflower is most sensitive to water stress "just before flowering through seed development" (Meyer et al., 2009). Schneekloth (2007) achieved 60% water saving compared to full irrigation when he applied water at the R-4 to R-5 stage. Seed and oil yields were equal or higher to those obtained with full irrigation in two (2003 and 2005) out of the four-year period (2002-2005) of the study. There was plenty soil moisture (field capacity at the 0- to 6-ft depth) at planting in 2002 and 2003. When there was less water available at planting or during the growing season, full irrigation outperformed the limited irrigation treatments. Withholding irrigation until R-6 to R-7 increased oil concentration significantly compared to full irrigation. Conversely, applying water at R-1 to R-3 (bud stage) *only* reduced seed oil concentration. Seed yield was similar to that of when irrigation was withheld until R-6 to R-7.

The study reported here was conducted in the Dolores Irrigation Project area. The latter provides irrigation water to approximately 62,000 acres of crop land in Dolores and Montezuma counties. Pressurized water of excellent quality is delivered to each farm in the full service area (FSA) of the project. Each farmer is allocated close to 2.0 acre-feet of water per season. The total FSA annual water allocation was reached or exceeded several times since irrigation began in 1987. Reasons for this include frequent droughts and the predominance of alfalfa (> 80% of the irrigated acreage), which is a relatively high water user. The price FSA irrigators pay for water has been on the rise due to increases in pumping and maintenance costs. Conserving water is important to the long-term sustainability of the FSA. This can be achieved with sound irrigation scheduling, efficient irrigation systems, and best crop management practices, among other things.

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[81] Colorado State University Extension Water Resources Specialist, US Central Great Plains Research Station, Akron, CO.

Sunflower may be a good alternative to dry bean, oat or spring wheat in rotation with alfalfa. It would extract more water (and residual N) from the soil profile due to its deeper root system, which would result in water (input) savings.

The main objective of this study was to determine the response of two sunflower varieties to irrigation deficit.

Materials and Methods

A field trial was conducted at the Southwestern Colorado Research Center (SWCRC) in Yellow Jacket, CO in 2012 and 2014. There were earlier sunflower irrigation trials at the SWCRC, but because of differences in methodology, the results from those trials are not included in this report. They can be found instead in CSU-AES reports TR12-7 and TR11-04.

The soil at the study site is Wetherill loam (fine-silty, mixed, superactive, mesic Aridic Haplustalfs). The elevation at the site is 6900 ft. The 1981-2010 average annual precipitation at the test site is 15.9 inches, with June being the driest month (0.5 inches), and Aug., Sept., and Oct. the wettest months (1.7 to 1.9 inches). Rainfall during the sunflower growing season was 1.0 inch higher in 2014 than in 2012, mostly due to above normal rainfall in September 2014.

Two sunflower varieties were planted each year: Mycogen 8H449CLDM and Syngenta 8H570CL. The latter was previously named Triumph s870CL. It is a short stature hybrid while Mycogen 8H449CLDM is a standard height hybrid. Sunflower was planted on June 1, 2012 at 25,344 seeds/acre and on June 6, 2014 at 27,198 seeds/acre. It was planted in 30-in rows with a 4-row Monosem NG Vacuum Planter. The plot area was sprayed with Sonalan @ 2.5 pt/acre on May 30, 2012 and with Treflan at 1.5 pt/acre on April 17, 2014. It was again sprayed with Roundup Max @ 40 oz/acre on June 3, 2014. Each plot was 4 rows wide. Only the two middle rows of each plot were harvested, in order to avoid border effects or effects from adjacent irrigation treatments. Harvest was completed in early (2012) to mid-November (2014)

In 2012, there were four nitrogen fertilizer treatments: 0, 30, 60, and 90 lb N/acre. Ammonium nitrate (34-0-0) was applied to the designated plots on May 29, 2012. It was broadcast with a hand-held fertilizer spreader and incorporated into the soil with a field cultivator. In 2014 there were only two nitrogen fertilizer treatments: 0 and 60 lb N/acre. Urea (46-0-0) was applied to the designated plots on July 22 & 23, 2014. It was injected through the drip irrigation system.

The drip tape that was used in 2014 was AquaTraxx (AQUA 510 12 22 – 600) with a thickness of 10 mil and a 12” emitter spacing. Drip tape was buried before planting at a depth of 6 inches with a spacing of 5 ft between drip tapes. A shut off valve was installed on each drip tape and a flowmeter was installed for each replication to track the amount of irrigation water used. Each irrigation treatment was irrigated as needed to match Eta (actual ET) as long as it was at a growth stage where irrigation was allowed (e.g. between the growth stages R1 and the end of R-6 for the R1-6 treatment). The irrigations often had to be split into several periods each day in order to avoid runoff, particularly for the full irrigation treatment. A similar setup was used in 2012.

The irrigation treatments are listed in Table 45. All treatments were irrigated with a side roll prior to planting to ensure good germination. Side roll irrigation was assumed to be 70% efficient and subsurface drip irrigation was assumed to be 90% efficient with 10% lost due to evaporation. The goal for the Full irrigation treatment was to irrigate enough so that net irrigation[82] plus rainfall was

[82] Net drip irrigation is 90% of total irrigation in order to account for evaporation losses.

equivalent to ETa between planting through the end of the R-8[83] growth stage (R-9 represents physiological maturity). The R1-6 treatment was irrigated starting at the R-1 growth stage and finishing at the end of R-6 so that net irrigation plus rainfall matched ETa during that period. The R4-6 treatment was similar except that irrigation started at the beginning of R-4. All plots received a small amount of irrigation (about 0.2") during fertilizer injection in 2014.

The treatments were arranged in a split-split plot design with three replications. The irrigation treatments were randomly assigned to the main plots, sunflower hybrid to the split plots, and N rate to the split-split plots. The latter were 10 ft by 55 ft in 2012 and 10 ft by 100 ft in 2014.

Table 43. Irrigation treatments and amounts.

Irrigation treatment	Description	Net post-planting irrigation depth (in)[84]		Physiological maturity date for the 2014 trial
		2012	2014	
I-1 (Pre-P)	Pre-plant irrigation (PPI) only	0.0	0.2	October 3
I-4 (R4-R6)	PPI + Irrigation at R-4 through the end of R-6[85]	4.5	3.6	October 13
I-3 (R1-R6)	PPI+ Irrigation at R-1 through the end of R-6[96]	8.7	8.7	October 12
I-2 (Full)	PPI + Full-season irrigation[96]	16.2	16.2	October 14
PPI (with side roll)		2.5	1.8	
Rainfall		4.4	5.4	
Full irrigation treatment crop ETa		20.5	21.2	

Figure 7 compares the water each treatment received with the calculated ETa for the 2014 trial. The post-planting irrigation + rainfall for the full treatment was very close to the target amount in 2012 and 2014. The calculated full season ETa goes down as the amount of water received goes down. This is because calculated ETa decreases as soil moisture depletion increases (the section on ETa calculation has more details).

[83] Sunflower growth stages are described at: http://www.ag.ndsu.edu/pubs/plantsci/crops/a1145.pdf

[84] Depth of irrigation after planting. Post-planting water was applied with subsurface drip irrigation (SDI) at approximately 90% efficiency.

[85] Irrigation to meet crop ET during the designated treatment period. R-1: The terminal bud forms a miniature floral head, R-4: The inflorescence begins to open, R-6: Flowering is complete.

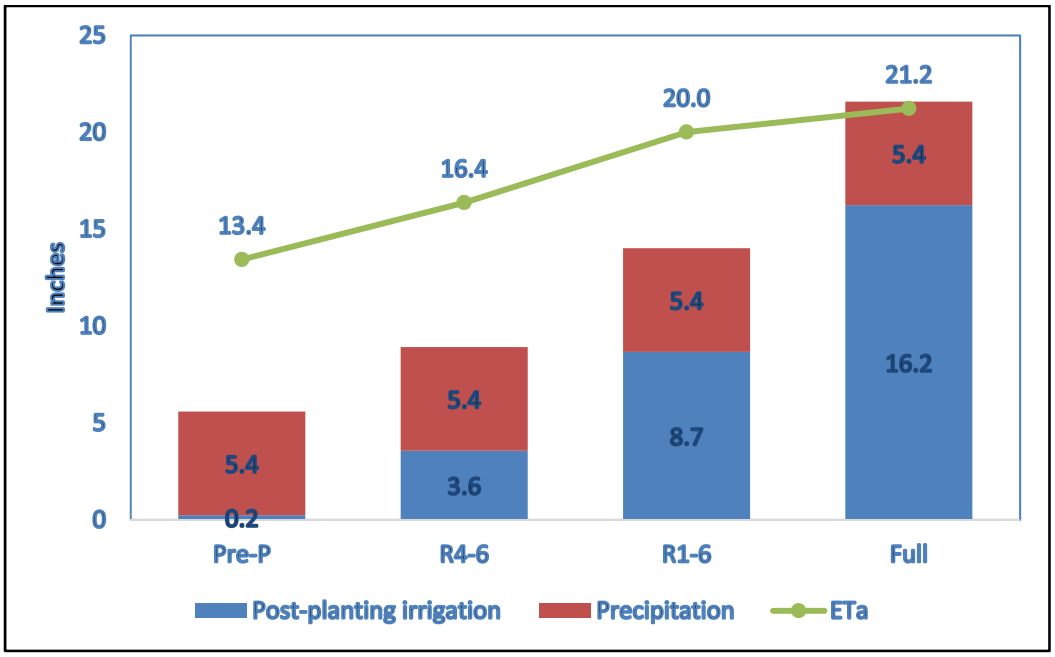


Figure 7. Post planting irrigation plus rainfall in 2014 compared to ETa from planting to physiological maturity.

Three watermark sensors[86] were installed in the 2014 trial on August 4 and connected to a data logger[87]. They were buried at a depth of 18". No thermistors were used (readings were not corrected for temperature). Figure 8 shows a graph of the watermark sensor readings and Table 46 provides information on how to interpret the readings. No watermark sensor was placed in the Pre-P treatment; hence the R4-6 treatment received the least amount of irrigation of all the watermark sensor sites and had the highest readings as would be expected. Watermark sensor readings in the Full and R1-6 treatments were similar. Many of the readings were over 100 centibars even for the Full treatment which according to the watermark sensor manufacturer's documentation is "dangerously dry for maximum production". However, the soil in the Full treatment often appeared to be saturated at ground level. This probably means that the watermark sensors were buried too deep to provide useful information and it would have been better to bury them at about the same depth as the drip tapes (about 6 inches).

[86] Model 200SS, made by the IRROMETER Company, Inc.
[87] AM400 soil moisture data logger made by the M.K. Hansen Company.

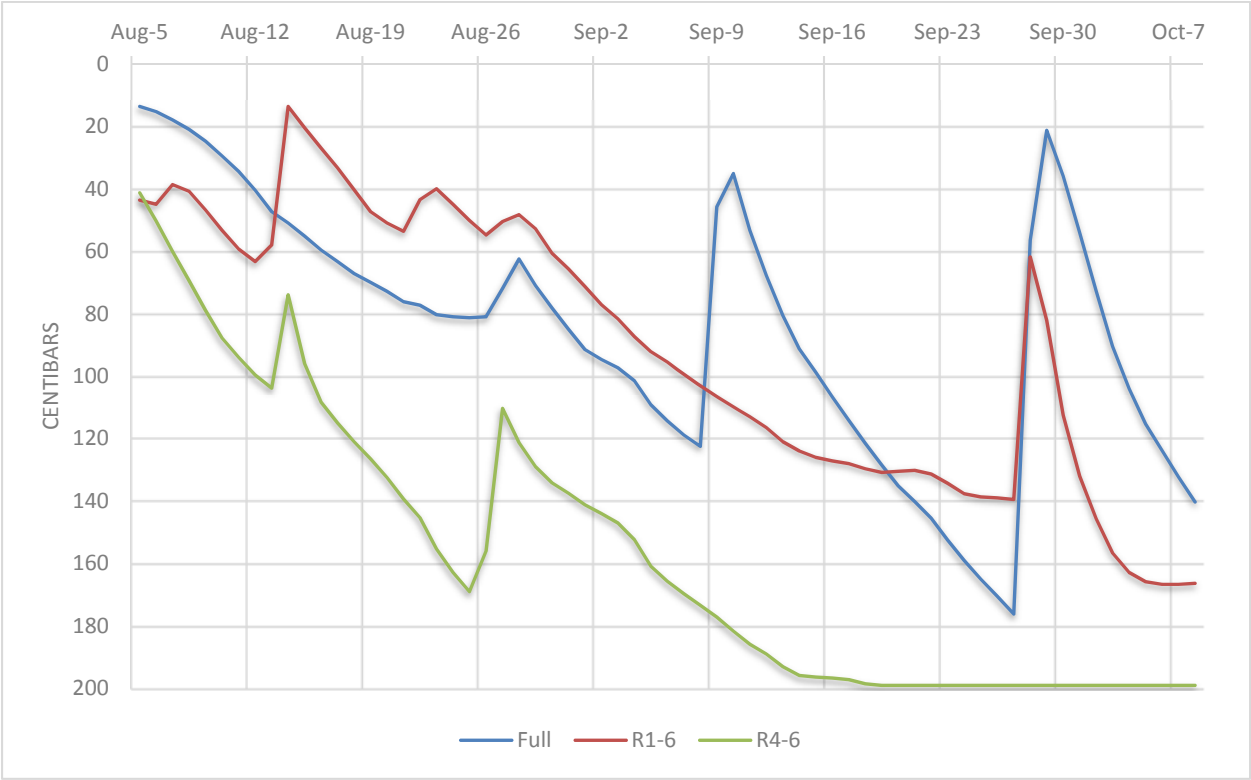


Figure 8. Watermark sensor readings.

Table 44. The IRROMETER Company guide to interpreting watermark sensor readings[88].

Sensor Reading	Comment
0 – 10 centibars	Saturated soil
10 – 30 centibars	Soil is adequately wet (except coarse sands, which are beginning to lose water)
30 – 60 centibars	Usual range for irrigation (most soils)
60 – 100 centibars	Usual range for irrigation in heavy clay soils
100 – 200 centibars	Soil is becoming dangerously dry for maximum production. Proceed with caution!

As the sunflower seed was starting to mature there was a substantial number of birds (probably hundreds) that would pluck the seed out of the sunflower heads and eat it. Several methods were used to try to repel the birds. The main method was to attach flash tape to the top of the sunflower plants. Flash tape works by creating bright flashes of light as it twists in the breeze, which frightens birds. The flash tape was very effective for a while, but gradually lost effectiveness as the birds became less scared of it.

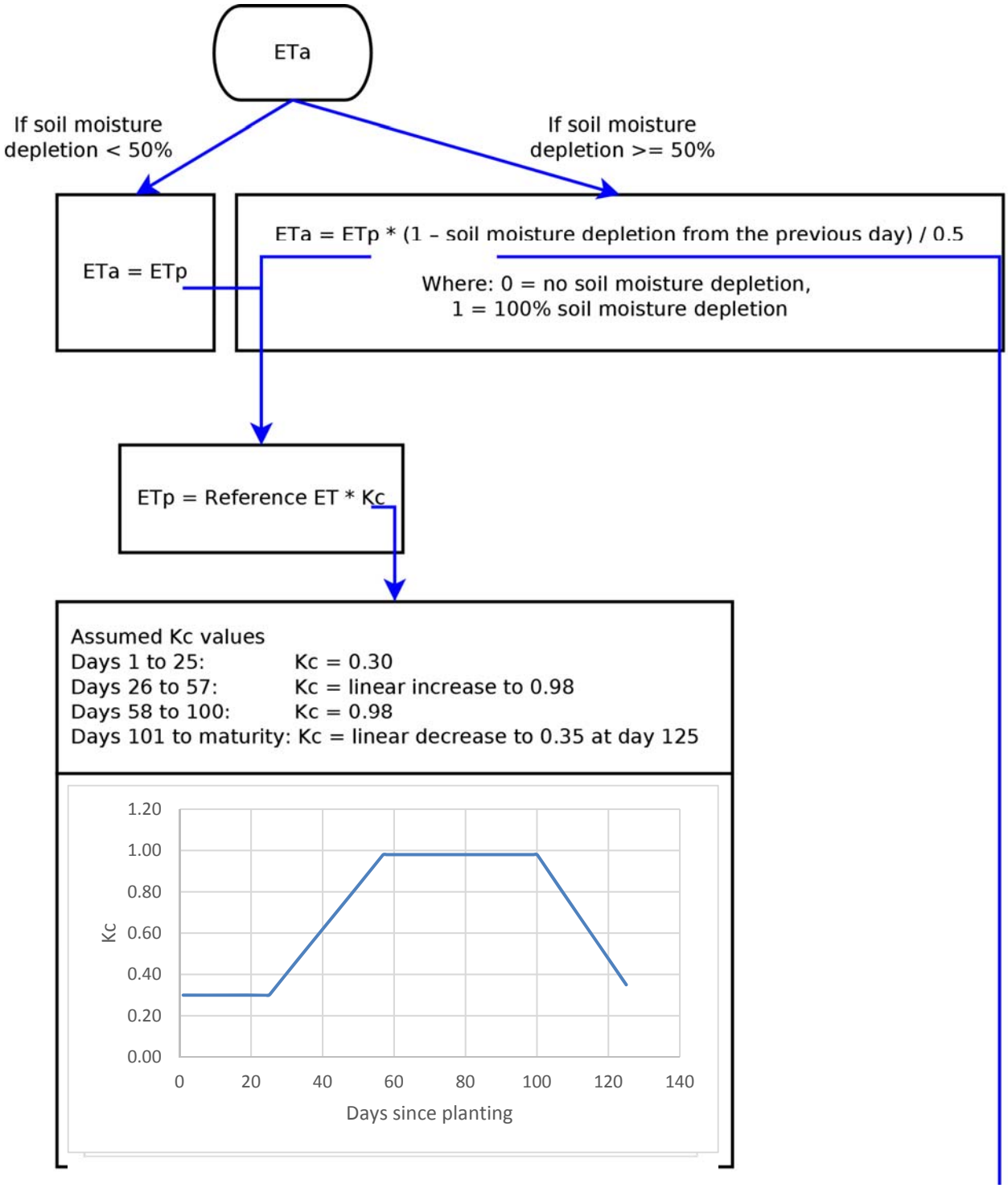
[88] Source: http://www.irrometer.com/pdf/instruction%20manuals/sensors/701%20Meter%20Manual-WEB.pdf

ETa calculation

Weather and ET data was obtained from www.coagmet.com . The Reference ET Model was Penman-Monteith in 2012. Penman-Monteith was later removed from www.coagmet.com so the ASCE Standardized Reference ET Model was used in 2014.

ETa was calculated through the end of the R-8 growth stage or through 125 days after planting[89], whichever occurred first. In 2012, ETa was calculated until day 119 and in 2014 until day 125. The method used to calculate ETa is shown in Figure 9.

[89] Planting day is considered day 1.


ETa
If soil moisture depletion < 50%
If soil moisture depletion >= 50%
ETa = ETp
ETa = ETp * (1 – soil moisture depletion from the previous day) / 0.5
Where: 0 = no soil moisture depletion,
1 = 100% soil moisture depletion
ETp = Reference ET * Kc
Assumed Kc values
Days 1 to 25: Kc = 0.30
Days 26 to 57: Kc = linear increase to 0.98
Days 58 to 100: Kc = 0.98
Days 101 to maturity: Kc = linear decrease to 0.35 at day 125
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Kc
0
20
40
60
80
100
120
140
Days since planting

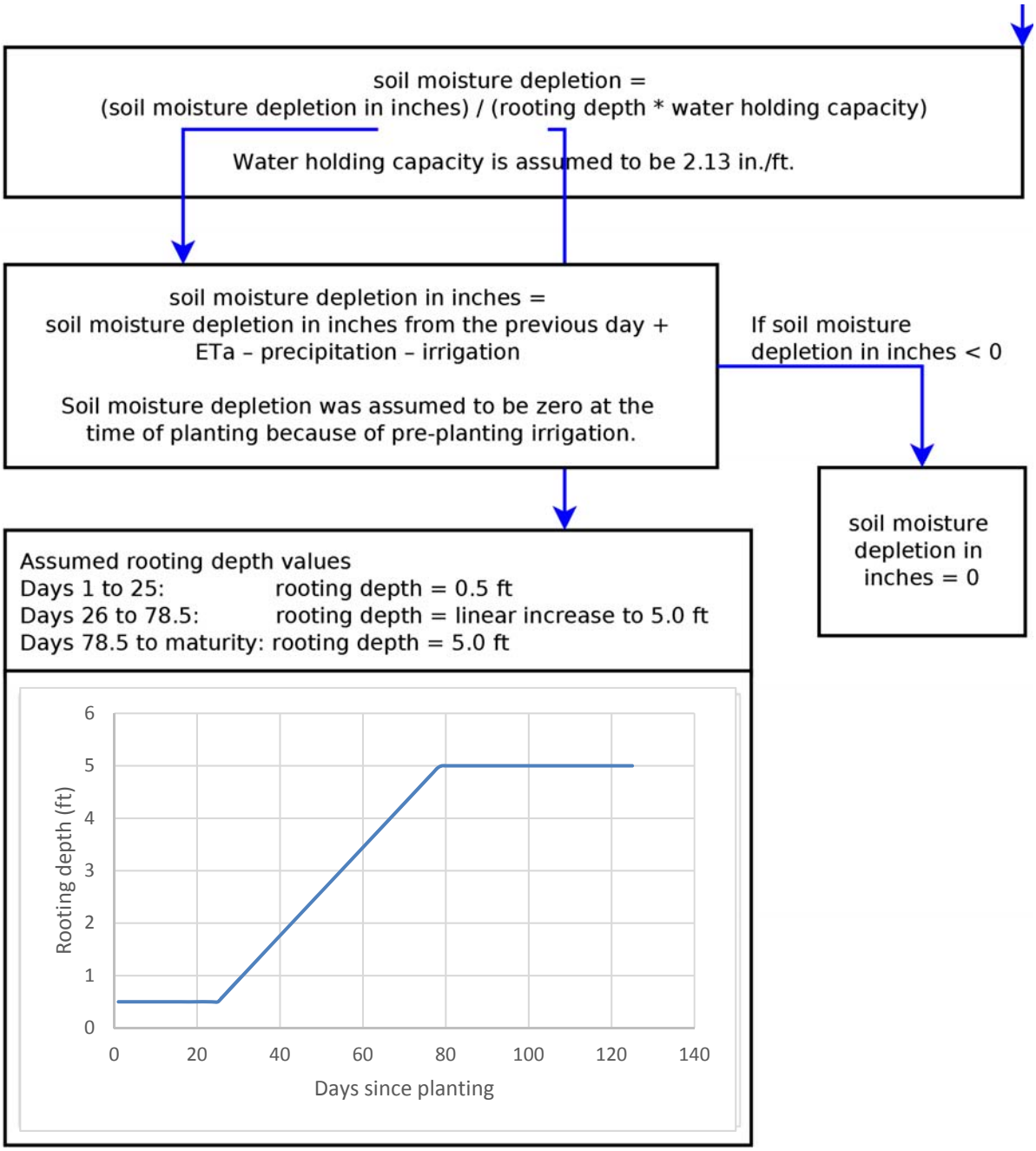


Figure 9. ETa calculation method.

It took longer than expected to install the drip irrigation system, so unfortunately drip irrigation of the trial in 2014 didn't start until July 14. The start of drip irrigation was also delayed in 2012. Because of the way ETa is calculated, ETa starts dropping as soil moisture depletion gets to 50% and above. Figure 10 shows a sharp drop in ETa between days 6 and 32.

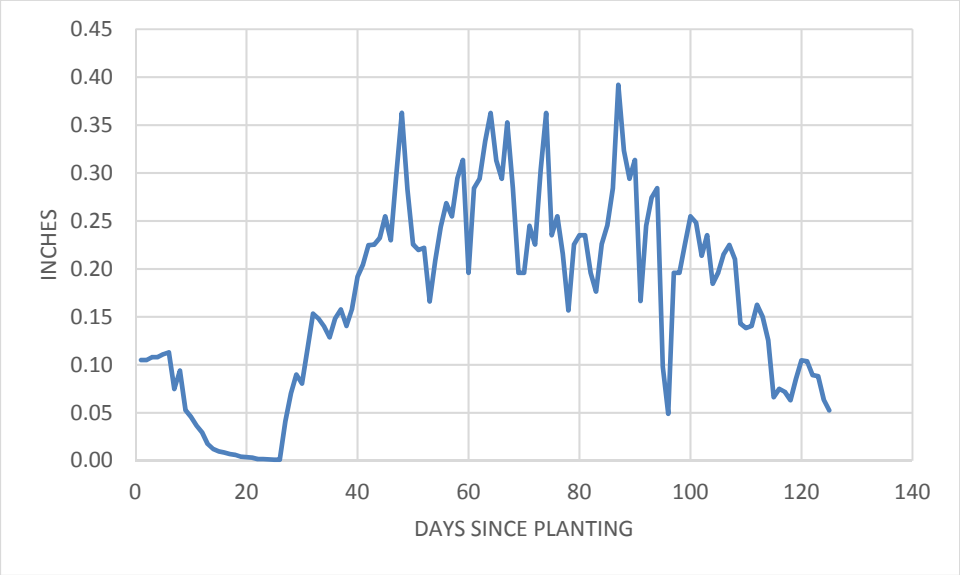


Figure 10. Calculated daily ETa for the Full irrigation treatment in 2014.

2012 Results

Table 45. Sunflower response to irrigation and N rate in 2012.

Treatment	Seed Yield lb/ac[90]	Seed Oil (%)	Plants/ac[91]	Plant Height (in.)	Seed Weight (mg)	Test Weight (lb/bu)	Bird Damage (%)
I-1	965 D[5]	41.7 C[5]	18135	26.5	38.2 D	33.0	5.8
H449CLDM[92]	1144	42.2	18177	33.2 a[93]	40.9	33.7 a[5]	5.8
s870HCL	786	41.2	18093	19.7 b	35.5	32.2 b	5.9
I-2	2715 A	43.8 A	16957	44.8	50.1 B	31.8	6.1
8H449CLDM	2721	44.6	17879	56.3 a	52.4	33.6 a	9.1
s870HCL	2708	43.0	16036	33.4 b	47.8	30.0 b	3.1
I-3	2397 B	42.2 B	17811	36.2	52.6 A	30.6	2.5
8H449CLDM	2533	43.0	18533	41.9 a	55.5	32.2 a	2.2
s870HCL	2261	41.4	17090	30.5 b	49.6	28.9 b	2.7
I-4	1547 C	42.5 B	19120	25.7	43.5 C	33.4	0.7
8H449CLDM	1781	43.0	18167	31.4 a	47.2	34.6 a	0.6
s870HCL	1314	42.1	20074	20.1 b	39.7	32.3 b	0.8
Hybrids							
8H449CLDM	2045 A	43.2 A	18189	40.7	49.0 A	33.5	4.4
s870HCL	1767 B	41.9 B	17823	25.9	43.2 B	30.8	3.1
N rate (lb/ac)							
0	1908	42.8	18841	33.5	46.9	32.3	3.2
30	1957	42.6	17548	33.5	45.3	32.4	5.3
60	1864	42.3	18027	32.7	46.1	32.1	3.3

[90] Seed yield adjusted to 10% moisture. The number of plants/ac was used as covariate.
[91] Number of plants with heads at harvest
[92] Triumph s870HCL is the same hybrid as Syngenta 8H570CL in 2014.
[93] Numbers followed by the same letter (within the same column) are nor significantly different at P = 0.05.

Treatment	Seed Yield lb/ac[90]	Seed Oil (%)	Plants/ac[91]	Plant Height (in.)	Seed Weight (mg)	Test Weight (lb/bu)	Bird Damage (%)
90	1895	42.4	17607	33.4	46.0	32.0	3.3
Average	1906	42.5	18006	33.3	46.1	32.2	3.8
CV (%)	-	2.3	11	7.1	7.0	2.1	-
Analysis of variance (Pr > F)							
Irrigation (Irr)	0.00	0.00	0.03	0.00	0.00	0.00	-
Hybrid (Hyb)	0.00	0.00	0.42	0.00	0.00	0.00	-
Irr X Hyb	0.16	0.51	0.06	0.00	0.52	0.00	-
N rate	0.32	0.35	0.08	0.60	0.40	0.18	-
N * Irr	0.15	0.93	0.45	0.96	0.25	0.11	-
N*Hyb	0.20	0.24	0.42	0.55	0.32	0.12	-
N*Hyb*Irr	0.23	0.33	0.27	0.31	0.78	0.42	-

Seed weight was only measured in 2012. It was greatest at I-3 followed by I-2 and I-4 (Table 47). Treatment I-1 had the lowest seed weight, seed yield, and oil content. Treatment I-2 had the highest seed oil content of 43.8%, significantly more than I-3 and I-4. Mycogen 8H449CLDM significantly outperformed Triumph s870HCL in seed yield, seed weight, and oil content. It also had greater test weight at all four irrigation treatments. As would be expected, the standard-height hybrid H449CLDM was taller than the short-stature hybrid s870HCL at all the irrigation treatments. Plants of both hybrids were tallest at I-2, followed by I-3. Treatments I-4 and I-1 produced similar plant heights with either of the two hybrids (Table 47). Birds caused the most damage to H449CLDM at I-2 (9% seed loss) and the least damage to either sunflower hybrid at I-4 (less than 1%).

Nitrogen application rates from 0 to 90 lb N/acre or N by Irrigation or N by Hybrid interactions had no significant impact on any of the measured parameters, which was unexpected based on soil test recommendations. Based on soil test results in 2012 (top three ft of soil), N fertilizer was recommended for seed yields above 1800 lb/ac. For example, a yield goal of 2800 lb/ac would have required the addition of 68 lb N/ac. Deeper soil sampling (e.g., 0 to 4 ft) and more research may be needed to better predict the response of sunflower to N rate (Joel Schneekloth, Personal Communication, December 2012).

In conclusion, the full-season irrigation treatment (I-2) produced the highest seed yield (2715 lb/ac), oil content (43.8%), and plant height (44.8 in.) in 2012. Irrigation from the beginning of the reproductive stage through flowering (I-3) produced 2397 lb/ac with 46% less irrigation water than I-2. Rainfall accounted for approximately 20% of crop ET at I-2 and I-3. The short stature hybrid Triumph s870CL averaged 278 lb/ac less seed than Mycogen 8H449CLDM, but it is more suitable to irrigation with side rolls, which are prevalent in SW Colorado. There was no significant increase in seed yield due to N application, possibly because not all the residual N in the root zone was accounted for.

2014 Results

Table 46. Sunflower response to irrigation and N rate in 2014.

Treatment (Irr./Var./N)	Seed Yield (lb/ac)	Oil Content (%)	Test Weight (lb/bu)	Plant Height (in)	Yield Loss (%)	Plants/ac at harvest
I-1	924 C	40.1	32.5	31.0 B	21%	22847
H449CLDM	917	41.2	34.7 A	36.6	31%	24176
0	918	41.5	34.6	36.8	35%	23348
60	916	40.8	34.7	36.3	27%	25004
8H570CL	930	39.0	30.4 B	25.3	11%	21519
0	975	39.8	30.6	25.7	10%	22303
60	885	38.1	30.2	25.0	13%	20735
I-2	2085 A	41.5	30.8	41.5 A	12%	23159
H449CLDM	2238	43.4	33.6 A	48.8	18%	25555
0	2129	42.9	33.6	49.0	17%	24510
60	2346	43.8	33.6	48.7	20%	26601
8H570CL	1932	39.7	28.0 B	34.2	7%	20764
0	1869	39.9	28.0	33.7	2%	20996
60	1995	39.4	28.1	34.7	11%	20531
I-3	1770 B	40.5	30.5	41.4 A	13%	23065

Treatment (Irr./Var./N)	Seed Yield (lb/ac)	Oil Content (%)	Test Weight (lb/bu)	Plant Height (in)	Yield Loss (%)	Plants/ac at harvest
H449CLDM	1852	42.2	33.6 A	48.7	16%	24045
0	1834	42.3	33.2	48.3	14%	23639
60	1870	42.1	34.0	49.0	18%	24452
8H570CL	1688	38.9	27.5 B	34.2	10%	22085
0	1669	38.6	27.5	34.0	13%	21809
60	1707	39.1	27.5	34.3	7%	22361
I-4	1744 B	40.9	31.8	31.3 B	5%	23624
8H449CLDM	1915	42.3	34.4 A	36.5	3%	24829
0	1859	42.4	34.4	36.3	3%	24626
60	1971	42.2	34.3	36.7	3%	25033
8H570CL	1572	39.4	29.3 B	26.0	6%	22419
0	1608	39.3	29.3	26.3	6%	22216
60	1535	39.5	29.3	25.7	7%	22622
Hybrid						
8H449CLDM	1731 A	42 A	34 A	43 A	17%	24651
8H570CL	1530 B	39 B	29 A	30 B	9%	21697
N rate (lb/ac)						
0	1608	41	31	36	13%	22931
60	1653	41	31	36	13%	23417
Average	1631	40.7	31.4	36.3	13%	23174
	Pr > F	Pr > F	Pr > F	Pr > F		
Irr	0.000	0.080	0.000	0.000		
Hyb	0.029	0.000	0.000	0.000		
Irr x Hyb	0.384	0.162	0.055	0.069		
N	0.211	0.280	0.606	0.947		
Irr x N	0.206	0.024	0.398	0.607		
Hyb x N	0.215	0.326	0.322	0.947		
Irr x Hyb x N	0.826	0.097	0.624	0.607		

Seed yield was in the order I-2 > I-3 = I-4 > I-1 (Table 48). The hybrid 8H449CLDM outperformed 8H570CL by about 200 lb/acre. It also had significantly more oil content (42 vs 39%) and test weight. The test weight of 8H449CLDM was greater than that of 8H570CL at all four irrigation treatments. As would be expected, the standard-height hybrid H449CLDM was taller than the short-stature hybrid s870HCL. On average sunflower plant height was in the order I-2 = I-3 > I-4 = I-1. Birds caused the most yield damage at I-2 (21%), more than at I-2 (12%) and I-3 (13%) and the least damage at I-4 (5%). The hybrid H449CLDM sustained almost twice as much bird damage (17%) as 8H570CL (9%). The application of 60 lb N/acre had no significant effect on seed yield or test weight or plant height on average or at any of the irrigation treatments. The only significant impact was on % oil content at I-1, whereby the check with no added N outperformed the treatment with 60 lb N/acre by 1.15%.

Comparison of the 2012 and 2014 results

Seed yield was greater in 2012 than in 2014 possibly due to earlier planting, less bird damage/yield loss, and slightly warmer weather in 2012. The full irrigation treatment I-2 had the highest seed yield in both years while I-1 had the lowest yield. The standard height hybrid 8H449CLDM outperformed the short stature hybrid 8H570CL (same as s870CL in 2012), although the difference between the two hybrids was small at I-2 in 2012 and at I-1 in 2014 (Figure 27 and Figure 28). Short-stature hybrids such as 8H570 may be suitable for irrigation with siderolls, which are common in SW Colorado. Fertilizer application of up to 90 lb N/acre in 2012 and 60 lb N/acre in 2014 had no significant impact on sunflower seed yield, % oil content or test weight despite soil test recommendations that would indicate otherwise. Yield loss due mostly to bird damage was greater in 2014 than in 2012. Growing sunflower and other oilseed crops at the SWCRC tended to attract a lot of birds since there was no sunflower grown within several miles of the Research Center. The following birds were observed feeding on sunflower: black birds, finches, turtle doves, and ravens. Control measures such as the propane canon and flashing tape were used, but were not very effective. Netting on the other hand was effective, but could only be employed in a small area (approximately 25 sq. ft.) of each plot in 2012.

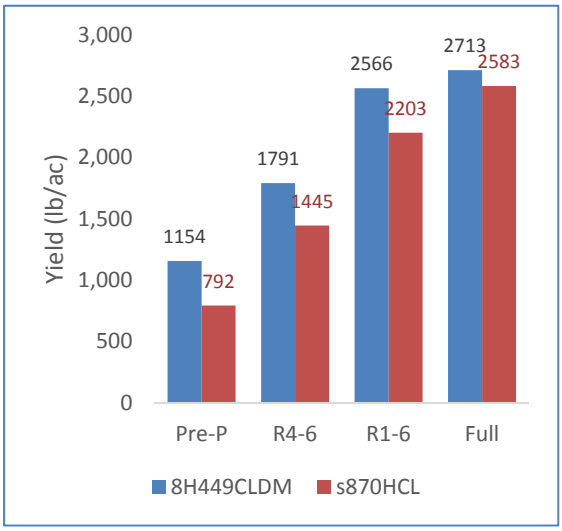


Figure 11. Seed yield of two sunflower hybrids in 2012 as affected by irrigation treatment.

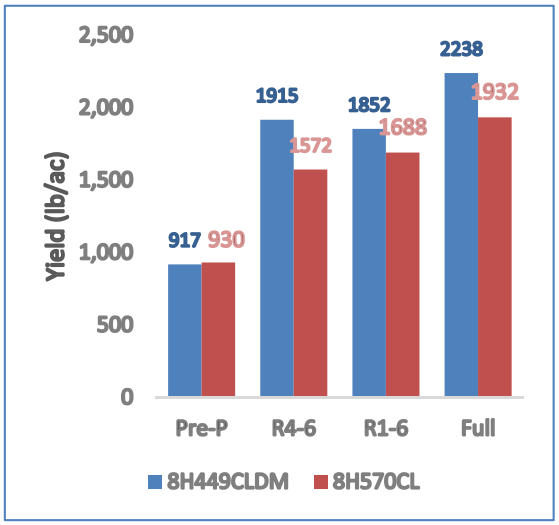


Figure 12. Seed yield of two sunflower hybrids in 2014 as affected by irrigation treatment.

Water use efficiency is a measure of how efficient a crop is at turning water into seed. It is calculated as the yield per inch of water received from irrigation[94] and rainfall[95]. In 2012, R1-6 had the highest water use efficiency (Fig. 13) and in 2014 R4-6 was the highest (Fig. 14). The full treatment had the lowest water use efficiency in both years.

[94] Net total irrigation including pre-planting irrigation.
[95] Rainfall from planting day through the end of R-8 or 125 days after planting, whichever came first.

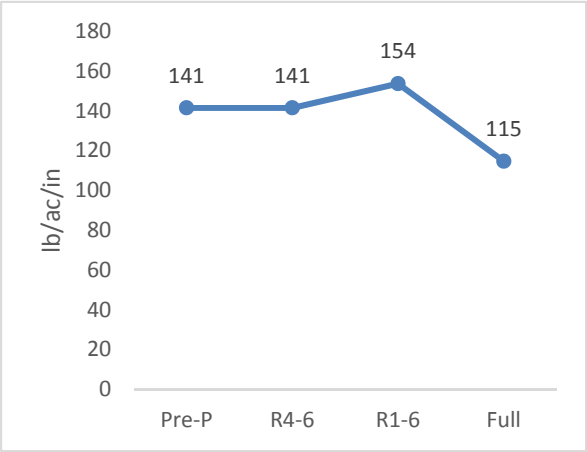


Figure 13. Water use efficiency in 2012.

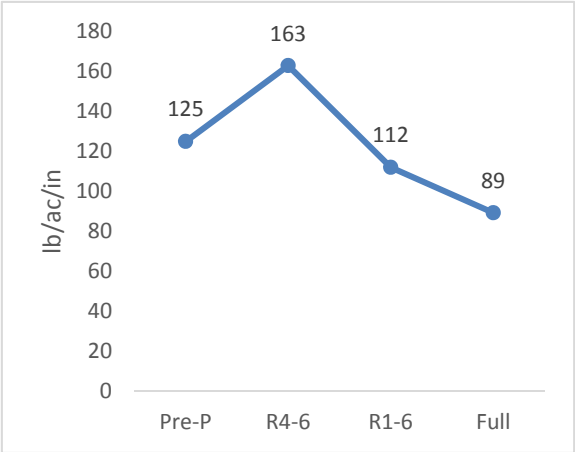


Figure 14. Water use efficiency in 2014.

Nitrogen application rate had almost no effect on yield in either 2012 or 2014 regardless of the irrigation treatment (Fig. 15 & Fig. 16). This is surprising because based on soil test results in 2012 (top three ft of soil), N fertilizer was recommended for seed yields above 1800 lb/ac. Deeper soil sampling (e.g., 0 to 4 ft) may be required to get more accurate N recommendations (Joel Schneekloth, Personal Communication, December 2012).

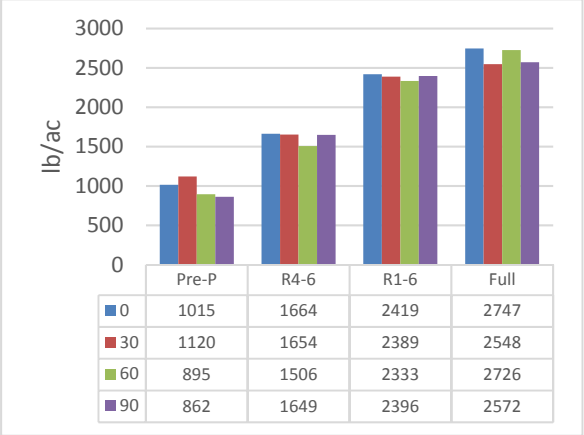


Figure 15. Effect of nitrogen application rate (in lb/ac) on yield in 2012.

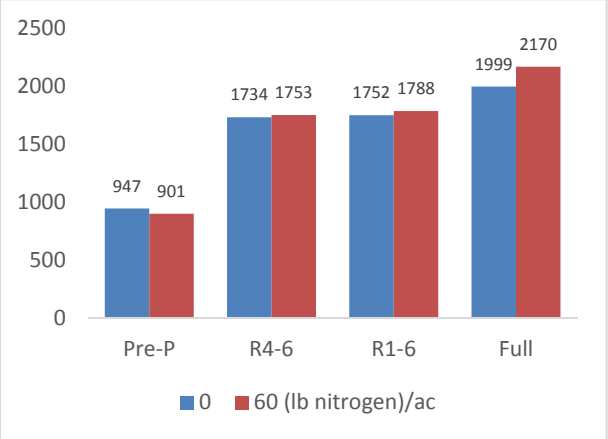


Figure 16. Effect of nitrogen application rate on yield in 2014.

There was damage to the sunflower crop in both years and was caused primarily by birds, particularly black birds, finches, and turtle doves. There appears to be more damage to the sunflower variety 8H449CLDM at the full irrigation treatment in 2012 and 2014 and at Pre-P and R1-6 in 2014 (Fig. 17 & Fig. 18). Yield reduction averaged 4% in 2012 and 13% in 2014.

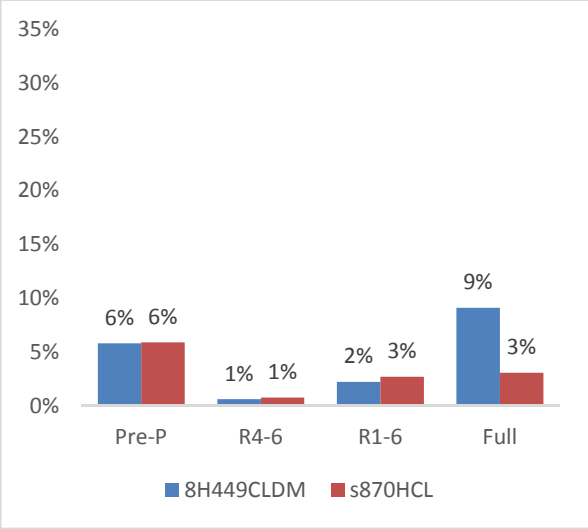


Figure 17. Average seed loss per sunflower head in 2012.

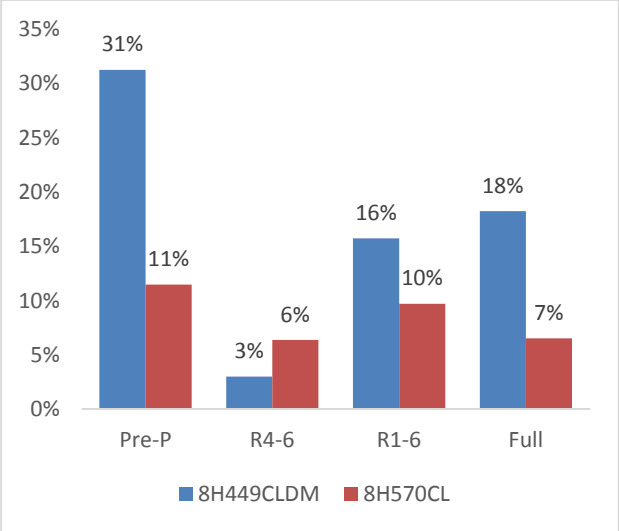


Figure 18. Average seed loss per sunflower head in 2014.

Increased irrigation led to higher seed oil content in the hybrid 8H449CLDM (Fig. 19 & Fig. 20). The exception was that the irrigation treatments R4-6 and R1-6 had about the same seed oil content. The amount of irrigation had little effect on the seed oil content of hybrid 8H570CL.

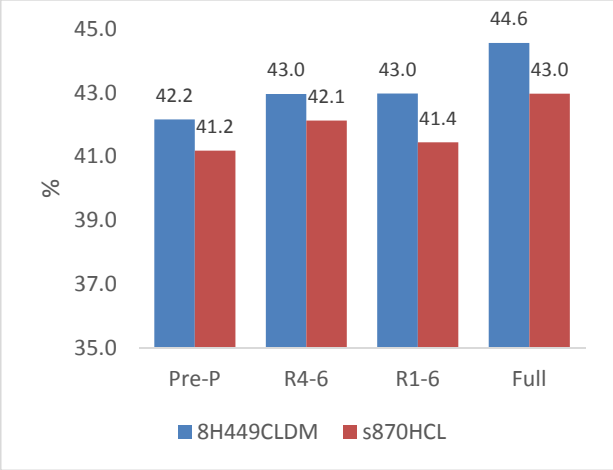


Figure 19. Seed oil content in 2012.

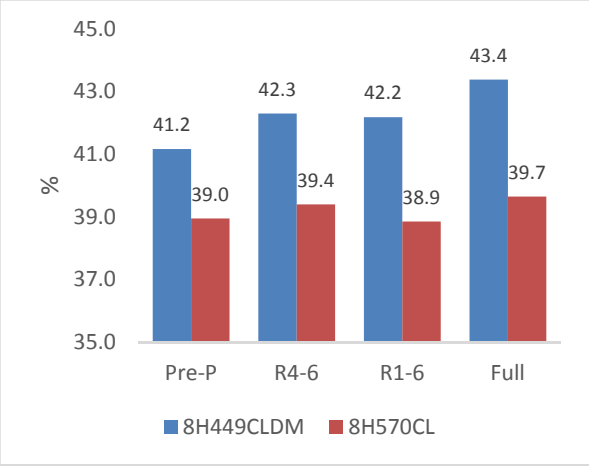


Figure 20. Seed oil content in 2014.

The variety 8H449CLDM was taller than 8H570CL in all irrigation treatments (Fig. 21 & Fig. 22). Height generally increased with more irrigation. However, the irrigation treatments Pre-P and R4-6 had the same height and were shorter than R1-6. This indicates that the final height of the sunflower plants was set somewhere between the R-1 and R-4 growth stages.

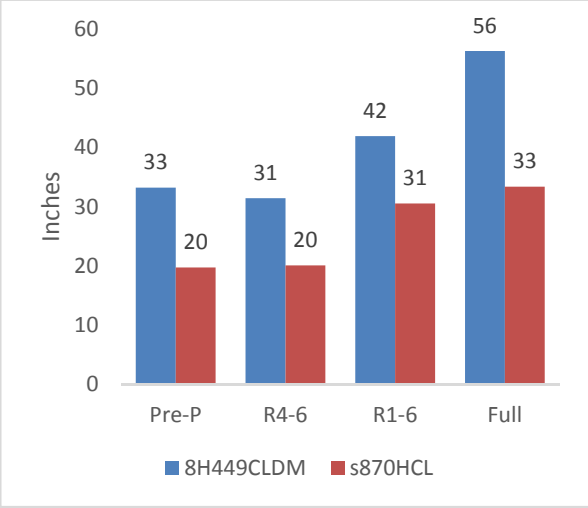


Figure 21. Plant height in 2012.

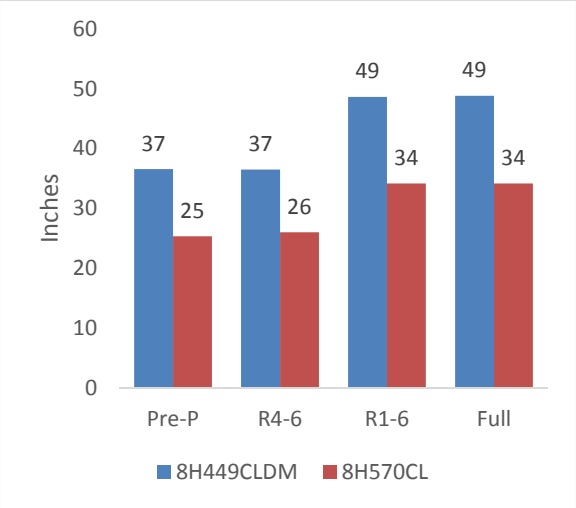


Figure 22. Plant height in 2014.

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Stone, L.R., D.E. Goodrum, A.J. Schlegel, M.N. Jaafar, and A. H. Khan. 2002. Water depletion depth of grain sorghum and sunflower in the central high plains. Agron. J. 94: 936-943.

Acknowledgments

This study was sponsored by the National Sunflower Association in 2012 with additional support from Colorado State University Agricultural Experiment Station.

Evaluation of Corn Hybrids for Drought Tolerance in 2014

A.F. Berrada and A.Y. Berrada

The objective of this study was to compare the yield of several corn hybrids at different irrigation amounts.

Corn is a minor crop in southwestern Colorado. However, with advances in drought tolerance and other traits, the potential exists for an increase in corn acreage. The drought tolerance of corn is enhanced through breeding (e.g., the so-called native gene approach) or with the use of molecular and transgenic techniques. Eight corn hybrids with or without genetic improvements for drought tolerance were tested in 2012 for their response to water stress[96]. Three of the best performing hybrids in 2012 and three 'new' hybrids were tested again in 2014.

Methods

Six corn hybrids were tested in 2014 at the Southwestern Colorado Research Center (SWCRC) for their response to water stress. A line-source sprinkler irrigation system similar to the one described by Hanks[97] et al. (1976) was used. With this system the amount of irrigation water applied decreases as the distance from the sprinkler line increases, generally in a linear or near-linear fashion, depending on nozzle configuration. There were three different irrigation treatments: 1/3 (33%), 2/3 (67%), and 3/3 (100%) of corn evapotranspiration (ET). The treatments received enough irrigation so that irrigation plus rainfall was equal to these percentages of ET. Corn ET that occurred between planting up until the day before physiological maturity[98] was included. From planting (May 30) to the day before physiological maturity (October 13) corn ET totaled 25.0 inches and rainfall totaled 5.6 inches.

The trial had four replications and was designed as a randomized block (Fig. 23). Each plot was 80 feet long by 10 feet wide.

[96] Berrada, A.F., and D. Reich. 2013. Evaluation of corn hybrids for drought tolerance. P. 15-22 in CSU-AES Technical Report Tr13-3.

[97] Hanks, R.J., J. Keller, V.P. Rasmussen, and G.D. Wilson. 1976. Line source sprinkler for continuous variable irrigation-crop production studies. Soil Sci. Soc. Am. J. 40: 426-429

[98] Physiological maturity was defined as the date when 50% of the corn ears in 50% of the plots showed a black layer at the tips of the kernels when the ear was opened up.

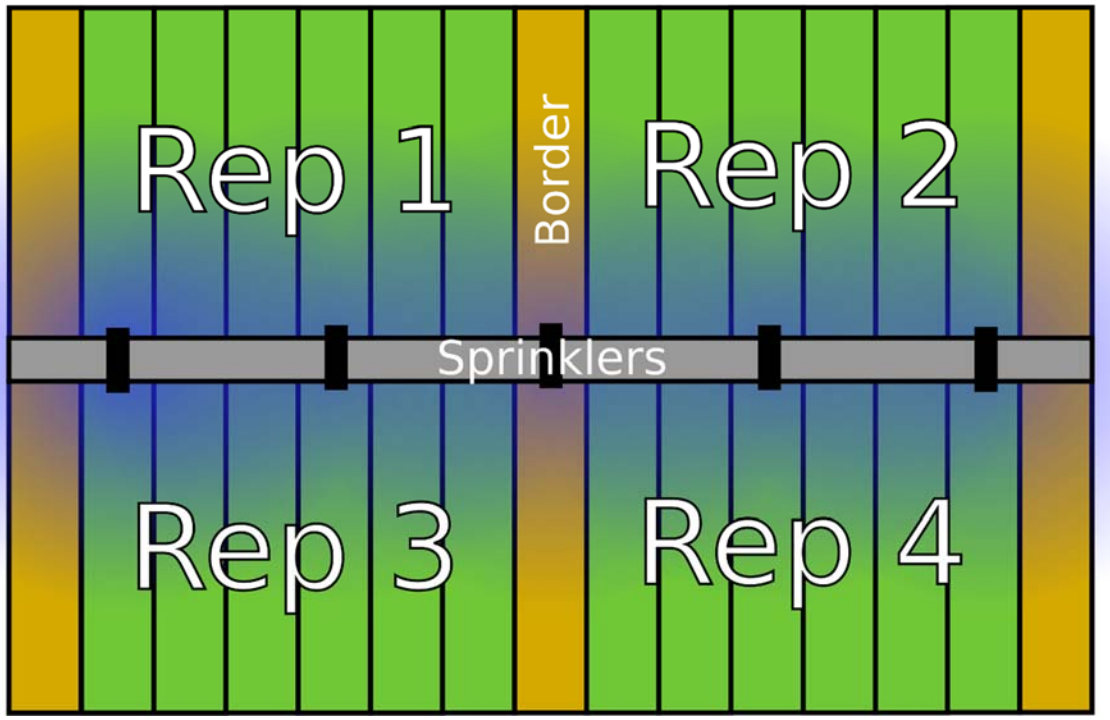


Figure 23. Corn trial approximate layout.

The entire trial received about 1.8 inches of irrigation from a side roll on May 5 in order to improve corn germination. Daily corn ET data was obtained from the Yellow Jacket Colorado Agricultural Meteorology (CoAgMet) weather station, which is located at the SWCRC. The corn was planted on May 30 at a seeding rate of about 29,870 seeds/acre with 2.5 feet between rows.

The sprinkler system was installed in early July and the first irrigation with the sprinkler system occurred on July 14. Cups to measure the amount of irrigation were placed at distances of 6, 20, 34, 48, and 62 feet from the sprinkler line about 2 feet above ground. The corn near the cups was cut down so that it wouldn't block the irrigation water. The trial was irrigated to catch up with corn ET and there-after was irrigated so that the total amount of irrigation (including the sideroll irrigation) matched the sum of corn ET starting from the planting date. The trial received 11 irrigations in July, 11 in August, and 4 in September. We could not irrigate more than about 2 hours at a time, otherwise there would be runoff in some plots.

The trial was sprayed with Roundup PowerMax at 40 oz/ac on June 3 and with 2,4-D (1 pt/ac) and Roundup PowerMax (30 oz/ac) on June 30. Black birds caused widespread damage in the trial, although they caused substantial (>50%) yield loss in only a few small areas.

The trial was harvested on December 2. Corn was harvested at the distances where it was estimated that the irrigation plus precipitation added up to 1/3 (33%), 2/3 (67%), and 3/3 (100%) of the corn ET. A trendline and the corresponding equation was created in Microsoft Excel for the north replications (Fig. 24) and the south replications (Fig. 25) in order to calculate where the corn should be harvested. To reduce any potential border effects only the center two rows of each plot were harvested. A length of six feet was harvested, centered on the distances listed in Table 49.

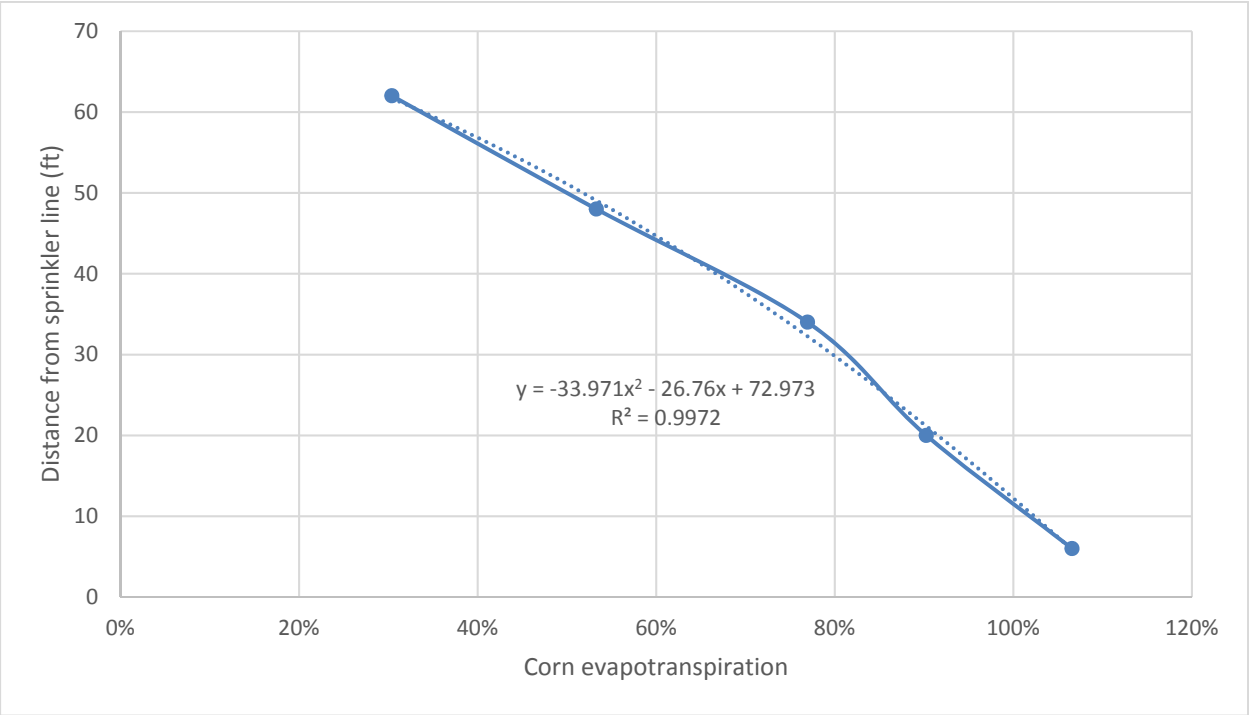


Figure 24. Distance vs. % of corn evapotranspiration (north replications).

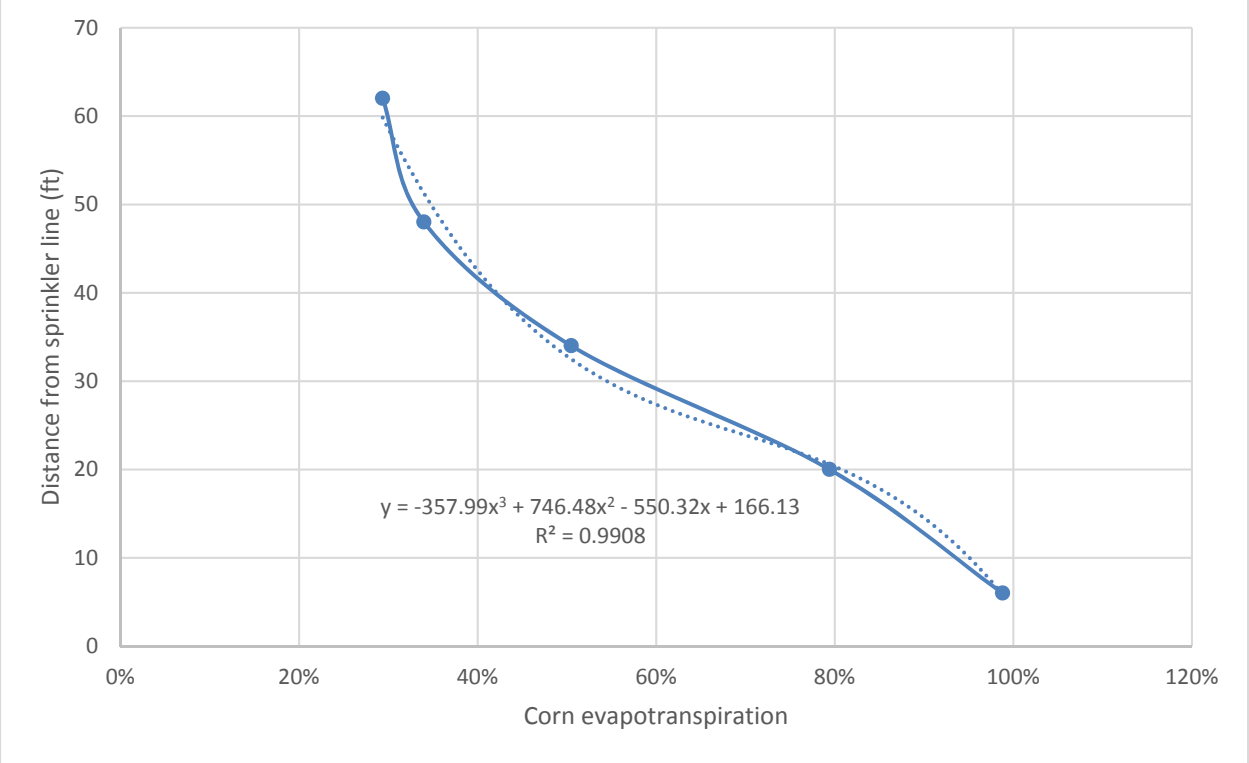


Figure 25. Distance vs. % of corn evapotranspiration (south replications).

Table 47. Corn trial harvest distances.

% of corn ET	Estimated irrigation[99]	Distance from sprinkler line (ft)	
		North replications	South replications
100%	19.5	12.2	4.3
67%	11.1	40.0	24.9
33%	2.8	60.3	52.4

After harvest, data about the corn ears was recorded including number of ears, pest damage, etc. The ears were then shelled, and total grain weight, moisture, and test weight was measured.

Results

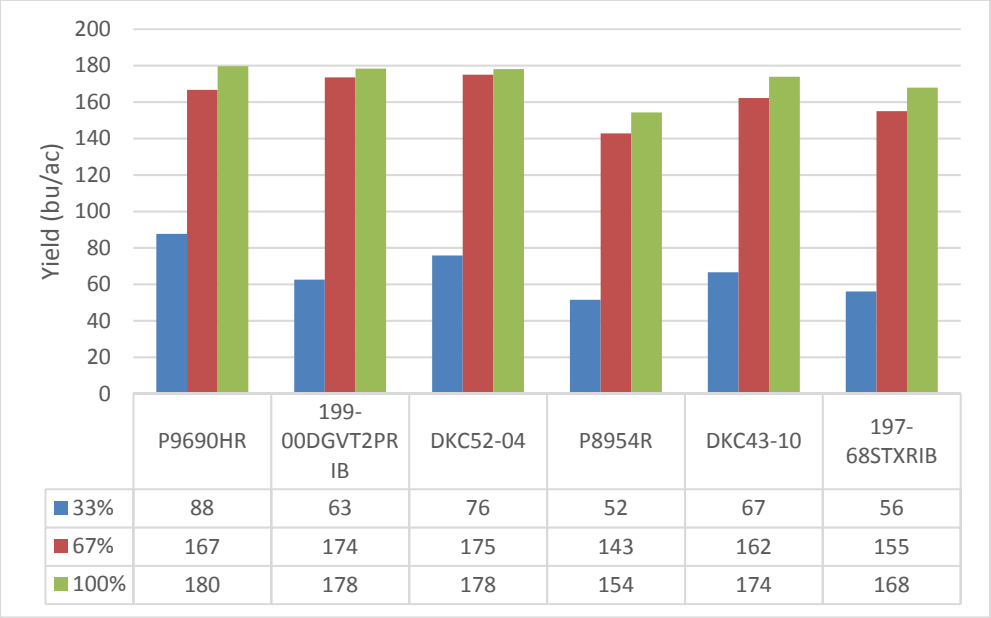
Several of the harvested areas were removed from the results for a few reasons: if it seemed like the area received a lot of runoff water, if 50% or more of the ears had 50% or more kernels missing due to pest damage, or if a row of corn plants was missing.

The yield of the 67% ET and 100% ET treatments was very close (Fig. 26). 100% ET had an average yield of 173 bushel/acre and 67% ET had a yield of 163 bu/ac. This means that the 67% ET treatment achieved 95% of the yield of the 100% ET treatment even though it received only 67% as much water.

The 33% ET treatment had an average yield of 68 bu/ac. This is 39% of the yield of the 100% ET treatment.

At 33% ET the hybrid P9690HR had the highest yield. At 67% ET, DKC-52-04 had the highest yield followed closely by 199-00DGVT2PRIB. At 100% ET, P9690HR had the highest yield followed by 199-00DGVT2PRIB and DKC52-04.

[99] Includes pre-planting irrigation.



	P9690HR	199-00DGVT2PRIB	DKC52-04	P8954R	DKC43-10	197-68STXRIB
33%	88	63	76	52	67	56
67%	167	174	175	143	162	155
100%	180	178	178	154	174	168

Figure 26. Corn grain yield[100].

Pest damage was recorded as the percentage of corn ears with pest damage, rather than the amount of damage per ear. The majority of the pest damage came from birds, but there were also many ears with damage from cutworms although the amount of cutworm damage on each ear was small. That's why the hybrid P9690HR had the most ears with pest damage at 33% and 100% ET (Figure 12) but was able to have the highest yield at those ET levels. The hybrid DKC52-04 had the fewest ears with pest damage. The percentage of ears with pest damage averaged 54% at 33% ET and 48% of ears at 67% ET and 100% ET.

[100] Yield was adjusted to 15.5% moisture and a bushel weight of 56 lb/bu.

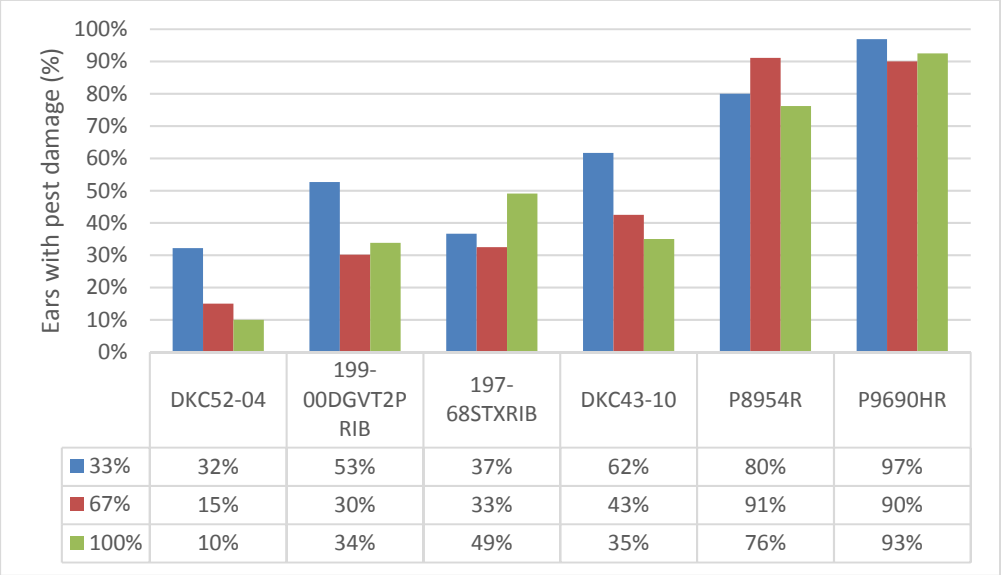


Figure 27. Percentage of ears with pest damage.

Corn plants in the 67% and 100% treatment were nearly the same height (Fig. 28). Plants in the 33% treatment were much shorter. This is similar to the effect of the irrigation treatment on yield.

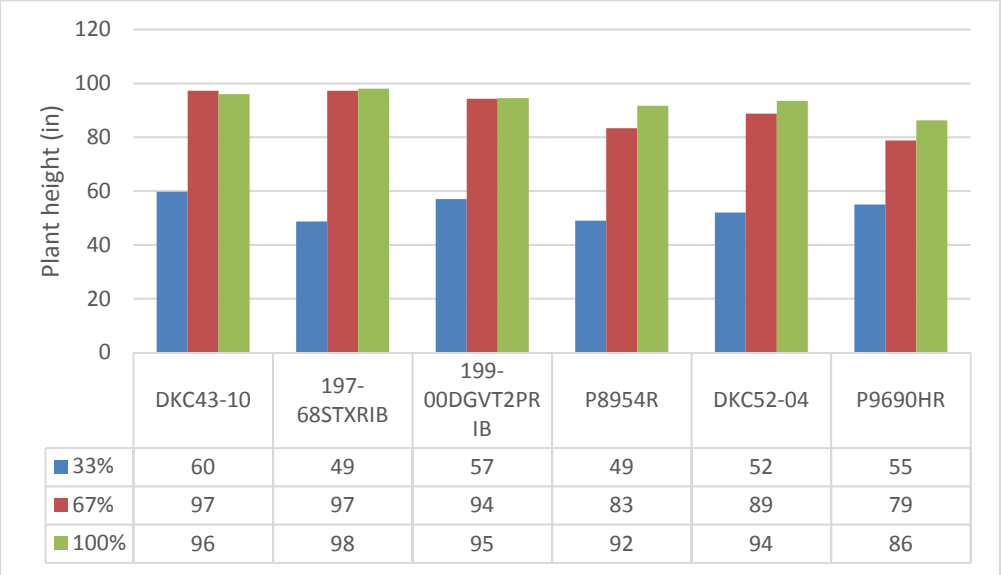
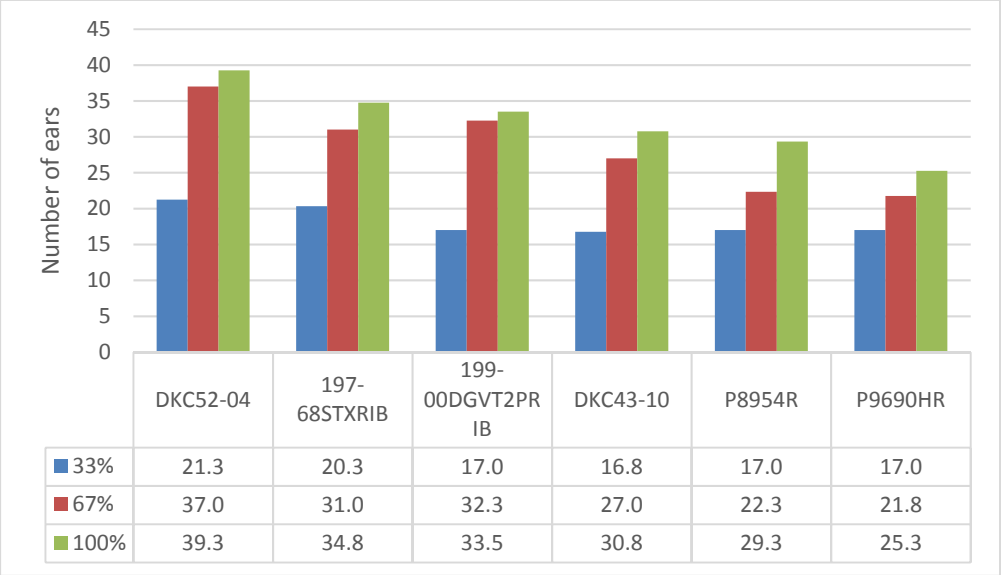


Figure 28. Plant height.

The irrigation treatment also had an effect on the number of corn ears (Fig. 29). Harvested areas in the 100% ET treatment had the most ears and harvested areas in the 33% treatment had the fewest number of ears.



	DKC52-04	197-68STXRIB	199-00DGVT2PRIB	DKC43-10	P8954R	P9690HR
33%	21.3	20.3	17.0	16.8	17.0	17.0
67%	37.0	31.0	32.3	27.0	22.3	21.8
100%	39.3	34.8	33.5	30.8	29.3	25.3

Figure 29. Average number of corn ears in each harvested area (5 ft x 6 ft).

Irrigation Water Requirements in the Full Service Area of the Dolores Project

A.F. Berrada and A.Y. Berrada

Support for using the Integrated Decision Support Consumptive Use Model was provided by Dr. Luis Garcia, Head of the Department of Civil and Environmental Engineering at Colorado State University and his student Nathan Baker. Additional support was provided by Dr. Allan Andales, Assistant Professor (at the time of this study) of Irrigation/Water Science in the Department of Soil & Crop Sciences at Colorado State University. The Dolores Water Conservancy District funded this study.

Introduction

This study was done at the request of the Dolores Water Conservancy District (DWCD). The District "develops water from the Dolores River for irrigation; municipal and industrial users; recreation; fish and wildlife; and hydroelectric power" (http://www.doloreswater.com/). The purpose of this study is to estimate irrigation water requirements for the full service area (FSA) of DWCD. The FSA receives all its irrigation water from DWCD.

The results of this study will be compared to those of a similar study done by Harris Water Engineering. Both studies calculate irrigation water requirements (IWR) and compare them to the actual diversions from McPhee Reservoir to determine if additional water should be allocated to the FSA.

Harris Engineering used the StateCU model developed to "estimate both crop and non-crop consumptive needs within the state" of Colorado. StateCU employs the modified Blaney-Criddle method to estimate crop consumptive use (CCU). Blaney-Criddle calculates CCU on a monthly basis using average monthly temperature and effective precipitation. The Blaney-Criddle method is simple and easy to use but it is not very accurate. Studies have shown that Blaney-Criddle can underestimate CCU by up to 60% in windy, dry, and sunny areas. It can overestimate CCU by up to 40% in calm, humid, and clouded areas (http://www.fao.org/docrep/S2022E/s2022e07.htm). The climate in the FSA is fairly dry with plenty of sunshine throughout the year and windy conditions in the spring. In a review of CCU methods, Sammis, Wang, and Miller (2011)[101] concluded that "the Blaney-Criddle formula, derived in farmers' fields under water stress conditions, calculates an ET that is most closely related to average county yields during the years the measurements were taken. But the empirical relationship and the originally derived coefficients are outdated and invalid for today's agriculture production systems and should be replaced with the Penman-Monteith equation when adjudicating water rights".

In this study, we used the Integrated Decision Support Consumptive Use Model (IDSCU) developed by Colorado State University (http://www.ids.colostate.edu/projects.php?project=IDSCUM&breadcrumb=IDSCUM). The IDSCU software offers several methods for calculating CCU, including Blaney-Criddle. The preferred method is the standardized reference crop evapotranspiration (ET) equation and

[101] Sammis, T.W., Wang, J., and Miller, D.R. 2011. The transition of the Blaney-Criddle formula to the Penman-Monteith equation in the western United States. Journal of Service Climatology. www.journalofserviceclimatology.org

calculation procedures recommended by the Task Committee on Standardization of Reference Evapotranspiration of the Environmental and Water Resources Institute of the American Society of Civil Engineers (ASCE). This method will be referred to as ASCE-PM. It employs a modified Penman-Monteith (PM) equation to calculate crop ET or CCU on a daily basis using air temperature, solar radiation, and wind speed. It integrates ET data with soil, water supply, and weather data to estimate the water use of various crops during the growing season. Weather and surface supply data can be accessed from Colorado's HYDROBASE (http://cdss.state.co.us/onlineTools/Pages/BulkHydroBaseDataExporter.aspx), from water conservancy districts, and from the Colorado Agricultural Meteorological Network or CoAgMet (http://ccc.atmos.colostate.edu/~coagmet/). Any input data including ET estimates can also be entered directly by the user.

Weather data from the Yellow Jacket CoAgMet station was used as the basis for estimating CCU in the FSA. The Dove Creek station was used to fill in missing data. Soil and crop characteristics such as soil water holding capacity, management allowable depletion, root depth, planting date, and harvest date were accessed from the IDSCU software library and, if need be, modified to reflect the prevailing conditions in the FSA. Effective precipitation was estimated by multiplying total precipitation by 0.7. The software input data are shown in Tables 57-61 in the Appendix.

In theory, CCU is the net amount of water needed to maximize crop production if there were no limiting factors such as diseases, insects, inadequate soil fertility, etc. Irrigation water requirement or IWR is the amount needed to be diverted from the water source, McPhee Reservoir in this case, in order to meet CCU. Irrigation requirement takes into account water losses by seepage, drainage, evaporation, or runoff during transport from McPhee Dam to the farm or during water application to the field or crop. The total water needed and IWR are depicted by equations 1 and 2.

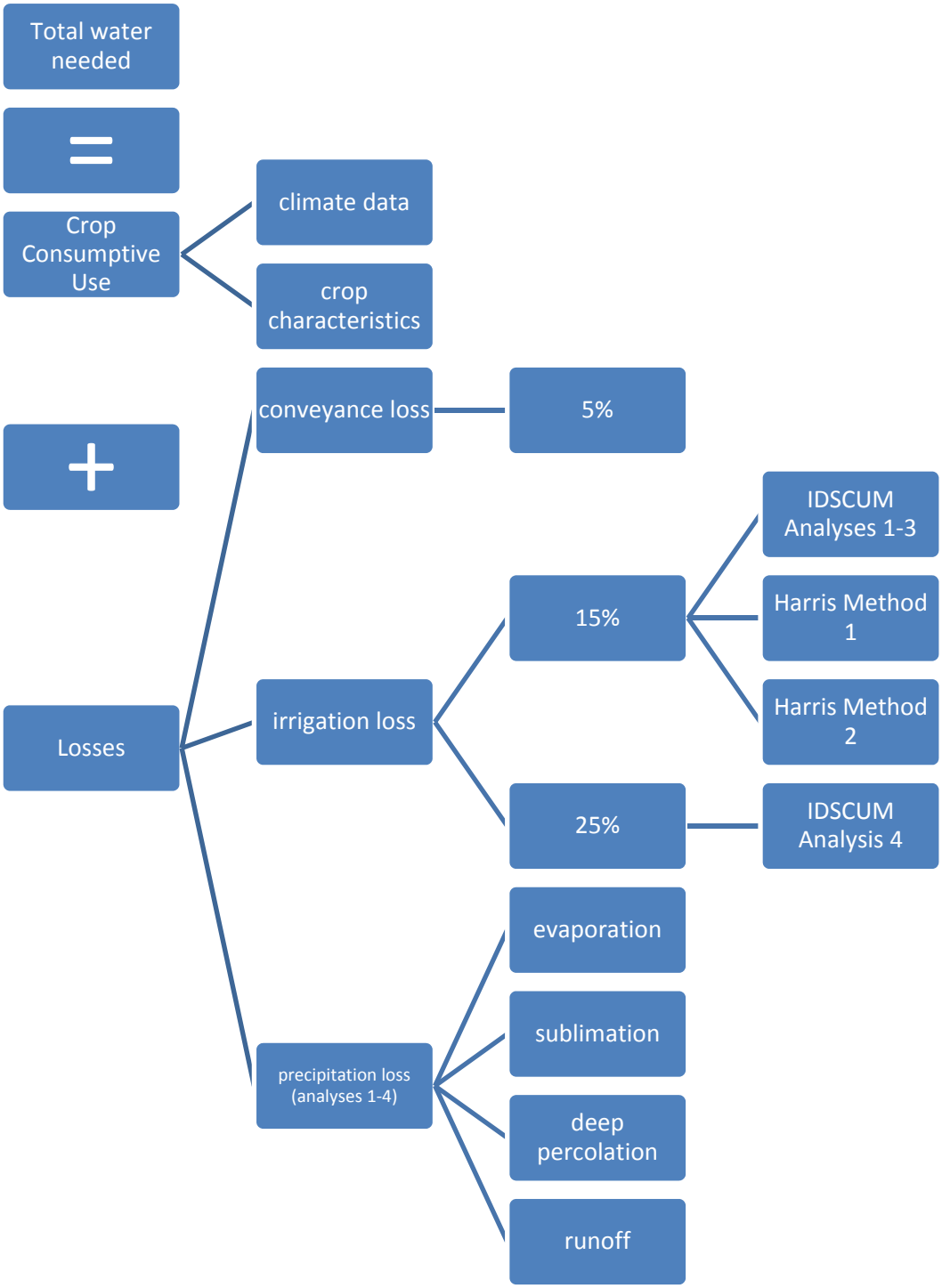
Both the Harris Engineering analysis and our study used the established conveyance efficiency for the Dove Creek Canal of 95%. The on-farm irrigation efficiency was assumed to be 85% since most, if not all FSA farmers use sprinkler irrigation. In one analysis we used an irrigation efficiency of 75% given the fact that there are more side rolls (wheelmove sprinkler irrigation systems) than center pivots in the FSA. The irrigated acreage allocated for the FSA is 28,560 acres corresponding to a water allocation of 56,490 acre-feet at the McPhee Dam (Ken Curtis, Personal Communication, February 2012). Alfalfa is the main crop grown in the FSA, with some spring grains and dry beans. Table 50 shows the actual irrigated acres from 1996 through 2010. These were derived from the crop census data required every year as part of each irrigator's allotment agreement with DWCD.

Table 48. Crop acreage in the Full Service Area (source: DWCD).

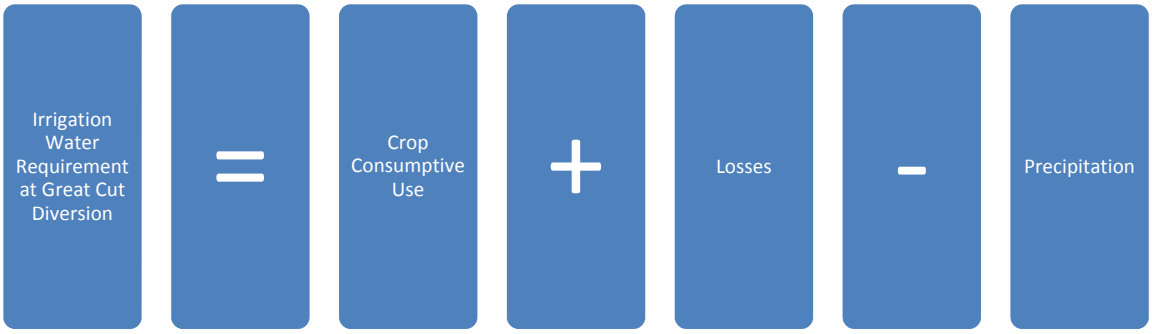
	Alfalfa		Dry beans		Spring grains		Miscellaneous		Total
Year	Acres	%	Acres	%	Acres	Year	Acres	%	Acres
1996	18,020	75%	644	3%	3,605	15%	1,608	7%	23,877
1997	19,521	78%	1,561	6%	3,301	13%	556	2%	24,939
1998	20,368	84%	1,324	5%	1,929	8%	662	3%	24,283
1999	21,968	88%	531	2%	1,909	8%	664	3%	25,072
2000	22,633	90%	345	1%	1,404	6%	798	3%	25,180
2001	22,731	92%	475	2%	1,265	5%	351	1%	24,822
2002	21,291	93%	298	1%	1,061	5%	182	1%	22,832
2003	19,598	88%	1,130	5%	1,392	6%	37	0%	22,157
2004	19,948	81%	2,700	11%	1,527	6%	405	2%	24,580

	Alfalfa		Dry beans		Spring grains		Miscellaneous		Total
Year	Acres	%	Acres	%	Acres	Year	Acres	%	Acres
2005	18,744	73%	4,482	17%	1,868	7%	599	2%	25,693
2006	19,831	78%	3,880	15%	1,020	4%	626	2%	25,357
2007	22,324	86%	1,868	7%	1,070	4%	721	3%	25,983
2008	21,284	82%	1,154	4%	2,564	10%	860	3%	25,862
2009	20,874	81%	2,004	8%	2,422	9%	465	2%	25,765
2010	20,742	79%	2,519	10%	2,047	8%	1,058	4%	26,366
Average	20,658	83%	1,661	7%	1,892	8%	639	3%	24,851

Equation 1: Total Water Needed.



Equation 2: Irrigation Water Requirement.



Four different analyses were performed using the IDSCUM software as summarized below and in Table 2.

- Analysis #1 used known crop types and acreage data from 1996-2010 (Table 1). Crop data prior to 1996 is not available.
- Analysis #2 was done using the same crop percentages as in Method 2 of Harris Engineering for the period of climate record at Yellow Jacket from 1992 to 2011.
- Analysis #3 looked at the same period but assumes that all allocated acres in the FSA are irrigated and that the percentage of land planted to alfalfa is 90%. This was done to simulate a high water usage scenario. Alfalfa acreage was highest in 2000 (90%), 2001 (92%), and 2002 (93%). The on-farm irrigation efficiency was assumed to be 85% in all three analyses.
- Analysis #4 is similar to analysis #3 except that the on farm irrigation efficiency was lowered to 75% to account for the fact that there are far more side rolls than center pivots in the FSA. The irrigation application efficiency of side rolls ranges from 60 to 85% and that of center pivots from 75 to 95% (Berrada and Reich, 2011)[102].

The analyses above were compared to the following analyses done by Harris Engineering (Table 51):

- Harris Method 1: The first method used known crop types and acreage data from 2000, 2001, 2004-2009 (Table 50). These remaining years were non-drought years with all land developed and a full water supply was available. The on farm irrigation efficiency was assumed to be 85%.
- Harris Method 2: The second method looked at the period of climate record at Yellow Jacket[103] from 1963 to 2009, while using the average crop types and acreage from the 2004 to 2009 data. There was a maximum of 28,566 acres available for irrigation. The on farm irrigation efficiency was assumed to be 85%.

[102] Berrada, A.F., and D. Reich. 2011. Alfalfa irrigation water management. p. 127-134 in Intermountain Grass and Legume Production Manual, 2nd Edition. Agricultural Experiment Station and Extension Technical Bulletin TB11-02, Colorado State University.

[103]The CoAgMet station at Yellow Jacket has been operational since 1992. Data prior to 1992 may have been obtained from a farmer-operated NOAA station that no longer exists.

Table 49. Analyses and methods included in this study.

Method & input data	Analysis 1a	Analysis 1b	Analysis 2	Analysis 3	Analysis 4	Harris Method 1	Harris Method 2
ET calculation	ASCE-PM	ASCE-PM	ASCE-PM	ASCE-PM	ASCE-PM	Blaney-Criddle	Blaney-Criddle
Conveyance efficiency (%)	95%	95%	95%	95%	95%	95%	95%
Irrigation efficiency (%)	85%	85%	85%	85%	75%	85%	85%
Alfalfa (%)		as reported	83.4%	90.0%	90.0%		83.4%
Dry beans (%)		as reported	8.3%	3.9%	3.9%		8.3%
Miscellaneous (%)	0.0%	as reported	0.0%	1.5%	1.5%	0.0%	0.0%
Spring grains (%)		as reported	8.3%	4.5%	4.5%		8.3%
Total (%)		100.0%	100.0%	100.0%	100.0%		100.0%
Alfalfa (acres)	as reported	as reported	23,821	25,704	25,704	as reported	23,826
Dry beans (acres)	as reported	as reported	2,375	1,124	1,124	as reported	2,375
Miscellaneous (acres)	0	as reported	0	435	435	0	0
Spring grains (acres)	as reported	as reported	2,364	1,297	1,297	as reported	2,364
Total irrigated acres	alfalfa + dry beans + spring grains	alfalfa + dry beans + spring grains	28,560	28,560	28,560	alfalfa + dry beans + spring grain	28,566

Results

Analysis 1a & 1b

Table 50. Result of analysis 1a & 1b and water diversions in 1996 through 2010.

Year	Analysis 1a IWR	Analysis 1b IWR	Diversions (ac-ft)
1996	65,385	70,611	54,760
1997	40,874	42,120	34,577
1998	57,606	59,645	47,206
1999	45,179	47,035	37,198
2000	73,391	75,896	57,237
2001	65,920	67,108	55,070
2002	80,040	80,721	16,893
2003	55,915	56,032	27,300
2004	48,612	49,590	49,584
2005	52,869	54,602	42,898
2006	65,454	67,312	46,177
2007	52,178	54,360	49,629
2008	48,042	50,433	55,589
2009	53,515	54,775	57,129
2010	47,409	49,757	49,129
Average	56,826	58,666	45,358
Average w/o 2002 & 2003	55,110	57,172	48,937

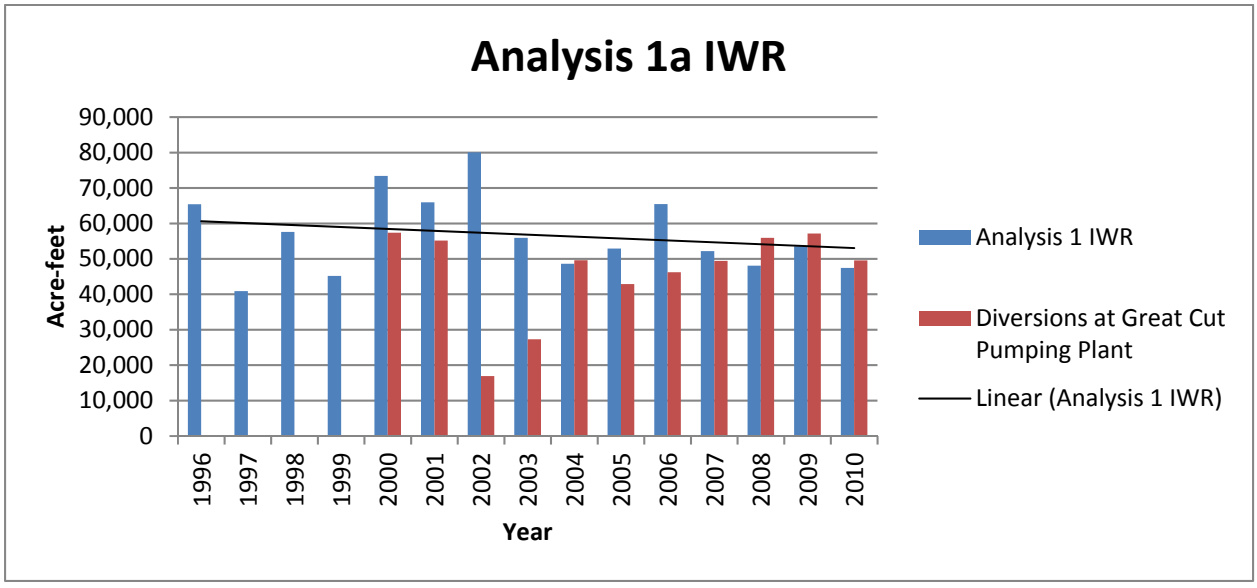


Figure 30. Analysis 1a IWR.

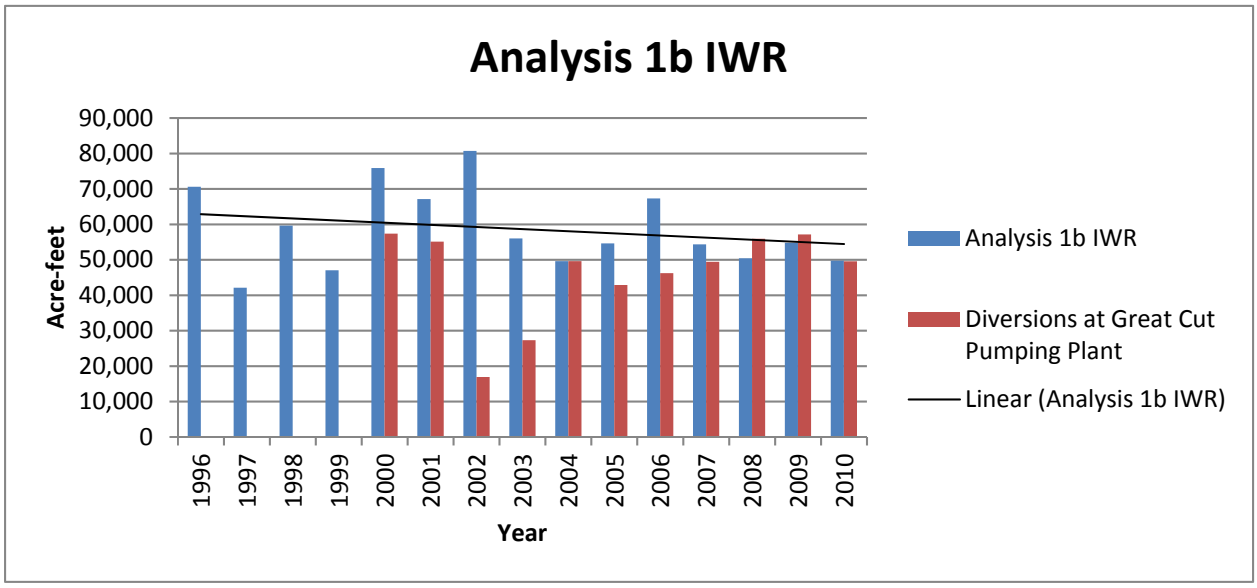


Figure 31. Analysis 1b IWR.

In **analysis 1a**, IWR is based on actual acreages for alfalfa, dry beans, and spring grains; miscellaneous crops are not included. The maximum IWR was 80,040 acre-feet in 2002 and the minimum was 40,874 acre-feet in 1997 (Table 52). The average IWR was 56,826 acre-feet. When 2002 and 2003 are excluded, IWR averaged 55,110 acre-feet and the diversions 48,937 acre-feet. The years 2002 and 2003 had low water supplies after several years of below average precipitation. The year 1997 received the most water from rain and snow (Table 53). Irrigation water requirements were greater than diversions in four out of 15 years of the analysis (Table 52).

In **analysis 1b**, miscellaneous crops are included and are assumed to be grass. The average IWR from 1996 through 2010 was 58,666 acre-feet. The average without the years 2002 and 2003 is 57,172 acre-feet (Table 52).

Table 51. Monthly precipitation (in inches) at Yellow Jacket from 1992 through 2011.

Month/Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total (in.)
30-yr avg.[104]	1.2	1.3	1.4	0.9	1.3	0.6	1.5	1.7	1.5	2.0	1.5	1.0	15.9
1992	0.0	0.0	0.0	0.2	3.9	0.4	1.6	1.2	1.3	1.1	0.1	0.0	9.8
1993	0.0	0.0	0.0	0.4	1.0	0.1	0.0	3.3	0.4	1.9	0.6	0.0	7.6
1994	0.0	0.0	0.9	2.1	0.9	0.3	0.5	0.8	1.3	1.1	1.2	0.9	10.1
1995	1.3	0.7	3.3	0.8	1.3	0.8	1.8	1.4	0.0	0.4	0.1	0.1	11.9
1996	0.4	0.4	0.5	0.2	0.1	1.4	1.1	0.2	1.3	3.3	1.4	1.3	11.7
1997	2.2	1.2	0.0	1.8	1.6	0.3	2.1	2.2	2.0	1.3	1.2	0.8	16.6
1998	0.9	2.0	2.2	0.9	0.4	0.1	2.2	0.5	0.8	3.4	2.3	0.1	15.6
1999	0.2	0.5	0.0	2.7	1.7	1.1	1.7	2.5	0.9	0.0	0.1	0.1	11.5
2000	1.2	0.6	1.6	0.4	0.4	0.1	0.6	2.3	0.8	2.0	0.7	0.4	10.9
2001	0.7	1.0	0.1	1.1	0.5	0.2	1.2	2.8	0.2	0.6	0.5	0.9	9.6
2002	0.0	0.0	0.5	0.2	0.1	0.0	0.1	0.8	2.7	1.8	1.3	0.6	8.1
2003	0.2	2.0	1.7	0.2	0.7	0.1	0.6	1.2	2.2	1.2	0.8	0.3	11.1
2004	0.7	1.5	0.4	2.5	0.0	0.2	2.1	0.3	3.2	2.0	1.5	0.9	15.3
2005	2.9	3.2	1.5	1.6	0.3	0.6	1.1	0.7	1.8	1.6	0.3	0.1	15.7
2006	0.3	0.0	1.5	1.0	0.2	0.3	1.0	1.4	1.7	4.1	0.3	0.4	12.1
2007	0.4	1.0	0.7	1.6	1.5	0.1	1.7	1.4	1.9	0.4	1.1	2.7	14.4
2008	1.1	1.5	0.1	0.7	0.7	0.5	0.7	2.2	0.4	1.2	1.1	1.2	11.4
2009	0.4	0.4	0.2	0.9	1.5	0.7	0.4	0.8	1.1	0.4	0.5	0.6	7.6
2010	1.3	1.1	1.1	0.9	0.2	0.4	1.0	3.3	1.7	1.9	0.4	2.2	15.5
2011	0.4	0.4	0.6	1.5	2.0	0.0	1.5	0.9	1.3	2.3	0.9	0.6	12.3

[104] 1971-2000 average. Note: the recorded (all years) precipitation from snow may not be accurate.

Analysis 2

Analysis 2 assumes that all 28,560 acres are irrigated and uses nearly the same crop acreages as with Harris Method 2 (which assumed that 28,566 acres were irrigated). The maximum IWR was 96,109 acre-feet in 2002 and the minimum was 47,987 acre-feet in 1997 (Table 54 & Fig. 32) as was the case with analysis 1a. The average IWR was 67,529 acre-feet. If one excludes the years 2002 and 2003 then the average IWR becomes 65,751 acre-feet.

Table 52. Results of analysis 2.

Year	Analysis 2 IWR
1992	79,760
1993	84,175
1994	86,000
1995	48,857
1996	83,522
1997	47,987
1998	68,523
1999	50,768
2000	82,616
2001	69,746
2002	96,109
2003	70,961
2004	57,976
2005	62,733
2006	77,736
2007	58,206
2008	54,179
2009	60,579
2010	54,105
2011	56,044
Average	67,529
Average w/o 2002 & 2003	65,751

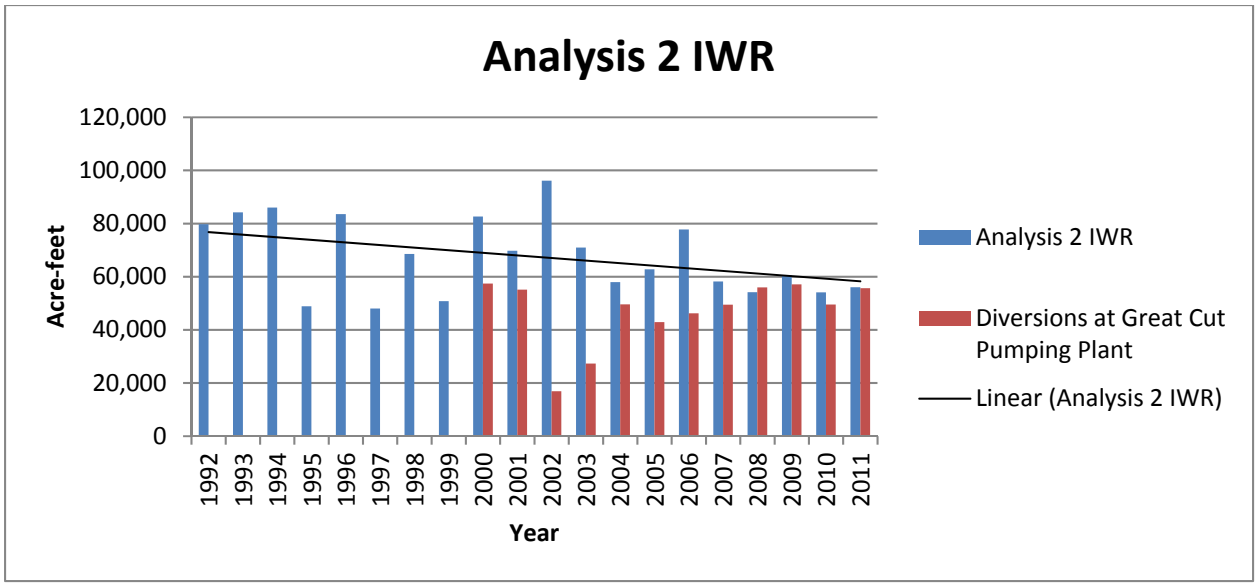


Figure 32. Analysis 2 IWR.

Analysis 3

Analysis 3 uses the same period and conveyance and irrigation efficiencies as analysis 1, but it assumes that 90% of the irrigated acreage was in alfalfa. It also assumes that miscellaneous acres were in grass. The maximum IWR was 99,668 acre-feet in 2002 and the minimum was 49,529 acre-feet in 1997 (Table 54 & Fig. 33). The average IWR was 70,215 acre-feet. The average without 2002 and 2003 is 68,422 acre-feet.

Table 53. Results of analysis 3.

Year	Analysis 3 IWR
1992	83,351
1993	87,477
1994	89,221
1995	50,545
1996	86,757
1997	49,529
1998	71,354
1999	53,130
2000	85,256
2001	75,928
2002	99,668
2003	73,039
2004	59,786
2005	64,766
2006	80,836

Year	Analysis 3 IWR
2007	60,211
2008	56,013
2009	62,858
2010	56,798
2011	57,778
Average	70,215
Average w/o 2002 & 2003	68,422

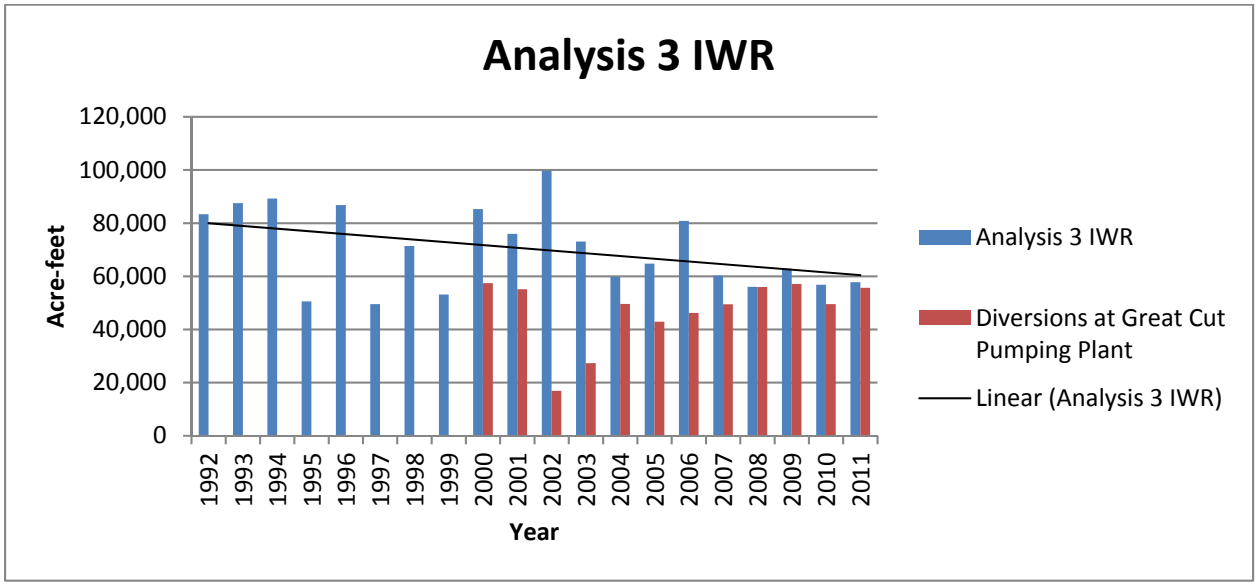


Figure 33. Analysis 3 IWR.

Analysis 4

Analysis 4 is the same as analysis 3 but assumes an irrigation efficiency of 75%. The maximum IWR was 112,957 acre-feet in 2002 and the minimum was 56,133 acre-feet in 1997 (Table 55 & Fig. 34. The average IWR was 79,577 acre-feet. The average without 2002 and 2003 is 77,545 acre-feet.

Table 54. Results of analysis 4.

Year	Analysis 4 IWR
1992	94,465
1993	99,141
1994	101,117
1995	57,284
1996	98,324
1997	56,133

Year	Analysis 4 IWR
1998	80,868
1999	60,213
2000	96,624
2001	86,052
2002	112,957
2003	82,777
2004	67,757
2005	73,402
2006	91,615
2007	68,239
2008	63,481
2009	71,239
2010	64,372
2011	65,481
Average	79,577
Average w/o 2002 & 2003	77,545

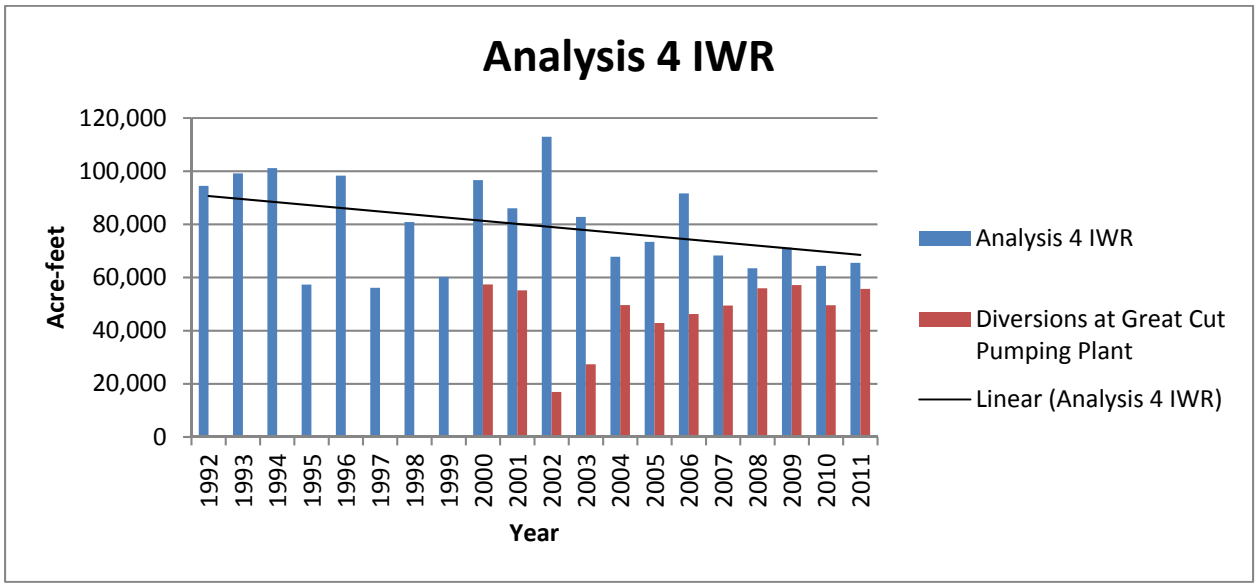


Figure 34. Analysis 4 IWR.

Comparison of Analyses

Note: the averages are only for the years shown in Table 56. The years 2002 and 2003 were excluded.

Table 55. Comparisons of IWR estimates in acre-feet.

Year	Diversions	Analysis 1 IWR		Analysis 2 IWR	Analysis 3 IWR	Analysis 4 IWR	Harris Method 1 IWR	Harris Method 2 IWR
		1a	1b					
2000	57,375	73,391	75,896	82,616	85,256	96,624	65,329	65,329
2001	55,129	65,920	67,108	69,746	75,928	86,052	68,490	75,305
2004	49,582	48,612	49,590	57,976	59,786	67,757	48,727	56,459
2005	42,869	52,869	54,602	62,733	64,766	73,402	54,889	62,928
2006	46,203	65,454	67,312	77,736	80,836	91,615	55,969	63,644
2007	49,427	52,178	54,360	58,206	60,211	68,239	57,290	61,658
2008	55,934	48,042	50,433	54,179	56,013	63,481	52,803	57,694
2009	57,129	53,515	54,775	60,579	62,858	71,239	55,033	60,784
2010	49,544	47,409	49,757	54,105	56,798	64,372	N/A	N/A
Average	51,466	56,377	58,204	64,208	66,939	75,864	57,316	62,975
Avg. w/o 2010	51,706	57,498	59,260	65,471	68,207	77,301	57,316	62,975

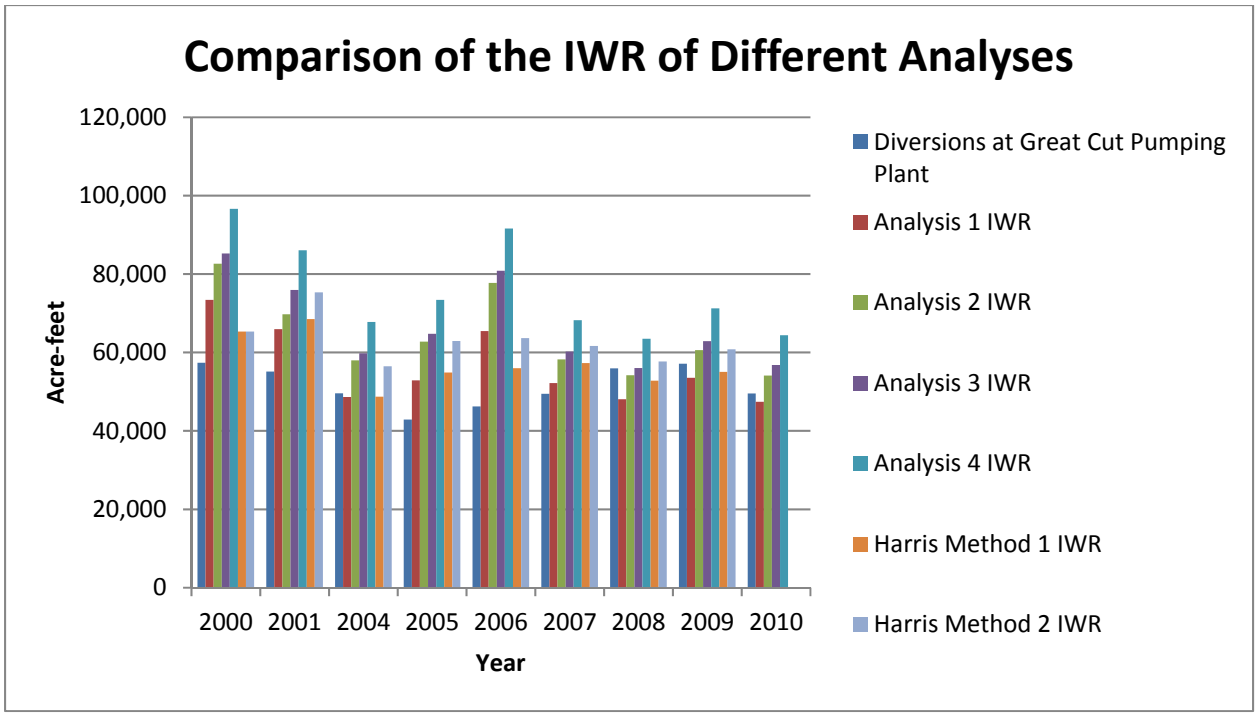


Figure 35. Comparison of the IWR of different analyses.

Conclusion

For the period of 2000, 2001, and 2004-2009, the estimated irrigation water requirements (IWR) for the FSA exceeded diversions with all the methods used in this study (Table 56 & Fig. 35). On average, IWR exceeded diversions by 5,792 acre-feet based on the standardized ASCE method of calculating CCU (analysis 1a). The deficit is 16,501 acre-feet with the high-usage scenario (analysis 3) and 25,595 acre-feet (analysis 4) if irrigation efficiency averaged 75% instead of 85% used in the other analyses. Irrigation water requirements estimate with analysis 2 was higher than the estimate obtained with Harris Method 2 (both used similar assumptions) by 2,496 acre-feet.

Based on the generally accepted opinion that the standardized ASCE-PM method is more accurate for calculating crop consumptive use than Blaney-Criddle, analysis 1b provides the best estimate of IWR, 58,204 acre-feet, based on actual[105] crop acreages for the period of comparison (2000-2001 & 2004-2010). The years 2002 and 2003 were excluded due to low water supplies, which were caused by a five-year (1999-2003) drought. The IWR estimate is slightly higher (58,666 ac-ft) when all the years from 1996 through 2010 are included in the analysis (Table 52). If all the allotted acres (28,560 ac) are irrigated, then IWR estimate becomes 64,208 acre-feet (analysis 2), which exceeds the current water allotment (56,490 ac-ft) by 7,718 acre-feet. The highest reported irrigated acreage was 26,366 acres in 2010 (data for 2011 was not available when this study was done). It has stayed above 25,000 acres since 2005 (Table 50). The full allocation of 28,560 acres may never be reached although it could come close if one considers new or future water allotments (through petitions) within FSA and class 6 land that may actually

[105] Crop acreage is reported by FSA farm operators or owners before the start of the irrigation season.

be irrigated even though it may not have been included in the original allocation (note: this is speculation on my part and may be ignored). Analyses 3 & 4 provide IWR estimates when 90% of the full FSA allocation of 28,560 acres is in alfalfa or irrigation efficiency is only 75% (analysis 4). Alfalfa acreage reached or exceeded 90% in 2000, 2001, and 2002; which is much higher than the 55% envisioned when the Dolores irrigation project was designed[106].

The basis for the ASCE –PM method is a well-watered, non-stressed alfalfa crop to calculate reference ET, which may explain the higher CCU estimates than with Blaney-Criddle. With ASCE-PM, daily reference ET is multiplied by a crop coefficient to calculate crop ET or CCU. The crop coefficients used in this study were estimated from work done in Kimberly, ID and eastern Colorado. Ideally, they should be calibrated to reflect the soil and climatic conditions in the FSA, which would require extensive field measurements. Ground truthing of soil water content would also increase the accuracy of CCU calculations as would direct measurements of the amount of water from snow. The CoAgmet stations at Yellow Jacket and Dove Creek do not have a special gauge or mechanism to catch and melt all the snow that falls in a given day. Whatever snow falls in the rain gauge and melts naturally is the amount of water recorded. Moisture from snow in excess of what the rain gauge can hold is not recorded. Water from snow can account for up to 40% of the total annual precipitation (from rain and snow) at Yellow Jacket (Gary Peterson, Personal Communication); thus, the importance of precise measurements. Furthermore, installing one or two additional weather stations at representative sites in the FSA would provide more accurate weather data for CCU calculations.

The results of this study indicate that more water (1,714 ac-ft with analysis 1b and 7,718 ac-ft with analysis 2) may be needed to meet crop water demand in the FSA than the current allocation of 56,490 acre-feet. Improvements in farming practices will have to be made to maximize water use efficiency and take advantage of all the water that is currently available or may become available to the FSA irrigators in the future. Improvements include the judicious choice of crops and crop varieties, optimum planting dates, sound irrigation scheduling, and adequate nutrient soil, crop (e.g. pest control), and nutrient management. Upgrading the irrigation equipment to more efficient systems or components would help as well. In years with limited water supplies, farmers may have to irrigate fewer acres than they normally would, reduce the number of acres in alfalfa[107] or apply water during the most sensitive crop growth stages e.g., flowering and grain formation for small grains.

[106] Dolores Project, Colorado--Definite Plan Report, Appendix B: Water Supply. U.S. Department of the Interior, Bureau of Reclamation, Upper Colorado Region, April 1977.

[107] Alfalfa uses more water than dry beans or spring grains for example.

Appendix

Table 56. IDSCUM software inputs[108].

Variable	Value	Reason for Value
ET method	ASCE-PM	
Annual carry-over soil moisture coefficient	0.5	Program default value
Use excess effective rainfall	Yes	Allows effective rainfall that is in excess of consumptive use to be stored in the soil (IDSCUM software help manual)
Fraction of NWR for alfalfa or pasture acreage to be met	1	So that 100% of the crop's net water requirement will be met
Calculate recharge from ditches and wells	No	Recharge of the Dolores River or McPhee Reservoir is not being considered in this simulation
Use water supply data	No	The purpose of this simulation is to calculate crop water needs regardless of the irrigation water supply available
The calculation includes soil moisture	Yes	"When soil moisture is included in the water budget calculation, the model will first meet crop demand by drawing water from the crop's soil moisture reservoir." (IDSCUM software help manual)
Model crop stress. This will reduce crop consumptive use when the field is water-short.	No	This simulation will assume that the crops aren't allowed to be water stressed.
Soil name	Wetherill loam	Soil type at the Yellow Jacket weather station (http://websoilsurvey.nrcs.usda.gov/app/websoilsurvey.aspx)
Average water holding capacity (in/ft)	2.2[109]	Water holding capacity of Wetherill loam (http://websoilsurvey.nrcs.usda.gov/app/websoilsurvey.aspx)
Import weather for Yellow Jacket (YJK01) using	CoAgMet	
Fill in missing data from Yellow Jacket with data from the following station	Dove Creek (DVC01)	The difference between the elevation of the two stations is less than four hundred feet, the distance between the stations is 30 km (according to latitude/longitude distance calculator at http://www.nhc.noaa.gov/gccalc.shtml)
Where to get weather data when data from both Yellow Jacket and Dove Creek was missing	Missing data was filled in with data from Yellow Jacket from the previous day when available. When data from the previous day was not available it was filled in with data from the following day.	

[108] Some of the variable names come directly from the IDSCUM software and some of the variable names are reworded to make them easier to understand.
[109] Calculated by dividing 11" of available water capacity by 5' soil depth.

Variable	Value	Reason for Value
Missing weather data from Yellow Jacket was replaced with:	• Day 3 in 1997: maximum temperature was 78.098 degrees F. Replaced it with maximum temperature from the previous day. • Day 116 in 2004: replaced with data from the previous day • Day 115 in 2007: replaced some data with data from the previous day • Day 223 in 2010: replaced some data with data from the previous day • Day 84 in 1994: replaced some data with data from the previous day • Day 216 in 1997: replaced some data with data from the previous day • Day 217 in 1997: replaced some data with data from the following day • Day 238 in 1997: replaced some data with data from the previous day • Day 264 in 1997: replaced some data with data from the previous day • Day 265 in 1997: maximum temperature was 103.73 degrees F. Replaced it with maximum temperature from the following day. • Day 341 in 1997: replaced some data with data from the previous day • Day 342 in 1997: replaced some data with data from the two days previous • Day 343 in 1997: maximum temperature was 95.342 degrees F. Replaced it with maximum temperature from the following day. • Day 346 in 1997: replaced maximum temperature data with data from the previous day • Day 347 in 1997: maximum temperature was 78.278 degrees F. Replaced it with maximum temperature from the following day. • Day 38 in 1998: replaced maximum temperature data with data from the previous day • Day 39 in 1998: replaced data with data from 2 days previous • Day 40 in 1998: replaced data with data from 3 days previous • Day 45 in 1998: replaced data with data from 2 days previous • Day 45 in 1998: replaced data with data from 2 days previous • Day 46 in 1998: replaced data with data from 3 days previous • Day 47 in 1998: replaced data with data from 4 days previous • Day 53 in 1998: replaced data with data from 1 days previous • Day 54 in 1998: replaced data with data from 2 days previous • Day 55 in 1998: replaced data with data from 3 days previous • Day 56 in 1998: replaced data with data from 1 days following • Day 65 in 1998: replaced data with data from 1 days previous • Day 66 in 1998: replaced maximum temperature data with data from 2 days previous • Day 200 in 2001: replaced minimum temperature data with data from 1 days previous • Day 328 in 2006: replaced minimum temperature data with data from 1 days previous • Day 144 in 2008: replaced minimum temperature data with data from 1 days previous • Day 264 in 1997: replaced minimum temperature data with data from 1 days previous • 7/19/2001: replaced with the Dove Creek data. • 4/25/04: replaced with Dove Creek data • 4/25/07: replaced with data from the previous day • 8/11/10: replaced with data from the previous day • 11/24/06: minimum temperature data is incorrect. Left it alone because it is probably close to the correct value. • 5/23/08: minimum temperature data incorrect. Replaced with data from the following day.	
Crop types used	Alfalfa, dry beans, spring grain, grass pasture	Miscellaneous crops were entered as grass pasture in the IDSCUM software
Irrigation water application efficiency	1	Efficiency is assumed to be 85%. IDSCUM software did not calculate inefficiency losses because no water supply data was input into the program. Losses were calculated later in a spreadsheet.
Sprinkler spray loss	No	Efficiency is assumed to be 85%. IDSCUM software did not calculate inefficiency losses because no water supply data was input into the program. Losses were calculated later in a spreadsheet.

Variable	Value	Reason for Value
Flood irrigation	No	
Latitude (degrees)	37.544015878267075	Latitude of Yellow Jacket weather station (From Google maps via http://www.daftlogic.com/sandbox-google-maps-find-altitude.htm)
Elevation (ft)	6967	From Google maps via http://www.daftlogic.com/sandbox-google-maps-find-altitude.htm
Effective precipitation calculation method (max, multiplier, or SCS curve no.)	Multiplier	Program default setting
Effective precipitation calculation multiplier value	0.7	Program default setting
Ignore frost dates when calculating the planting date	No	
Fraction of winter precipitation carry-over	0.5	Template default setting
Fraction of Maximum Allowed Soil Water at the start of simulation	1	This assumes that the water content of the soil within the root zone will be at field capacity at the start of the simulation. This may or may have been true.
User-supplied data represents	Actual crop consumptive use	
Model groundwater upflux	No	
Coefficient values represent Kt * Kc	No	

Table 57. Crop coefficients using a well-watered alfalfa crop to calculate reference ET.

Period (Alfalfa (%))	Alfalfa (Crop Coefficient)
Use GDD	No
Ref Crop	Alfalfa
0	0.55
10	0.70
20	0.82
30	0.91
40	0.96
50	0.99
60	1.00
70	1.00
80	0.98
90	0.96
100	0.94
0	0.30
10	0.40
20	0.50
30	0.80
40	0.96
50	0.99
60	1.00
70	1.00
80	0.98
90	0.96
100	0.94
0	0.30
10	0.40
20	0.50
30	0.60
40	0.65
50	0.63
60	0.61
70	0.59
80	0.57
90	0.55
100	0.50

Table 58. Crop coefficients using a well-watered alfalfa crop to calculate reference ET.

Period (Perennial (Days))	Grass Pasture (Crop Coefficient)
Use GDD	No
Ref Crop	Alfalfa
0	0.60
20	0.70
40	0.78
60	0.78
80	0.78
100	0.78
120	0.78
140	0.78
160	0.78
180	0.76
200	0.74

Table 59. Crop coefficients using a well-watered alfalfa crop to calculate reference ET.

Period (Annual (%))	Spring Grain (Crop Coefficient)	Dry Beans (Crop Coefficient)
Use GDD	No	No
Ref Crop	Alfalfa	Alfalfa
0	0.20	0.20
10	0.20	0.20
20	0.21	0.20
30	0.26	0.26
40	0.39	0.35
50	0.55	0.45
60	0.66	0.55
70	0.78	0.66
80	0.92	0.80
90	1.00	0.90
100	1.00	0.95
0	1.00	0.95
10	1.00	0.95
20	1.00	0.90
30	1.00	0.67
40	0.90	0.33
50	0.50	0.15
60	0.30	0.10
70	0.15	0.05

Period (Annual (%))	Spring Grain (Crop Coefficient)	Dry Beans (Crop Coefficient)
80	0.10	0.00
90	0.00	0.00
100	0.00	0.00

Table 60. Crop characteristics.

Crop Name	Alfalfa	Spring Grain	Dry Beans	Grass Pasture
Crop Type	Alfalfa	Annual	Annual	Perennial
Subcrop Type	<none>	<none>	<none>	Pasture Grass
Initial Root Depth (ft)	5	3	2	2
Max Root Depth (ft)	5	3	2	2
MAD %	55	60	50	50
Planting month	1	1	1	1
Planting day	1	1	1	1
Harvest month	12	12	12	12
Harvest day	31	31	31	31
Planting--full cover	75	45	43	75
Length of season	365	130	100	365
Planting temp (F) >= 0	50	45	60	45
Harvest temp (F) >= 0	28	32	32	45
Spring Frost Method	Monthly Mean Temp	Monthly Mean Temp	Monthly Mean Temp	Monthly Mean Temp
Fall Frost Method	Published 28 Degree Date	Published 32 Degree Date	Published 32 Degree Date	Monthly Mean Temp
Alfalfa second cut	45	NA	NA	NA
Alfalfa third cut	45	NA	NA	NA

2014-2015 Cover Crop Trial

A.F. Berrada and A.Y. Berrada

This trial was conducted in anticipation of a western SARE grant to study the feasibility of cover crops in dryland cropping systems in SW Colorado and SE Utah. The grant was awarded in the spring of 2015 and field testing began in late summer of 2015. The results of this project will be published in a technical bulletin.

The purpose of the 2014 trial was to evaluate the establishment and growth of several species of cover crops in monoculture (single species) or in mixes of two, three or four species.

Methods

The design of the trial was a randomized block with two replications. Plots were 200 ft long by 6 ft wide. Row spacing was 12 inches. The north half of each plot was kept as dryland while the south half was irrigated with a side roll. There was a total of 22 treatments, 10 single species (Table 37) and 12 mixes of the same species.

Single cover crops were planted at the rates listed in Table 37. This is 125% of the planting rates found on the website https://smartmix.greencoverseed.com/ . Seed was ordered from this same website. Cover crops in mixtures were not planted at the full planting rate, but at a rate that decreased proportionally with the number of crops in the mix. For example, in a two crop mix each cover crop was planted at 50% of the planting rate shown in Table 62, in a three crop mix 33% of the full planting rate, etc. Legume crops were inoculated with the appropriate rhizobium to enhance nitrogen fixation.

Table 61. Cover crop information.

Cover crop	Abbreviation	Planting rate (lb/ac)
Flax	FX	27.5
Hairy Vetch	HV	17.5
Nitro Radish	NR	7.5
Rapeseed	RS	5
Red Clover	RC	7.5
Spring Forage Barley	SB	72.5
Spring Forage Peas	SP	53.75
Spring Lentil	SL	16.25
Winfred Hybrid Turnip	WT	7.5
Yellow Sweet Clover	YC	7.5

The trial was planted on April 8 or 9 at a depth of 1.0 to 1.5 inches. Soil moisture at planting was adequate. Irrigation of the south side of the trial was started on May 19 and ended on June 3, 2014. The irrigated portion of the trial received a total of approximately 6.0 inches of water in three applications (irrigation start dates of May 19, June 5, and June 16).

An eight square foot area of the dryland portion of each plot was harvested on June 12 for biomass.

Plants were cut at ground level and weeds were separated out from cover crops and the samples were air-dried indoors. Only the weeds data is shown from this sampling (see Fig. 42). More sampling was done on July 3 (non-irrigated) and July 7 (irrigated) from a 24 square-foot area of each plot. A subsample of each cover crop biomass sample was oven-dried at 65 degrees Celsius for 24 hours to determine plant moisture.

The whole plot area was mowed on July 7 and 8 to control weeds and encourage re-growth. Weedy plots were mowed again on July 25. No re-seeding was done in the summer or fall or 2014 or spring of 2015, except from fallen seeds. No irrigation water was applied either. On June 24, 2015, a 6.0 square feet area of each plot was harvested to determine plant biomass. A subsample was oven-dried at 65 degrees Celsius for 24 hours to determine plant moisture.

Total precipitation (rainfall) from planting in 2014 through harvest on July 7 was 2.66 inches. Spring precipitation was about normal, but June and July were very dry, while August and September had above normal precipitation, followed by a dry or below average fall 2014 and winter 2014-15. Early spring 2015 was dry but May and June had more than three times the normal rainfall while July was about normal. No irrigation water was applied to the south side of the trial after June 3, 2014.

2014 Results

Biomass yields were adjusted to 0% moisture. On the dryland side of the trial yields ranged from 172 lb/ac for a hairy vetch/yellow sweet clover mix and up to 4,057 lb/ac for spring barley (Fig. 35). Pure spring forage barley and mixtures that contained spring forage barley had the highest yield. Where spring forage barley was part of a mixture it tended to dominate the mixture and other crops were sparse and stunted or leggy. This situation could probably be improved by reducing the planting rate of spring forage barley. Single cover crops and cover crop mixtures that included only legumes had the lowest yield, with the exception of spring forage peas. Figure 36 shows a picture of spring forage barley and Figure 37 shows a picture of the hairy vetch/yellow sweet clover mix. The spring forage barley is much taller and has better canopy coverage whereas the plants in the hairy vetch/yellow sweet clover mix are smaller and a lot of bare ground can still be seen between the rows. If the cover crops had been allowed to grow for more time before harvest, the differences in biomass yield probably may not have been as large. However, in a situation where cover crops are grown during part of the fallow period to reduce soil erosion, suppress weeds, fix nitrogen or provide other benefits, terminating the cover crops at the right time and with the right method can be critical to the sustainability of the cropping system that includes cover crops.

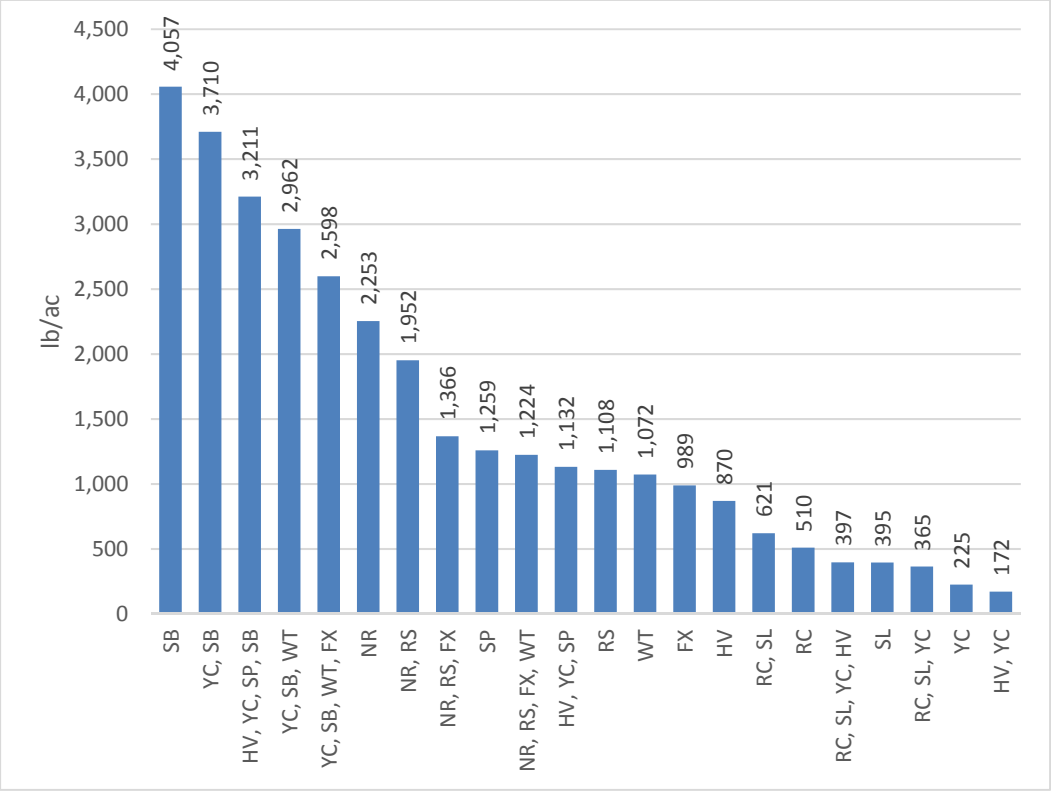


Figure 36. Dryland biomass yield[110] on July 2, 2014.

[110] Adjusted to 0% moisture.

Figure 37. Spring forage barley on June 13, 2014 (dryland).

Figure 38. Hairy vetch and yellow sweet clover mixture on June 13, 2014 (dryland).

Yields on the irrigated side of the trial were higher, but the trends were similar (Fig. 38). Biomass yields ranged from 908 lb/ac for a red clover/spring lentil/yellow sweet clover/hairy vetch mix, up to 8,774 lb/ac for a yellow sweet clover/spring forage barley mix. Figure 39 shows a photo of the

yellow sweet clover/spring forage barley mix. Note that the spring forage barley is dominant, and the yellow sweet clover cannot be seen. Figure 40 shows a photo of the red clover/spring lentil /yellow sweet clover /hairy vetch mix. There is significant weed growth because of the small size and poor canopy coverage of the cover crops.

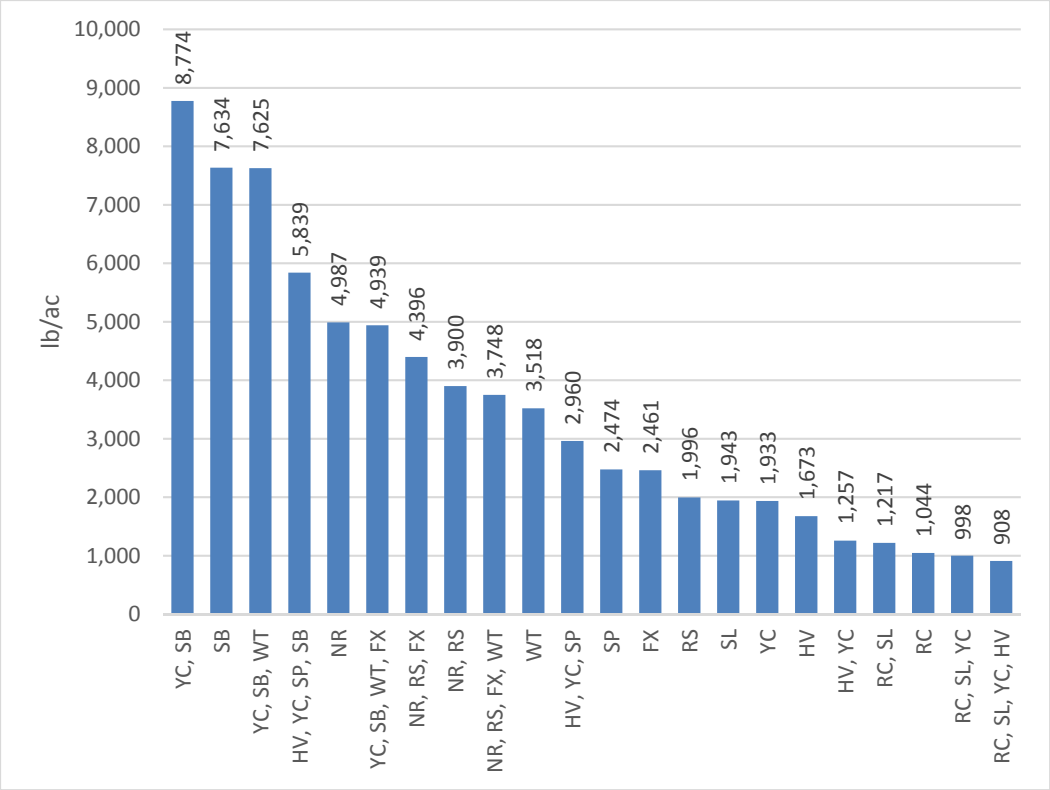


Figure 39. Irrigated biomass yield111 on July 7, 2014.

[111] Adjusted to 0% moisture

Figure 40. Yellow sweet clover and spring forage barley mixture on June 13, 2014 (irrigated).

Figure 41. Red clover, spring lentil, yellow sweet clover, and hairy vetch mixture on June 13, 2014 (irrigated).

Data about the amount of weeds in the dryland side of the trial shows that weeds were not much of a problem for most of the cover crop trial (Fig. 41). Weed biomass as a percentage of total biomass

ranged from 0% for a number of cover crops and cover crop mixes, up to 12% for spring lentils. The cover crops that had lower yields tended to have higher weediness.

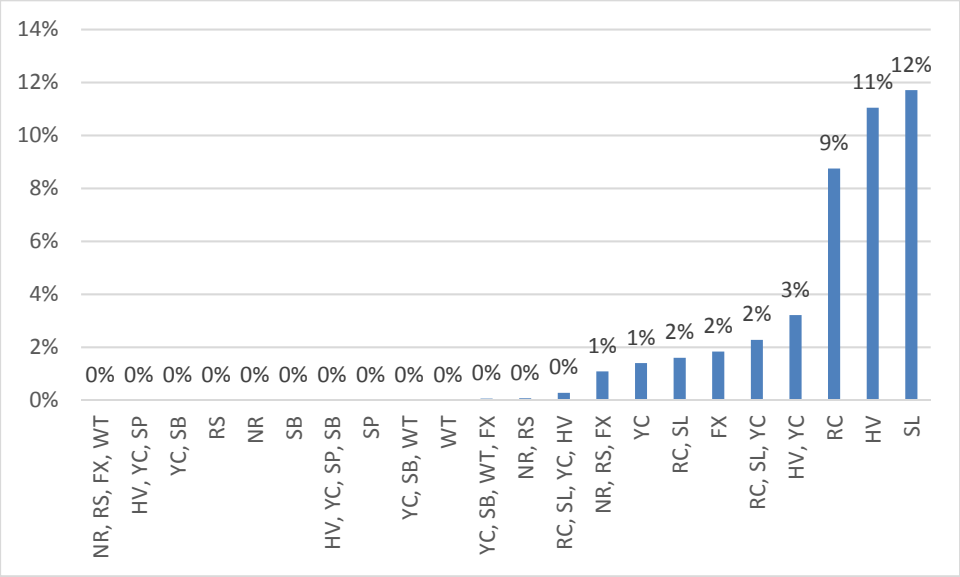
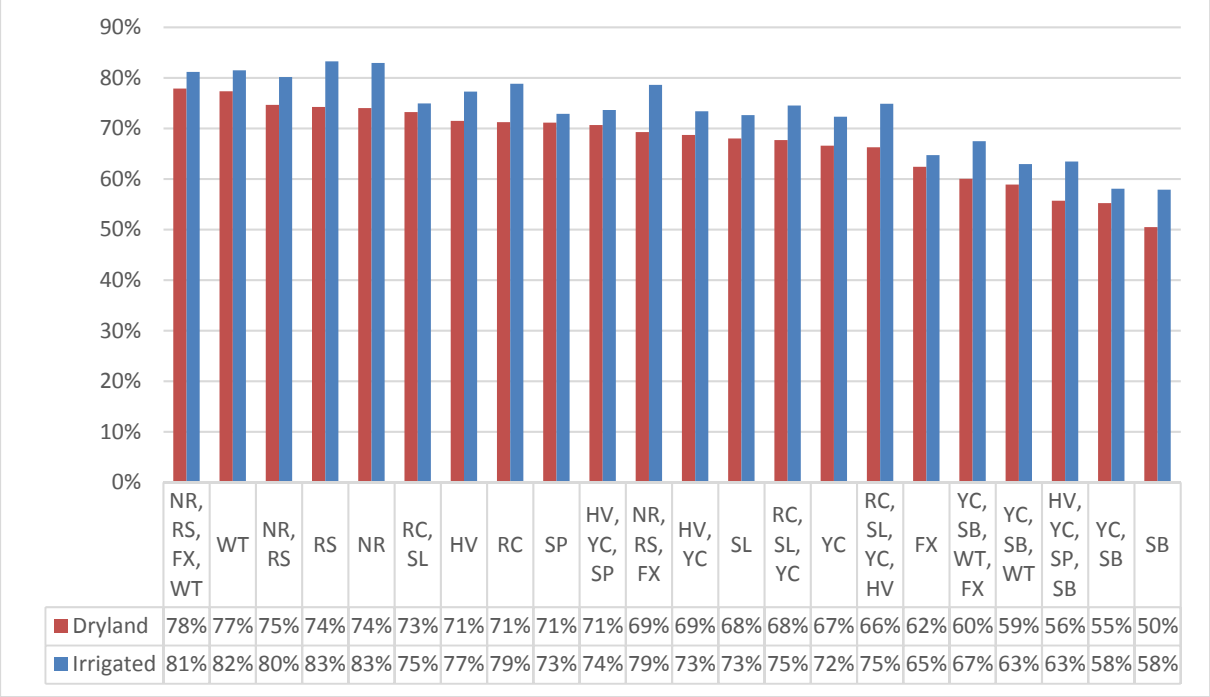


Figure 42. Weeds as a percentage of air-dried biomass on June 12 (dryland side of trial).

Moisture of the harvested biomass samples averaged 68% for the dryland side of the trial and 73% for the irrigated side (Fig. 42). Spring forage barley and yellow clover/spring forage barley had the lowest moisture. On the dryland side the nitro radish/rapeseed/flax/Winfrid hybrid turnip mix had the highest moisture. On the irrigated side rapeseed and nitro radish had the highest moisture.



	NR, RS, FX, WT	WT	NR, RS	RS	NR	RC, SL	HV	RC	SP	HV, YC, SP	NR, RS, FX	HV, YC	SL	RC, SL, YC	YC	RC, SL, YC, HV	FX	YC, SB, WT, FX	YC, SB, WT	HV, YC, SP, SB	YC, SB	SB
Dryland	78%	77%	75%	74%	74%	73%	71%	71%	71%	71%	69%	69%	68%	68%	67%	66%	62%	60%	59%	56%	55%	50%
Irrigated	81%	82%	80%	83%	83%	75%	77%	79%	73%	74%	79%	73%	73%	75%	72%	75%	65%	67%	63%	63%	58%	58%

Figure 43. Moisture of biomass samples harvested on July 2, 2014.

2014-2015 Results Summary

Table 62. Results of the 2014-2015 cover crop trial at the SWCRC.

Cover Crop Mix		2014 Dryland			2014 Irrigated		2015 Dryland	
No.	Species	Weeds (% by Weight)	Moisture (%)	Biomass (lb DM/ac)	Moisture (%)	Biomass (lb DM/ac)	Moisture (%)	Biomass (lb DM/ac)
1	FX	1.8	62.4	988.7	64.7	2461.1	41.8	1790.0
2	WT	0.0	77.3	1072	81.5	3518.2	74.5	4054.0
3	SL	11.7	68.0	394.8	72.6	1942.7	51.7	1995.0
4	SP	0.0	71.1	1258.6	72.9	2473.6	64.3	3301.0
5	YC	1.4	66.6	225.4	72.3	1933.2	40.4	7157.0
6	RC	8.8	71.2	510.3	78.8	1044.1	17.0	4026.0
7	HV	11.0	71.5	869.8	77.3	1673.5	32.9	7884.0
8	NR	0.0	74.0	2253.2	83.0	4986.9	48.0	2566.0
9	RS	0.0	74.2	1107.7	83.3	1995.6	65.5	9121.0
10	SB	0.0	50.5	4057.1	57.9	7633.6	41.5	2180.0
11	YC, SB, WT, FX	0.1	60.0	2598.2	67.5	4938.5	46.3	6174.0
12	YC, SB, WT	0.0	58.9	2962.3	62.9	7624.8	39.3	10628.0
13	YC, SB	0.0	55.2	3709.9	58.1	8774.1	44.4	5419.0
14	NR, RS, FX, WT	0.0	77.9	1223.7	81.2	3747.6	69.1	3520.0
15	NR, RS, FX	1.1	69.3	1366.4	78.6	4396.5	60.3	8028.0
16	NR, RS	0.1	74.7	1951.6	80.2	3899.8	61.2	8828.0
17	RC, SL, YC, HV	0.3	66.3	396.6	74.9	908.4	39.2	5895.0
18	RC, SL, YC	2.3	67.7	364.9	74.5	997.7	37.4	7290.0
19	RC, SL	1.6	73.2	621	75.0	1217.4	22.4	4820.0
20	HV, YC, SP, SB	0.0	55.7	3211	63.4	5839	37.5	4118.0
21	HV, YC, SP	0.0	70.7	1132.1	73.6	2959.8	35.2	4457.0
22	HV, YC	3.2	68.7	171.7	73.4	1256.9	34.6	5603.0

Cover Crop Mix		2014 Dryland			2014 Irrigated		2015 Dryland	
No.	Species	Weeds (% by Weight)	Moisture (%)	Biomass (lb DM/ac)	Moisture (%)	Biomass (lb DM/ac)	Moisture (%)	Biomass (lb DM/ac)
Average		2.0	67.5	1474.9	73.1	3464.7	45.6	5402.5
$LSD_{0.05}$		NA	7.0	660.0	4.8	1680.2	16.5	4415.4
Pr > F		0.084	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.075
CV (%)		191	5.0	21.5	3.5	23.2	17.3	47.5

Weed infestation in 2014 was low but highly variable. Spring lentil (SL), hairy vetch (HV), and red clover (RC) had the most weeds by weight (9-12%), followed by 'hairy vetch +yellow sweet clover (YC)' and 'RC+SL+YC' (2-3%). All the other treatments had less than 2% weeds by weight (Table 63). Cover crop moisture content averaged 67.5% in 2014 with no supplemental irrigation and 73.1% with irrigation. In general, spring forage barley (SB) in monoculture or in mixture had the lowest water content at termination. Brassicas had some of the highest water content in monoculture [Winfred hybrid turnip (WT), Nitro radish (NR), rapeseed (RS)] or in mixture (NR and RS). Cover crop biomass averaged 1475 lb DM/ac with no irrigation and 3465 lb DM/ac with supplemental irrigation. Spring barley and 'SB + YC' had the highest biomass with no irrigation, followed by the other mixtures that included SB. The legumes YC, SL, and RC produced the lowest biomass in monoculture or in mixture with other legumes, except SP. HV averaged 870 lb/ac and significantly less when mixed with YC (172 lb/ac) and less than half when mixed with RC, SL, and YC. With supplemental irrigation, SB in monoculture or in mixture with YC or YC plus WT produced significantly more biomass (7625 to 8774 lb/ac) than the other treatments. The other two mixtures that included SB and NR produced 4939 to 5839 lb/ac. Red clover and mixtures than included RC, HV, SL or YC produced the lowest biomass (908 to 1217 lb/ac). Hairy vetch performed similarly to RC but significantly less than WT.

The 2015 results are not very useful in the context of dryland cropping systems in SW Colorado but may give an indication of the adaptability of certain cover crop species. Flax (FX), SL, SB, and NR did poorly, followed by spring forage peas (SP). Flax and SL were almost absent in the mixtures where they were included in 2014. In the mixtures that included YC, YC was the dominant species. The same was true for RS or WT when YC was not included in the mixture. Rapeseed (RS), HV, and YC produced much more biomass in 2015 than in 2014, with or without irrigation. This may be because the varieties planted in 2014 were winter hardy, but may also reflect the amount of seeds produced in 2014 that were viable in 2015 or that YC may be a biennial. Moreover, some of the seeds that did not germinate in 2014 may have germinated in 2015. With a few exceptions (FX, NR, SB, 'YC+SB'), plant biomass was similar or higher in 2015 than in 2014 with supplemental irrigation. Spring barely and some of the other spring species did not do as well as in 2015 due to winter kill, poor stand, etc.

A potential application from the 2015 results is to plant biennial yellow sweet clover in fallow ground in early spring, mow it in late spring-early summer before it goes to seed, plant winter wheat into it by mid to late September, and terminate it in the spring of the following year with 2,4-D or the like. A similar recommendation can be made for other winter hardy legumes (e.g. HV or RC) or brassicas (e.g. RS or WT) but they should not be mowed in Year 1 until after they produce viable seeds, which should occur in our environment by mid-July depending on the species. This recommendation could lead to a significant amount of plant biomass & residue with minimal input and would ultimately result in increased soil health and reduced erosion, but this would only be viable with NT management and may affect soil water and nutrient availability and the cash crop yield.

The Feasibility of Cover Crops in Dryland Cropping Systems in SW Colorado and SE Utah

A.F. Berrada and C. Roseberry[112]

2015-2018 Results Summary[113]

Our long-term goal is to enhance the sustainability of dryland cropping systems in SW Colorado and SE Utah by growing cover crops during the fallow period between two cash crops. Our objectives are to: 1) evaluate the performance of several cover crop mixtures (CCMs); 2) assess the impacts of cover crops on soil health and quality, soil moisture, cash crop, and profitability; and 3) disseminate project results and contribute to improved soil health management in the region. To date, we conducted 10 field trials and tested 19 CCMs. These trials encompassed two crop rotations (winter wheat-fallow and winter wheat-safflower-fallow), two tillage practices (conventional tillage and no-till), and conventional and organic crop production. CCMs were planted in late summer or in the spring and consisted of three to ten species of legumes, grasses, brassicas, and other plants. Two of the three growing seasons had below average precipitation. The 2017-2018 season was especially dry (42% of normal) and resulted in crop failure at six of the nine sites that had a cover or cash crop. Hence, the results are not conclusive yet, but some trends have emerged.

Late summer-planted cover crops produced significantly more biomass than the spring-planted ones. However, in general, the greater the biomass, the less soil moisture and soil NO_3-N was available to the cash crop. Moreover, when cover crops were planted too early after wheat harvest, volunteer wheat tended to dominate plant canopy and biomass. This can be mitigated somewhat with no-till and timely rainfall, and by minimizing wheat harvest losses. Some cover crop species performed poorly (e.g. teff, flax, sunn hemp, balansa clover) and the notion that the more species (i.e., greater diversity) in the mix, the better may not hold true in the project area due primarily to water limitations. Hence, the climate in the region (semi-arid with short growing season), in addition to seed cost and proper management (i.e., planting date, seeding depth, inoculation) are key considerations for developing high performance cover crop mixtures. Winter wheat yields were lower following cover crops than after fallow and this is likely due to temporary immobilization of soil nitrogen and reduced soil moisture at planting. No fertilizer was applied to the wheat crop and this will be reconsidered moving forward. Input costs were higher and the returns were lower for the cover crop treatments, but with continued management refinements and the expected benefits (e.g., reduced soil erosion and improved soil health and quality) from cover crops, the costs will go down in the medium- to long-term. Further testing and analysis will be done in 2018-2021 thanks to continued funding by Western SARE–Project SW18-500.

Project concepts and highlights were presented at multiple events (http://drylandcovercrops.agsci.colostate.edu). Attendance to the outreach events was generally good. This and other indicators bode well for the adoption of cover crops and other soil health improvement practices in the region.

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[112]Former Project Coordinator & Field Technician, Research Associate.

[113] Detailed results for 2015-2016 and 2016-2017 were published in CSU-AES Technical Bulletin TB18-1.

Dryland Crop Rotation Trial: 2014-2015 Results

Investigators: A.F. Berrada, K.D. Dillivan[114], and R.W. Hammon[115]

Objective and Methodology

The objective of this study for 2014 was to determine crop yield and estimate profit for each crop and each crop rotation.

The following crop rotations were tested:

1. Winter Wheat-Fallow (WW-FW)
2. Winter Wheat-Safflower-Fallow (WW-SA-FW)
3. Winter Wheat-Sunflower-Fallow (WW-SU-FW)
4. Winter Wheat-Dry Bean-Sunflower-Fallow (WW-DB-SU-FW)
5. Winter Wheat-Dry Bean-Dry Bean-Fallow (WW-DB-DB-FW)
6. Winter Wheat-Opportunity Crop-Sunflower-Fallow (WW-OP-SU-FW). The opportunity crop was camelina in 2010 and 2011 and corn in 2012-2014.

The experiment was located at the Southwestern Colorado Research Center in Yellow Jacket, CO. It was started in the spring of 2010. The 2010 results are not included in this summary since the site was irrigated for approximately 20 years before it was converted to dryland in the summer of 2009.

The trial was designed with three replications and 20 plots in each replication. Each plot was about 170 ft long by 30 ft wide. A representative portion of each plot was harvested. Planting dates and other information for each crop is shown in Table 31.

[114] Former Director of Extension in Dolores County, CO.
[115] Extension Agent, Entomology, Tri River Extension, Grand Junction, CO

Table 63. Crop information.

Crop	Planting Date	Planting Rate	Row spacing (ft)	Herbicide on April 17	Herbicide on June 4	Comments
Corn for Forage	May 30	22,009 seeds/ac	2.5		Roundup PowerMax @ 40 oz/ac	Variety was DKC 43-10
Dry Bean	June 4	23,232 seeds/ac	2.5	Treflan @ 1.5 pt/ac		Variety was Cahone
Fallow					Roundup PowerMax @ 40 oz/ac	
Safflower	April 15	24 lb/ac	1			
Sunflower	June 2	17,294 seeds/ac	2.5	Treflan @ 1.5 pt/ac	Roundup PowerMax @ 40 oz/ac	Variety was Triumph 657
Winter Wheat	October 2, 2013	60 lb/ac	1			

Most of the cost estimates are from a report called "Custom Rates for Colorado Farms & Ranches in 2012"[116] and the cost that was used is the average of the low and high costs for the Western Region. Cost categories are based on a table that was published on the internet[117] that lists the production costs and returns of dryland sunflower in northeastern Colorado. Most of the costs are based on actual field operations such as plowing, planting, etc. However, some of the costs are hypothetical such as "General Farm Overhead" and "Real Estate Taxes". Most crop value estimates come from a report called "Crop Values 2012 Summary"[118]. The report contains crop values for several years, but for this experiment values from the year 2012 are used. The value of corn for forage is estimated based on an article titled "Estimating a Value for Corn Stover"[119]. An example of income ('money in") and cost ('money out') estimates is shown in Table 65. Profit or loss estimates for all the crops is shown in Table 45. No government subsidies were included in these estimates.

Results

[116] http://www.coopext.colostate.edu/ABM/custrates12.pdf
[117] http://www.coopext.colostate.edu/abm/nedrysunoil12.pdf
[118] http://usda.mannlib.cornell.edu/usda/nass/CropValuSu//2010s/2013/CropValuSu-02-15-2013.pdf
[119] http://www.extension.iastate.edu/agdm/crops/html/a1-70.html

Table 64. Income and cost estimates for winter wheat in 2013-2014.

Winter Wheat - 09/01/2013 to 09/01/2014

Selected Accounts

- *Winter Wheat*

Money into selected accounts comes from	
Crop Sales	$196.53
Money In	**$196.53**
Money out of selected accounts goes to	
Cultivating	$22.50
Harvest	$25.00
Pesticides	$17.95
Planting	$12.50
Plowing	$22.50
Seed	$7.50
General Farm Overhead	$10.00
Hauling	$6.04
Labor	$13.55
Real Estate Taxes	$1.25
Money Out	**$138.79**
Difference	**$57.74**

The only profitable crop in 2014 was winter wheat (Table 66); all the other crops were estimated to have lost money. The main issue in 2014 was damage caused by birds. Sunflower, safflower, and corn were all severely damaged by birds (black birds, finches, ravens, magpies). The sunflower wasn't harvested because of the damage. The corn was harvested for its forage value because the corn ears were eaten by birds. Another reason for reduced yields was below average precipitation.

Table 65. Yield by crop in 2014.

Crop	Estimated Profit ($/ac/year)	Yield[120] (lb/ac)	Standard Moisture (%)	Test Weight (lb/bu)
Winter Wheat	$57.74	1,541	12	54.7
Dry Bean	-$0.44	453	14	55.8
Corn for Forage	-$127.41	2,087	10	NA
Sunflower	-$137.82	0	10	NA
Fallow	-$150.87	0	10	NA
Safflower	-$166.13	14	9	32.1
Average	-$63.35	635	11	52.8

None of the crop rotations were profitable in 2014 (Table 67). Between 2011 and 2014 (4 years) the only crop rotation that did not show a loss was WW-FW.

Winter wheat had an average protein content of 16.3% when adjusted to standard grain moisture of 12%.

Table 66. Estimated profit by crop rotation.

Crop rotation	Estimated profit in 2014 ($/ac/year)	Estimated annual profit 2011-2014 ($/ac)
WW-FW	-$36.26	$0.68
WW-SU-FW	-$92.02	-$5.36
WW-SA-FW	-$93.72	-$9.35
WW-DB-SU-FW	-$56.47	-$11.33
WW-DB-DB-FW	-$10.08	-$12.96
WW-OP-SU-FW	-$92.79	-$15.89
Average	-$63.35	-$10.17

[120] Adjusted to standard moisture.

Fairview winter wheat was planted on September 18, 2014. No spring crops were planted in 2015 after it was decided to terminate this trial. The intended seeding rate of winter wheat was 50 lb/acre but the actual rate was approximately 78 lb/acre due of an error in adjusting the drill to the right setting. Wheat was harvested on July 28, 2015. It averaged 2524 lb/acre or 42.1 bu/acre, which was much higher than in 2013-2014 and may have been due to above normal precipitation in May through July 2015, combined with the higher than normal (50-60) seeding rate. Consequently, gross income (Money in) was $321.80 and expenses (Money out) were $114.57, resulting in an estimated profit of $207.23.

Yellow Jacket Fruit Tree Demonstration Project: 2017 Report

Gus Westerman, Colorado State University Extension, Dolores County Director
Tom Hooten, Colorado State University Extension, Montezuma County Director
Abdel Berrada, Colorado State University Southwestern Colorado Research Center Manager

Figure 45. AmeriCorps volunteers assist with the 2017 Tree Planting Workshop held in April.

(One hundred rare and endangered apple trees were provided by the Montezuma Orchard Restoration Project were planted in 2017.)

Project Background

The Fruit Tree Demonstration Project was implemented in April 1991, and is a cooperative effort among Montezuma County Extension, Dolores County Extension, Natural Resources and Conservation Service in Dolores County, and the Colorado State University Southwest Colorado Research Center at Yellow Jacket, Colorado. The completion of the Dolores Irrigation Project resulted in a substantial number of new client requests for local research-based information/data on fruit tree and vineyard varieties, equipment usage, and cultural practices. Prior to this project, all fruit tree information originated from the Grand Junction area Experiment Stations which have a considerably different growing environment. Presently, the Team is evaluating 70 different fruit tree varieties including 21 field apples, 38 trellised apple varieties, 2 apple varieties

planted in a "super high density," 5 peach varieties, 4 pear varieties, and 3 plum varieties. The Team is also studying 1 raspberry variety, and 14 grass varieties. The only remaining original grape variety is Lemberger. Interest has been expressed in planting modern hybrid grapes to evaluate performance however this has not been undertaken as the focus has shifted to heritage varieties and varieties conducive for cider production. In 2017 the High-Altitude Fruit Tree Project partnered with the Montezuma Orchard Restoration Project or MORP. MORP has been working to locate, identify, and propagate rare and endangered heritage apple varieties in the Four Corners Region. In 2017 26 varieties with a total of 100 trees, procured from MORP were planted on heavily dwarf rootstock continuing the high-density trellised planting. The goal is to study how these varieties perform on modern rootstock and in a modern commercial setting. The High-Altitude Fruit Tree Project will trial these varieties in a modern commercial setting and evaluate their performance. In the spring of 2018 100 more trees from MORP will be planted. These will include both trellised dwarf trees and full-size field trees. The focus for this planting is on the newly emerging cider market in the Four Corners Region.

Orchard management practices such as irrigation techniques, frost and freeze management, high-density apple planting, trellised apple planting, fruit thinning, tree pruning, and integrated pest (insect, disease, weed, and wildlife) management have been tested and demonstrated. Thirteen grass species or varieties and one legume were planted between fruit tree and grape rows in 1993 and 1995 to control soil erosion and suppress weeds. A popular fruit tree pruning workshop is held every year. The proceeds from the sale of the fruit during an annual "U-Pick" help fund the operation of the orchard. The annual "U-Pick" attracts hundreds of people and is also used as an educational opportunity to inform the public of different fruit varieties and their uses, fruit processing and preservation, as well as proper long-term storage of fruit. The fruit tree demonstration project is managed by the Extension personnel of Dolores and Montezuma Counties. It has generated considerable interest and attracts a large number of visitors throughout the year, including students from Fort Lewis College in Durango and San Juan College in New Mexico, elementary students and teachers from area elementary schools, and visitors from the Ute Mountain Ute Senior Center. Volunteer labor, which is essential, from the Master Gardener Program was very limited in 2017. Dolores County furnished a seasonal employee to work 20 hours per week during the summer months to offset the lack of volunteers. Dolores County Extension office staff also spent considerable time assisting with the project over the season.

Highlights of the 2017 Season

In 2017 100 trees procured from the Montezuma Orchard Restoration Project were planted in a high-density trellised setting. This allowed a tree planting workshop and a grafting workshop to be conducted to expand the educational opportunities the project provides. A 10-person AmeriCorps crew assisted in planting these trees. 4 trees were lost giving a 96% survival rate as of November 2017. The crop loss presented an opportunity to remove 12 large field trees to make room for new varieties. The removed trees include 5 Golden Delicious, 3 Cameo, and 3 Scarlet Gala. These were removed because the project has an abundance of Golden Delicious and Scarlet Gala, and the Cameos were getting very large and difficult to manage. 2 Cameos remain in the project. The 2017 season was a poor year for fruit production in SW Colorado with the total fruit production of 85 lb. for the 3-acre project. Due to winter snow, pruning operations began the 1st week of February and were completed the second week of March. Prunings were cleared by the 2nd week in April. A dormant oil and micronutrient application was not conducted in 2017 due to lack of an appropriate frost-free period before bud break. The 2017 spring was

warm early on which allowed the trees to break dormancy in mid-March. Early varieties of peaches, pears, and plums bloomed in the first week of April. Full bloom on most varieties hit the second and third weeks of April. By mid-May natural thinning had occurred rendering a nice fruit set allowing for limited chemical thinning of all apple varieties which was planned to take place. The morning of May 19th showed a low temperature of 25.8 degrees Fahrenheit causing nearly 100% loss of the fruit crop.

From May 19th on there was no crop to manage. No insect or bird control was conducted. Weed management was accomplished through timely application of glyphosate and was very successful. Outbreaks of powdery mildew began as soon as temperatures came up in June and were managed throughout the season with timely fungicide applications. Bayleton and Topsin fungicides were alternated to combat chemical resistance. There are dire concerns as we move into the late fall.

Temperatures have been unseasonably warm for the fall of 2017. Blooms were observed on several apple varieties during the 3rd week in November along with significant bud swell on many apple trees. The trees are observed to be breaking dormancy severely reducing cold hardiness. Tree damage is expected from freezing temperatures and will be assessed in the spring of 2018. Workshops for the 2017 season include the Pruning Workshop, Grafting Workshop, and Tree Planting Workshop.

Variety Testing Results to Date

Apples – The 2017 crop was non-existent due to the freeze on May 19th. Sporadic production was observed from the Nured Jonathan rendering approximately 15 pounds of fruit from the 10 trees. The apples have performed exceptionally well since they began producing. With the exception of 7 seasons (freezing temperatures in 2001, 2014, 2015, and 2017; hail in 1995, 2003, 2004, and 2015), the orchard has experienced consistent production. Even with the hail damage in 2004, over 7,000 pounds of fruit was sold. Tree losses included 8 trees out of 226 planted, with 3 of those lost as the result of severe trunk damage due to excessive crop overload. Of the 2017 planting 3 trees were lost to pocket gopher damage and 1 to an unidentified canker. Ten trees were lost in the trellis due to herbicide drift in 2010. They were replaced in 2011 with Improved Golden Delicious and four new varieties: Scarlet Spur, Spartan, Ruby Mac, and Schlect Spur which have come into production and are producing well. With the exception of varieties on the wrong rootstock for field or trellis applications, additional varieties that are questionable for our area include Honey Crisp, Improved Red Delicious, and possibly Idared. The Nured Jonathan was the only variety that showed any consistent production in 2017.

Peaches – The 2017 season was non-existent due to frost with no production from the 5 current varieties. A much different situation exists here when compared with the apples. Virtually all of the plantings (old and new) have suffered 50% tree losses within the first year. This is attributed in part to a late planting date for peaches and the possibility that planted trees were of too large a diameter with a limited root system. The peach trees arrived partially leafed out, and when this is compounded with tree transplant shock, early tree death is inevitable. The first 2 varieties planted in 1991, Redskin and J.H. Hale, have been eliminated with one crop in seven years and significant yearly die-back. Four new varieties have been added: Flamin'Fury PF#15A, Starfire FA11, Suncrest, and Red Globe which seem to have more promise. The severe hail of 2004 damaged the upper surface of branches that led to infection with perennial canker. Many of the peach trees exhibit gradual decline and branch death since then. Perennial canker continued to develop in 2014 leading to infection and death of larger branches and persisted in 2017.

Pears – The 2017 pear crop was poor due to frost with 30 pounds from the 4 current varieties. The four varieties planted; Max Red Bartlet, Du Comice, D'Anjou, and Bronze Beauty have all developed well with minor problems. They do require considerable limb training and are highly susceptible to the pear slug and pear psylla. A small outbreak of Fire Blight occurred in 2007, but immediate action of pruning out the infected wood, complete cleanup of leaves and debris and several applications of Streptomycin have apparently taken care of the problem for now. No evidence of the disease has been observed to date (2016). Pears take time to produce with the Max Red and Du Comice (planted in 1996) producing their first crop in 2001. All trees are now in production and have produced generously with the exception of 2013 and Bronze Beauty in 2014. Production was low for unknown reasons.

Plums – The 2017 plum crop was poor due to frost with 40 pounds from the current 3 varieties. Production was consistent across the three varieties however the fruit on the President trees did not reach an edible state until after our harvests were complete. Three varieties of plum on Myro rootstocks (Empress, Improved Duarte, and President) were planted in 2008 in three row-groups of five trees each. Initial growth was very good. However, in 2010 President suffered significant die-back to the main scaffold limbs due to freezing temperatures. The damaged trees required substantial reconstructive pruning. Recovery has been very good. Observations will continue. The first significant crop of 1,000 lb. was produced in 2012. Production was 2,000 lb. in 2013 and only 500 lb. in 2014. 2015 production was almost non-excitant due to spring frosts during bloom.

Grapes - Of the original 8 varieties planted in 1994, Seyval Blanc, Pinot Noir, and White Riesling were removed in 1998. These varieties require a longer growing season than what is "normal" for the location of the vineyard. In their place, Cayuga White, DeChaunac, Edelweiss, and Chardonel were planted in 1999. The performance of these four varieties has been extremely disappointing. The year 2001 was the third growing season and the vines have not performed any better. The reason for this poor performance is baffling as these vines received the same treatment as the more mature plantings. In 2000, there was a 100% infestation of crown gall in the Foch, Gewurztraminer, Merlot, and Chardonnay vines. When the infestation of 2000 occurred in all of the 4 above named varieties, they were removed.

The only remaining original planting is Lemberger. This red variety has produced crops from the third season until present. Shoot thinning and cluster removal prior to veraison are methods used to promote fruit development and maturation. This is continuing, though labor for the tasks is limited. Discussion has occurred regarding elimination of the grape trial due to poor performance.

Grasses - Thirteen different grasses along with one legume were planted between the fruit tree rows in the demonstration orchard between April 1993 and November 1995 to evaluate their erosion control potential. These were dryland plantings with no supplemental water given. Lovington blue grama, Canbar canby bluegrass, birdsfoot trefoil/Ephraim crested wheatgrass mix, and Topgun buffalograss have been judged unsuitable for erosion control.

Irrigation

The team is currently evaluating a variety of irrigation systems including various types of drip emitters, several types of maxi and mini sprinklers, pulsators, and surface drip tubing. We currently use a 50- mesh filtration system due to very good irrigation water quality. Plugging of the filter screens has not been a problem, though they do need occasional cleaning. Our only significant problem has been with the maxi and mini sprinklers that have moving parts. A slight buildup of calcium carbonate causes the spinners to jam and spray only in one direction. These were removed and replaced with static sprinkler heads with a 360-degree spray pattern. Another issue recently emerged as ground squirrels took up residence near the orchard. Their persistent damage to the irrigation systems has increased the labor for maintenance.

Additional Investigations

Work continues on frost protection management for the fruit trees and grapes, bird control, and integrated pest management of insects and diseases. Workshops on pruning and fruit management are conducted every year in cooperation with the Colorado Master Gardener program. Volunteers from the program are instrumental in maintaining the viability of the orchard project. Volunteer labor from the Master Gardener Program was very limited in 2017.

Strong emphasis continues to be placed on demonstrating, evaluating, and testing varieties, irrigation equipment, orchard equipment, and cultural practices that are cost effective, user friendly, and available through local suppliers.

The team continues to investigate marketing opportunities as well as “Home-Based Business” opportunities as they relate to fruit and vineyard product utilization, i.e. fruit by-products. In addition, there has recently been interest from landowners to begin to rejuvenate some of the old, neglected apple orchards in Montezuma County. This may be due to the surging interest in local food production that has been burgeoning in SW Colorado over the last several years. Another result of this growing interest is the creation of the non-profit Montezuma Orchard Restoration Project (MORP). One activity of MORP is the grafting of historic, heritage apple varieties found in SW Colorado onto modern rootstocks to preserve the variety in a cultural setting. Some of these heritage varieties were planted at the Extension Fruit Tree Project at the SWCRC in the spring of 2017 as well as some classical cider apple varieties. The Fruit Tree and Vineyard Research and Demonstration Project will continue to attract interest and visitors as it remains relevant to the needs of the stakeholders in Southwest Colorado.