Technical Report TR16-07

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Colorado State University

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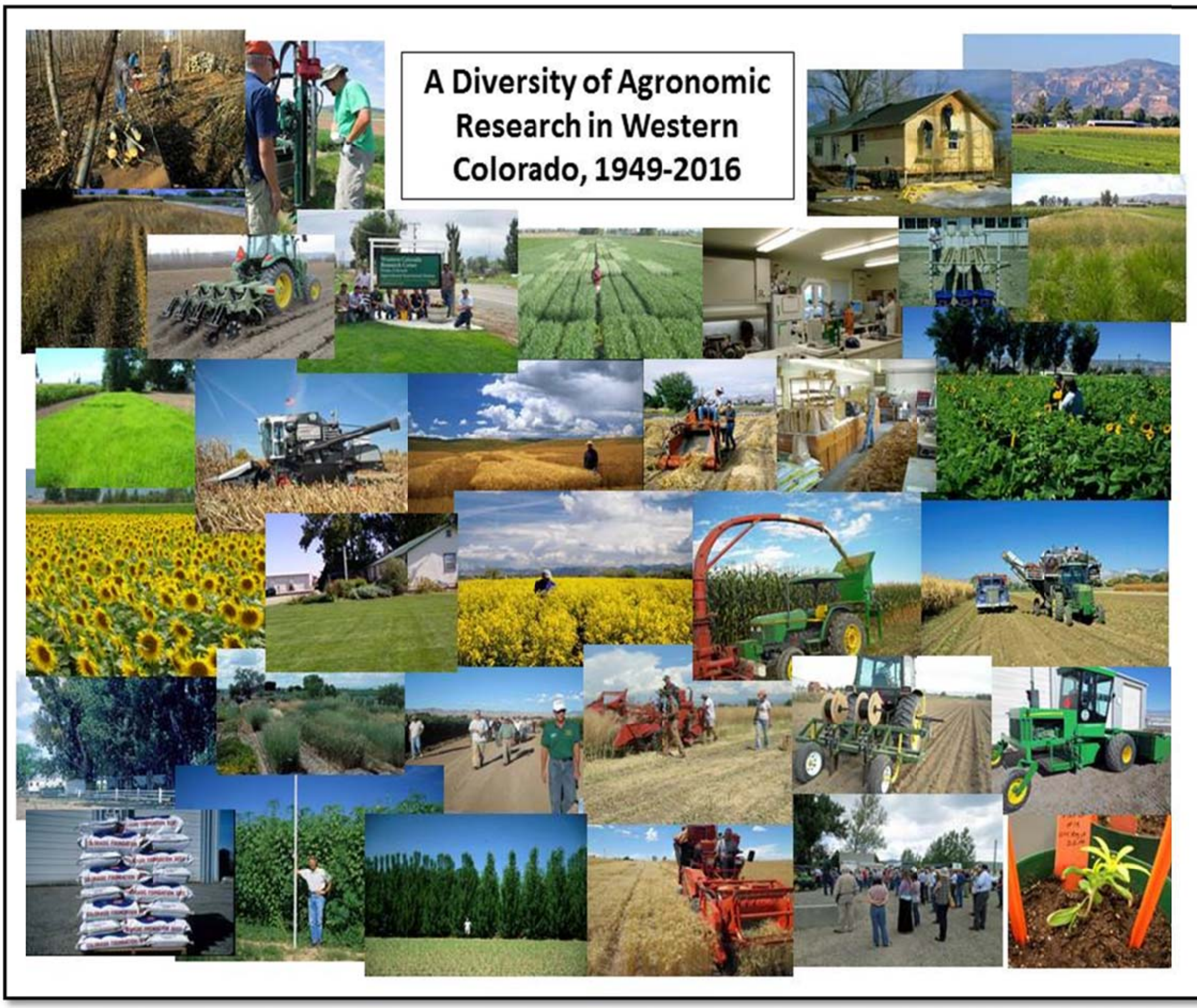

Cover photo: Collage of research and related activities conducted over the years at the Western Colorado Research Center at Fruita. Photos by Calvin H. Pearson.

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A Diversity of Agronomic Research in Western Colorado, 1949-2016

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A DIVERSITY OF AGRONOMIC RESEARCH IN WESTERN COLORADO, 1949-2016

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INTRODUCTION

There are more than 600 main experiment stations and branch stations that dot the landscape across the United States (Pearson and Amaya, 2015). Branch stations can be found in a variety of sizes, capabilities, and managements with each one seeking to serve the site-specific needs of the region in which they are located. As a part of the land-grant university system and in association with agricultural experiment stations, branch stations are a valuable national resource given the research, outreach, and technological contributions developed at them.

In Colorado, branch stations are referred to as "research centers." One of the seven research centers located in Colorado is the Colorado State University, Western Colorado Research Center (WCRC). It is comprised of two sister stations- one in Grand Junction on Orchard Mesa and one near Fruita. Research centers in Colorado including WCRC are operated under the direction of the Colorado Agricultural Experiment Station. Research centers around the country are typically located in agricultural regions of the state and conduct agricultural research on topics and issues that are of interest and value to the region where they are located.

Researchers at WCRC conduct research in the western region of Colorado. This region of Colorado consists of 14 counties in northwest and west central Colorado with a land area of nearly 20 million acres, representing almost 30% of the total land area of the state.

The agriculture in these 14 counties varies considerably in the type of agriculture that occurs in each county by the amount and kind of cropland and whether the land is used to produce crops and/or livestock. In total, this region of the state contains a large amount of land used for agriculture and the 2012 market value of the agricultural products in this region exceeds $410 million annually (USDA-NASS, 2012).

The western region of Colorado is unique in geographic location and in agricultural production systems with associated opportunities, challenges, constraints, and limitations. High water alkalinity, desert vegetation, heavy soils, variable precipitation, seasonal water availability, and frost/freeze injury are a just a few of the challenges producers face in western Colorado. In some areas of western Colorado such as the Craig/Hayden area, producers are mainly limited to wheat and forages. These limited cropping options are mainly a function of the local climate given the short growing season with much of the cropland being dryland with low, sporadic precipitation of varying intensity. Furthermore, producers in the Craig/Hayden area and in other locations in the region are isolated from many of their markets.

When viewed as a region, there is a large diversity of crops grown in western Colorado given the various geophysical and climatic conditions. Throughout the region there is a

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wide range of agronomic crops along with a range of vegetable and fruit crops grown in specific locations in the region.

Traditional farming continues to come under pressure from population growth, urbanization, rural subdivisions, recreation, endangered species, and energy exploration that encroaches on and impacts agriculture. Thus, WCRC has a major role to play in developing and delivering agricultural production technology to address these challenges and create alternative/new options and opportunities for western Colorado agriculture.

The number of farmers in the country including western Colorado that rely solely on agriculture for their livelihood continues to decrease. While it is difficult to predict changes as a result of external changes that apply pressure on agriculture, growers will need to continue to develop new and alternative agricultural practices and operations that result in increased net farm income to keep farming operations profitable.

The WCRC-Fruita office and headquarters are located in the Grand Valley of Mesa County, two miles northeast of the City of Fruita, Colorado. At an elevation of approximately 4500 feet, the area receives from 8 to 12 inches of annual precipitation with an annual frost-free season of approximately 180 days. Many soils in the area formed in residuum were weathered from sandstone or shale. Some soils formed in alluvium were derived from sandstone and shale deposited in the major valleys and on bordering uplands.

The mountains and valleys of western Colorado create unique environments that permit farming in many locations. Because of the unique conditions in these locations, farming practices must be suited to these environments. Site- and situation-specific agronomic research is essential to develop local adapted technologies that are appropriate for these unique environments. The mission of the Colorado Agricultural Experiment Station is to focus and support research leading to an agriculture that is economically viable, environmentally sustainable, and socially acceptable. The central focus of the historic research conducted at WCRC-Fruita is to plan, implement, and conduct agronomic research programs that address the broad needs of agriculture in western Colorado.

Personnel at research centers have specific expertise and experience that are valuable for conducting agricultural research. Personnel at WCRC-Fruita conduct agronomic and related research throughout west central and northwest Colorado. Research results are intended for clientele in this region; however, research findings may be applicable to other regions, states, and countries.

Personnel at WCRC-Fruita, along with support from local governments, agencies, private companies, and other assorted organizations have sought to be responsive to the agricultural needs in the region by conducting agronomic research that provides answers to related problems and identifies new opportunities for growers, while at the same time seeking to develop and support a sustainable agriculture (Pearson and Larsen, 2008).

HISTORY OF AGRONOMIC RESEARCH IN WESTERN COLORADO

Documented histories provide a record of activities over time and are intended to provide readers with an understanding and appreciation for developments and changes that brought us to the present. Furthermore, histories provide us with perspective and may be an indicator of the trajectory for the future.

Two previous histories of WCRC-Fruita have been prepared. Golus and Pearson (1988) presented a history covering 39 years of agronomic research in western Colorado from 1949 to 1988. Pearson et al. (1998b) covered 50 years of agronomic research conducted at WCRC-Fruita and western Colorado. The report herein provides a continuation of the history of WCRC-Fruita focusing mainly on the years 1998-2016.

Research in the Western Colorado Region

To support western Colorado agriculture we have conducted agronomic and related research on various crops, cropping systems, and a number of other research projects. Our vision at WCRC-Fruita is to meet the agricultural needs as related to agronomic and related field and laboratory research to support the sustainable production of field crops and the livestock industry in western Colorado.

A broad research approach has been taken at WCRC-Fruita in order to address as many needs and create as many opportunities as possible. There are many considerations to take into account in deciding what research to conduct (Pearson, 2013b). The mission of WCRC-Fruita is to plan, implement, and conduct scientific investigations and outreach programs to address the needs of western Colorado agriculture in terms of agronomic and related issues.

Alfalfa/Forages

Evaluating alfalfa varieties under local production conditions provides site-specific information that is useful to local producers and others who grow alfalfa in similar environments and growing conditions. Local variety performance information is also valuable to breeding and seed companies to guide them in developing and marketing seed of their varieties. Alfalfa variety performance tests at the WCRC-Fruita have routinely been conducted for more than 30 years. Prior to planting test plots, alfalfa breeding and seed companies were solicited for varieties to enter into the test. Company representatives determined which of their varieties to include in the test. They paid a fee to the University for each entry and the testing period for the trial was for three years.

The results of these commercial variety tests conducted at WCRC-Fruita have been regularly published (Johnson et al., 2000a; Johnson et al., 1999a; Pearson, 2013f; Pearson, 2008d; Pearson, 2007d; Pearson, 2004g; Pearson, 2004h; Pearson, 2000d; Pearson, 2000m; Pearson, 2000v; WAIC, #5-15) and has been published in numerous reports (Pearson 2015d; Pearson et al., 2011c: Pearson and Mucklow, 2011; Pearson and Sharp, 2011; Pearson, 2004b; Pearson and Brummer, 2004; Pearson and Rechel, 1999; Pearson and Mucklow, 1999: Pearson and Sharp, 1999). These reports have been distributed to ag producers, industry representatives, and various public agency personnel. Furthermore, these published reports have been made available in the public domain in an attempt to make them readily available to people seeking information related to alfalfa variety performance results and related production information.

The need for alfalfa varieties that are resistant to the alfalfa stem and other nematodes became apparent during the late 1970's. Over the years, field studies have been conducted to identify alfalfa germplasm that is resistant to nematodes that adversely affect alfalfa production. We have worked cooperatively with industry representatives for many years, in particular Forage Genetics Int'l, to test advanced alfalfa breeding materials for their performance in western Colorado primarily for their resistance to nematodes. Data obtained from this effort provides adaptation information to the alfalfa breeder at Forage Genetics for use in developing new alfalfa varieties. These new alfalfa varieties are subsequently sold to seed companies and in turn seed is made available to western Colorado growers and others around the country for purchase and planting. Because selections are made under western Colorado field conditions, many of these new varieties are well adapted to our local conditions. Over the years of conducting alfalfa trials from 1995-2016 in cooperation with Forage Genetics Int'l we have conducted 15 trials, many of which evaluated Roundup-Ready alfalfa material.

From 1995-2010 more than twenty alfalfa varieties were developed by Forage Genetics Int'l for commercial production during this period of 15 years of testing at WCRC-Fruita. The decision on marketing these cultivars was due, in large part, to their performance in the trials at Fruita. Estimates of acres of these alfalfa varieties planted between 2005 and 2010 (based on seed sales and an 18 lb. seeding rate) are in excess of 3.1 million acres annually. Developing strong university/industry collaborative relationships are valuable in conducting research projects that not only benefit the university and industry but are also highly beneficial to the agricultural industry (Pearson and Reisen, 2011).

Livestock production in western Colorado contributes significantly to the economic stability of western Colorado. According to the 2012 Census of Agriculture, livestock sales in western Colorado exceed more than $280 million each year (USDA-NASS, 2012). Grasses are produced on more land in western Colorado than any other single crop. Both irrigated and non-irrigated pastures, meadows, and rangelands are found throughout the mountain and valley areas of western Colorado. These crop and rangeland areas produce forage for grazing animals or hay that is fed later. These forages are essential to support the large livestock industry in western Colorado. Pastures, meadows, and ranges in western Colorado contain a diversity of forage plant species, some of which are native while others are introduced species. Grasses as found in these pastures, meadows, and other grasslands are also utilized for wildlife habitat and ecological services. At WCRC-Fruita we have conducted forage grass research both on and off-station (Pearson 2004d; Pearson 2004e; Pearson 2004f; Pearson 2000j; Pearson 2000k; Pearson, 2000n; Pearson 2000o; Pearson 2000q; Pearson 2000r; Pearson 2000s: Pearson and Gaus, 2000; Pearson, 1999c;) and we have published articles for our agricultural clientele (Pearson 2012a; Pearson 2011a; Pearson 2011c; Pearson et al., 2011a; Pearson, 2003; Brummer and Pearson, 2002).

Harvesting forage plots is labor intensive and time consuming without automated equipment. We developed an automated forage plot harvester using a field-scale commercial swather for harvesting small field plots (Pearson and Robinson, 1994). The automated forage plot harvester has been a valuable piece of research equipment that has allowed us to conduct alfalfa and pasture grass research. Several years ago, we made improvements in the design and performance of our automated, forage harvester (Pearson, 2007a) and how harvested alfalfa forage plots are managed was modified (Pearson, 2009b). What used to require several people to harvest forage plots can now be accomplished with one person operating the plot harvester from the comfort of a climate-controlled cab. Furthermore, with the automated forage plot harvester one operator can easily harvest several hundred plots in a single day. The forage plot harvester has not only allowed us to conduct more alfalfa and forage research, but it has also improved the quality of the data.

Small Grains

Soft white winter wheat was grown in the valley areas of western Colorado for many years, but in the 1990s production dwindled. In recent years growers again began growing winter wheat. We have conducted winter wheat cultivar performance trials to support producers in western Colorado. Data obtained from these trials aid growers and industry representatives in selecting which cultivars and market classes to produce in western Colorado (Berrada et al., 2002a; Berrada et al., 2001b; Johnson et al., 2008c; Pearson et al., 2009; Pearson et al., 2008e; Pearson and Haley, 2008; Pearson et al., 2007c; Pearson, 2000t).

Oats are an important crop in Colorado, including western Colorado. Although oats do not command a large acreage, they have been a mainstay in Colorado for a long time. Agricultural production technology continues to change which creates the need to evaluate new oat varieties and compare them to varieties that have been traditionally grown. We have conducted several oat variety performance trials at WCRC-Fruita over the years (Berrada et al., 2001a; Berrada et al., 2000; Pearson, 2011b).

Malting barley is important in the brewing of various beer products in Colorado. Performance testing of malting barley varieties has been conducted at WCRC-Fruita (Pearson, 1999e). Grain yields of malting barley varieties were low in a spring–planted trial conducted in 2007 at WCRC-Fruita (Pearson, 2008b). Grain yields of the 2007 fall-planted malting barley varieties were excellent to exceptional. Grain yields of the four varieties tested in this trial were 156, 201, 218, and 190 bushels per acre. Spring 2008 was favorable for malting barley production and the cool spring temperatures were likely a contributing factor for high grain yields (Pearson, 2009a). Throughout the years these malting barley trials were sponsored by the Coors Brewing Company.

In northwest Colorado small grain (dryland winter wheat, spring wheat, and barley) variety performance testing has been ongoing for more than 30 years (Golus et al., 1997). Over the years, grain yields of varieties have ranged from approximately 10 to 70 bushels per acre, depending largely on rainfall that occurs during a particular growing season. Small grain variety performance tests have been conducted in northwest Colorado to identify varieties adapted for commercial production in the region. Dwarf bunt resistance, plant height, test weight, crop maturity, protein content, along with yield are important crop traits for growers in northwest Colorado. Small grain research results from northwest Colorado have been published regularly and are available to the public (Berrada et al., 2003; Berrada et al., 2002a; Berrada et al., 2002b; Berrada et al., 2001a; Berrada et al., 2001b; Berrada et al., 2000; Johnson et al., 2008c; Johnson et al., 2005b; Pearson and Haley, 2016; Pearson and Haley, 2015; Pearson and Haley, 2013a; Pearson and Haley, 2013b; Pearson and Haley, 2008; Pearson et al., 2008c; Pearson et al., 2008d; Pearson et al., 2007c; Pearson, 2006c; Pearson, 2005b; Pearson et al., 2005b; Pearson et al., 2004b; Pearson et al., 2004c; Pearson, et al., 2003c; Pearson, 2000u).

We initiated a study in 2015 to evaluate the potential for the commercial production of winter rye in western Colorado. This field research is conducted on station and is being supported by KWS Cereals. The first year of results were encouraging and are publically available (Pearson and Rock, 2016). Additional field research with winter rye is being conducted at WCRC-Fruita in 2016.

Corn Grain and Silage

In 1969, one corn variety in a long-season grain trial at WCRC-Fruita produced a hand-harvested yield of 304 bushels per acre. Over subsequent years, yields of 300 bushels per acre or higher have been readily obtained under machine harvest conditions. These results demonstrate the crop production capabilities in the Grand Valley given a long growing season, favorable temperatures, low humidity, low disease incidence, high solar radiation, fertilizer-responsive soils, and plentiful irrigation water that allows researchers and farmers who use good management to optimize economic crop yields. Western Colorado was recognized years ago by crop modelers as a location where climatic conditions are conducive to produce very high corn yields (Muchow et al., 1990).

For more than 30 years, we had a long-season corn grain hybrid performance test at Fruita, a short-season corn grain hybrid performance test at Fruita, a short-season corn grain hybrid performance test at Delta, a corn silage performance test at Fruita, and a corn silage performance test at Olathe. We solicited corn seed companies each year and they chose the entries they wanted us to evaluate. The companies paid a fee to the University for each corn hybrid they entered into each trial. Our testing program in western Colorado was part of a statewide testing program coordinated from our agronomist on campus. The number of entries in these tests in western Colorado began to decrease in the early 2000’s and in 2006 the decision was made to end commercial corn hybrid testing for both corn grain and corn silage. These commercial corn hybrid performance trials were conducted for many years on station and with farmer-cooperators in western Colorado (Johnson et al., 2008a; Johnson et al., 2006; Johnson et al., 2005a; Johnson, et al., 2003b; Johnson, et al., 2002; Johnson et al., 2001b; Johnson et al., 2000c; Johnson et al., 1999c; Johnson et al., 1998; Pearson, 2000e; Pearson, 2000f).

Blunt ear syndrome, also called “beer-can ears”, “hand-grenade ears,” and “stunted ears,” is a disorder of corn that is characterized by normal-appearing corn plants having reduced ear lengths and fewer kernels per row (Fithian et al., 1998; Pearson et al., 1998a; Pearson and Fithian, 1993). A portion of the ear tip is barren in an otherwise normal-looking husk. Yield losses from BES have ranged from minor amounts to as much as 75%, and farmers reported that BES is often most severe on productive soils (Pearson and Golus, 1990). Our research showed that corn hybrids differed in their susceptibility to BES (Pearson, 2008a; Pearson, 1999a). We conducted studies to determine if biotic or abiotic factors were causal agents of BES (Pearson et al., 1998a; Pearson, 2000i). Blunt Ear Syndrome continues to be a concern periodically in western Colorado (Pearson, 2014a).

In 2007 Grand Valley Hybrids, a corn hybrid breeding and seed company located in Grand Junction, proposed we conduct a corn grain hybrid testing program for them. Thus, in 2007, we had three large trials at Fruita and another smaller yield trial at Delta, Colorado. From 2007 through 2011, we had these trials at Fruita and Delta for Grand Valley Hybrids. The impact of that research was summarized by Pearson and Rooks (2011).

In 2011, Grand Valley Hybrids was sold to Dow AgroSciences. Since the sale of Grand Valley Hybrids we have been conducting contract corn grain and corn silage tests for Dow AgroSciences (2012-2016). Under this arrangement, the "raw" data (data from research plots and not converted to commercial yields) collected for Dow AgroSciences were sent directly back to them. Thus, the data and associated information were not managed and published by CSU researchers and made available to the public. The data from our trials obtained at WCRC-Fruita were used at the discretion of Dow AgroSciences.

Conducting field research necessitates the use of suitable research equipment. Over the years we have purchased, designed and fabricated, or otherwise acquired needed field research plot equipment. Two used combines were donated from industry to CSU and the research center (Pearson, 2013d), one of which we spent considerable time improving and upgrading for use in harvesting corn grain plots. What used to take several people to harvest corn grain plots can now be done with one person in a climate-controlled cab and we can capture all the yield data (plot yield, grain moisture, test weight) while harvesting in the field. We also designed and fabricated a weighing hopper that we use for harvesting corn silage plots (Pearson, 2004c; Pearson et al., 2013d). This piece of equipment has been a major improvement in the harvest performance of plots, has improved data quality, and has provided better personnel safety during corn silage plot harvest.

Our research with transgenic field crops began with a study in corn in 1998 (Pearson, 1999b). We were among the early researchers who conducted field research with transgenic crops and over the succeeding years we have worked with several different transgenic crops in field and laboratory conditions (Pearson, 2015a).

Dry Beans

Dry bean variety performance tests have been routinely conducted over many years at WCRC-Fruita. Research results obtained from dry bean variety performance tests are important to provide Colorado farmers and others with information that has been obtained under local conditions in the dry-bean producing areas of the state.

Western Colorado has traditionally been an important seed-growing area of the state. Thus, it is also important to test yield performance of dry bean varieties in the seed-producing areas of Colorado. Seed growers must know if yields of popular dry bean varieties for commercial production will be profitable for growers who grow dry bean varieties for seed production. Variety yield performance results can be used by various people– farmers when selecting varieties to plant on their farms, seedsmen in knowing which varieties to grow for seed production, companies to determine which varieties to market and in which locations varieties are best adapted, and university personnel in developing new dry bean varieties and in educating people about them.

We conducted dry bean research routinely in western Colorado for many years (Johnson et al., 2005c; Johnson et al., 2003a; Johnson et al., 2001a; Johnson et al., 2000b; Johnson et al., 1999b; Pearson et al., 2006a; Pearson et al., 2004a; Pearson, 2004a; Pearson et al., 2003b; Pearson, 2000l). Given our dry bean expertise and the importance of communicating science-based information to our clientele we have participated in authoring various publications intended to provide production information for growers (Brick and Pearson, 2015; Brick et al., 2004; Pearson et al., 2015b; Pearson, 2015c; Smith and Pearson, 2004). Furthermore, we at WCRC-Fruita have participated in the development and release of several dry bean cultivars years (Brick et al., 2002; Brick et al., 2000; Brick et al., 1999)

Nuña bean is a special market class of common bean (*Phaseolus vulgaris* L.) indigenous to the Andean mountains of Ecuador, Peru, and Bolivia. Nuña bean is often referred to as "popping" or "pop" beans because the seed expands rapidly when heated in oil. South American nuña bean cultivars are not adapted to production in the USA because they are photoperiod sensitive and have an aggressive climbing, indeterminate growth habit. Nuña breeding lines were developed by CSU researchers that were adapted to Colorado growing environments. More specifically, the popping characteristic from the nuña bean of South America was successfully introgressed into ten dry bean lines with determinate growth habit and adaptation to the temperate climates of North America (Ogg et al., 1998). These new breeding lines were evaluated for yield, popping ability, and seed size at three locations in Colorado. Two lines, CO49956 and CO49957, had the highest popping frequency (70 and 68%, respectively) among the lines tested. Nuña popping bean has potential for commercial on-farm production in suitable temperate locations and as a commercial product to the American consumer. Complete details of this research project were published by Pearson et al. (2012a).

WCRC-Fruita has been the major location in Colorado for more than 30 years for increasing seed of promising dry bean material and potential new varieties. Personnel at WCRC-Fruita have worked closely with the Dry Bean Breeding Project that is located on campus with the research and development of new dry bean varieties. Furthermore, at WCRC-Fruita we have the responsibility as part of the Seed Certification system to produce Foundation seed of dry bean varieties developed by Colorado State University and the Colorado Agricultural Experiment Station. The objectives of the Foundation Dry Bean Seed Project are to provide the seed industry with genetically pure and disease-free seed stocks of Foundation class dry bean, especially those cultivars developed by the Colorado Agricultural Experiment Station.

Also, we work cooperatively with Foundation seed projects in other western states in the exchange of Breeder and Foundation dry bean seed. Lastly, we work closely with the dry bean seed industry in Colorado to supply quantities of seed required to meet commercial agricultural production needs.

Soybean

Commercial acreages of soybean have been grown sporadically and on limited acreages in the Grand Valley since the 1980s. Mainly because of limited markets and transportation costs, commercial production of soybean in the Grand Valley has remained sparse although in recent years commercial acreages in western Colorado have been on the increase. Roundup-Ready® soybean cultivars have been commercially available for many years and they are widely used in commercial agriculture throughout the USA. Roundup-Ready soybean varieties provide producers with a convenient, cost-effective, and highly effective weed control management tool that results in weed-free fields and promotes high yield soybean production. Commercial production of soybean using Roundup-Ready cultivars allows considerable timing and application flexibility with glyphosate, thus, controlling weeds in a soybean crop during the growing season is now straightforward.

In 2004, we conducted a soybean performance trial in which soybean cultivars from a broad range of maturity groups were evaluated at WCRC-Fruita (Pearson, 2005a). Additionally, in 2011, we conducted another soybean performance trial to evaluate ten Roundup-Ready soybean varieties for seed yield and related agronomic performance (Pearson, 2012b). We also compared planting a single seed row of soybean on a 30-inch bed to planting twin seed rows on a 30-inch bed. Based on one year of field results, planting twin seed rows of soybean on a 30-inch bed would be advantageous for commercial soybean producers in western Colorado (Pearson, 2013e).

Entomological Research

The Russian wheat aphid was discovered in the western US in 1986, and it became a serious pest of wheat across most of Colorado within the next year. Several entomologists were hired by the Agricultural Experiment Station in 1988 in response to this threat to the Colorado wheat industry. One of these new research entomology positions was located at Fruita, and a research program focused on Russian wheat aphid on the west slope of Colorado was in place for the next 10 years.

Initial research was conducted to identify the crop growth stages during which damage occurs, chemical control, biological control, management of fall infestations by adjustments of planting dates, and evaluation of Russian wheat aphid resistant wheat and barley germplasm to ensure maximum production. (Hammon et al., 1997b; Hammon et al., 1999a; Hammon et al., 1999b).

Studies on the Russian wheat aphid have shown that microclimate effects on south-facing slopes allow overwintering of not only Russian wheat aphid, but Banks grass mite, wheat curl mite, and western flower thrips. These insect and mite pests affect production of corn, sweet corn, and other small grains grown in the region. Management of pests on these overwintering sites is an important aspect of the integrated Russian wheat aphid management program.

Genetic diversity within the Russian wheat aphid program became an important issue when the first biotypes of the aphid were discovered in 2003 (Haley et al., 2004). Biotypic diversity was an important consideration when Russian wheat aphids became resistant to resistant wheat varieties (Randolph et al., 2003) Research conducted on sexual forms of native *Diuraphis* aphids (Stoetzel & Hammon, 1992; Kindler & Hammon, 1996; Hammon & Peairs, 1998) were used as models in the search for sexual reproduction within Russian wheat aphids. This search culminated with the discovery of sexual populations of Russian wheat aphids in western Colorado in 2011 (Puterka et al., 2012).

New varieties of spring and winter wheats and barleys that are resistant to Russian wheat aphid are evaluated as they are developed. These varieties come from universities in Colorado, Idaho, Montana, and USDA-ARS research locations around the country. Experiments on effect of planting date on a plant virus complex in wheat has helped define the best times to plant fall grains (Hammon et al., 1997a).

Spider mites, especially Banks grass mite, are consistent pests of corn grown in the lower valleys of western Colorado. Miticides are tested annually for effectiveness against Banks grass mite. These trials are funded by industry and several effective miticides have been identified that are now used by west slope corn growers for mite management in corn. Education of growers to identify and manage overwintering sites to reduce spider mite levels during the growing season is a high priority project.

Alfalfa seed production has been grown in the Grand Valley since the mid 1990's, with considerable variation in acreage. A study on pollen movement by native and managed bees culminated in a comprehensive overview of gene flow in alfalfa (Van Deunze, 2008).

Conservation Tillage

Conservation tillage is defined as any tillage and planting system that maintains at least 30%

of the soil surface covered by residue following planting, or maintains at least 1,000 pounds of small grain residue per acre on the soil surface. Conservation tillage is an umbrella term that includes tillage systems such as strip tillage, mulch tillage, no-till, zero tillage, minimum tillage, slot planting, till-plant, rotary till, ridge till, zone tillage, and others.

Farmers in many furrow-irrigated areas have been reluctant to adopt conservation tillage. This is probably a result of concerns associated with tilling, planting, irrigating, and harvesting in fields with surface crop residue. Production practices under conservation tillage are different than conventional tillage methods farmers are accustomed to using on furrow-irrigated cropland. Furthermore, conservation tillage technologies developed for rainfed or sprinkler-irrigated conditions are not generally directly applicable to furrow-irrigated conditions.

A major concern with conservation tillage under furrow irrigation is the uncertainty of being able to furrow-irrigate in fields containing surface residue. Farmers may also be reluctant to make the encompassing changes, including the necessary financial and management investments, that may be needed to adopt conservation tillage successfully on their furrow-irrigated cropland.

Considerable progress has been made on campus at CSU and at WCRC-Fruita in learning how to manage surface crop residue without causing problems when furrow irrigating. We also conducted simulation research involving surface residue and furrow roughness which helped increase our understanding of how surface residue and furrow roughness interact (Pearson et al., 1998c). Identifying suitable planting and cultivating equipment that will operate in high residue conditions and in furrow-irrigated cropping systems, and developing cropping systems that are adapted for furrow-irrigation conditions are important components of this research project.

Conservation tillage under furrow-irrigated conditions provides growers with profitable and more environmentally-sustainable farming alternatives than is currently available with many clean-tillage systems. A considerable amount of research that addresses various aspects of conservation tillage and related topics has been conducted at WCRC-Fruita over the years (Pearson, 2000p; Pearson et al., 2000; Ashraf et al., 1999). Thus, science-based guidelines for using conservation tillage under furrow irrigation have been developed based on our research and other similar research projects at Colorado State University (Wardle et al., 2015; Pearson, 2002a; Pearson et al., 2002a).

Alternative Cropping Systems

Developing alternatives to traditional crop production technology is an important agronomic research area to ensure that agriculture is sustainable. Alternative crop production research must include evaluating and integrating new technology into production practices and evaluating the cost/benefit relationship of such alternatives.

Soil health and high operating costs are important issues that threaten the sustainability of agriculture. Integrating “living mulches” with no-till crop production practices can potentially offset environmental and economic issues. Living mulches consist of perennial plants that are used as cover crops in the production of annual cash crops. Much in the same way as annual cover crops, living mulches can decrease soil erosion, suppress weeds, improve soil structure and nutrient cycling, sequester carbon, protect seedlings of other crops during establishment, and supply nutrients to the associated crop, especially nitrogen when using legumes. A major advantage of perennial living mulches is that they provide soil cover all year since they do not have the regular establishment periods required for annual cover crops.

Living mulches are cover crops grown in association with annual grain or forage crops. These vegetative covers are unique in that they are not completely killed prior to planting of the annual crop. Rather, growth is suppressed allowing persistence and coexistence of the cover crop with the annual crop throughout the season and beyond. While the living mulch can be seeded with the annual crop, benefits are often increased when perennial covers are established beforehand. Such a scenario requires suppression of the cover, either chemically or culturally, prior to planting the cash crop. A research project with living mulches was initiated at WCRC-Fruita in 2006 and continued for several years (Pearson et al., 2014; Pearson et al., 2010a; Pearson and Brummer, 2008).

Producing two crops in a single growing season or year is an appealing way to increase farm income. Field research at WCRC-Fruita with dry bean planted as a double crop after winter barley has been shown to be a potential cropping system option for Grand Valley farmers (Pearson, 2000g; Pearson, 2000h). Our research results suggest that selection of pinto bean cultivars for use in this double-cropping system is less critical than the selection of a winter barley cultivar. Double-cropping pinto bean after winter barley was successful, but to use our double-cropping technology in commercial agriculture in adapted locations will require developing or identifying a winter barley cultivar with the proper maturity. A winter barley cultivar used in this double-cropping system must mature early but not too early for barley to experience freeze damage during flowering. An early-maturing winter barley cultivar must also have acceptable agronomic characteristics such as limited lodging, high grain quality, and high grain yield.

Compared to sole cropping, double-cropping pinto bean after winter barley will require an additional level of skilled management by producers for this cropping system to be successful, particularly related to timely harvest of winter barley and timely planting of pinto bean (Pearson and Sharp, 2010).

Irrigation Studies

To obtain sustainable irrigated crop production systems more efficient irrigation water applications are needed. This dictates the use of improved management and the adoption of advanced irrigation technologies to avoid overwatering to reduce runoff, deep percolation, evaporation, and salt and selenium loading and other contaminants into water supplies that affect downstream users. Increasing competition for water resources and demands for irrigation practices that are environmentally friendly is ongoing motivation to use irrigation water more efficiently.

Modernization and automation of irrigation practices and technology are essential for the continued mitigation of local environmental issues and adoption of sustainable agricultural practices. An Automatic Gate Valve Actuator (AGVA) is a programmable device that is attached to gated pipe, and automatically opens and closes gates individually. An AGVA unit is needed for each furrow. Thus, each furrow can be individually controlled using the AGVA unit that is assigned to that furrow. With the use of AGVA technology the concept of surge irrigation can be targeted on a per furrow basis rather than a surge set that stretches across numerous consecutive furrows. Under a Bureau of Reclamation grant we evaluated the performance of AGVA units in the field over a two-year period (Pearson, 2010a).

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

With SDI, water is applied below the soil surface at a depth to meet crop water needs while allowing for crop production using mechanization. Optimum management and performance of SDI is the most efficient method of irrigating to deliver water to the root zone of the crop. A field study in a side-by-side comparison of furrow and SDI was conducted in alfalfa from 2012-2014 and corn in 2015 at WCRC-Fruita. The study compared irrigation performance and crop yield of SDI with traditional furrow irrigation (Pearson and Guccini, 2016; Pearson and Guccini, 2015; Pearson, 2014b).

Given the similarity in environments in Colorado and Afghanistan we were invited to teach an irrigation workshop to farmers and agricultural extension agents, consultants, engineers, and others in Afghanistan in 2012 (Pearson, 2013c; Reich and Pearson, 2012).

A new concept to address the growing problem of limited water sources in the western United States is water banking. A Western Slope Water Bank would entail agricultural water users entering into short-term leases and temporarily withholding or reducing irrigation. This approach could be a partial solution to free up water to fulfill these obligations. WCRC-Fruita was a research site for a recent water banking study (Jones et al., 2013).

Biomass for Biofuel

Sustainable biomass to biofuel supply chain systems could contribute significantly to mitigating climate change, enhancing the environment, and improving economic conditions (Pearson, 2012c). Biofuels produced from lignocellulosic biomass, in particular, have potential to provide public benefits including increased energy independence and security, foreign exchange savings, rural development, and job creation. Accordingly, congressionally mandated revised Renewable Fuel Standard objectives call for 16 billion gallons of cellulosic biofuels to be produced annually by 2022. Perennial grasses are a preferred feedstock for second-generation biofuels. In essence, perennial grasses possess many of the optimal characteristics as a plant species and for sustainable crop production systems, including: (1) carbon neutrality; (2) low input production requirements; (3) cultivation on marginal land to reduce competition with established food/feed cropland; (4) low water use requirements; (5) profitability to agriculture and the processing/conversion industry; and (6) desirable sociological aspects. We initiated a research project on the potential of biomass to biofuel in western Colorado in 2010 (Pearson et al., 2012b; Pearson, 2010b). Based on our research results in western Colorado we subsequently published a Microsoft Excel program to aid clientele in assessing the profitability of growing biomass (Keske et al., 2014). Furthermore, a book was recently published in which we authored a chapter that discusses the status of biomass production potential at high elevations in the mountain states of the country (Pearson et al., 2015c).

Production of biofuel in western Colorado has the potential for the production of alternative crops such as canola and sunflower in western Colorado to supply vegetable oil for biofuel production or food uses. We have conducted field trials with canola for many years (National Winter Canola Variety Trial, 2005, 2006, 2007, 2008, 2009, 2010, 2013, 2014, 2015; Pearson and Johnson, 2009; Pearson, 2007b; Pearson 2006a; Pearson, 2006b). We also participated to a small degree in the release of a public variety of canola named, “Riley” (Stamm et al., 2012).

Numerous sunflower varieties were evaluated over several years for seed and oil yield and other agronomic characteristics to determine the potential for commercial production of sunflower under irrigation in western Colorado (Johnson et al., 2008b; Pearson 2009c; Pearson, 2008c: Pearson, 2007c).

Prickly pear cactus (*Opuntia polyacantha* Haw spp.) is a native plant species widely distributed throughout the Intermountain West of the USA. *Opuntia* is well adapted to areas of limited rainfall where high heat and drought stresses are common. The potential of prickly pear cactus as a biomass to biofuel resource has not been investigated. A study was conducted at WCRC-Fruita for four years from 2010-2013 to determine the potential of prickly pear cactus as a source of biomass when grown under modern agricultural production conditions.

Prickly pear cactus yields over the 4-year testing period at WCRC-Fruita grown under agricultural conditions with limited irrigation ranged from 12.5 to 21.6 tons/acre of dry matter biomass. To be produced using mechanized agriculture several problems with *Opuntia* would have to be solved including equipment that would be suitable for mechanical planting and harvesting, along with developing management strategies to control pests such as insects and weeds (Pearson et al., 2015d).

Sunflower Rubber Project

Natural rubber (cis-1,4-polyisoprene) is an indispensable biomaterial for our modern standard of living. The United States is dependent on imports of natural rubber from countries located halfway around the world (Cornish et al., 2005). A collaborative research project was initiated in 2001 to transform sunflower (*Helianthus annuus* L., Asteraceae) into a rubber-producing crop (Cornish et al., 2006; Pearson et al., 2002b; Pearson, 2001a). Sunflower naturally produces a small amount of natural rubber. The overall objective of this research project was to insert genes into sunflower to optimize rubber synthesis. Traditional plant breeding is often limited by the genetic diversity within a species. The use of biotechnology allows specific traits that come from another plant species to be introduced into the genetic code of the target host species (McMahan et al., 2006; Pearson, 2015a; Pearson et al., 2007a; Pearson et al., 2006b).

Sunflower is notoriously recalcitrant to genetic transformation and regeneration when subjected to tissue culture. We conducted studies to improve the regeneration success of sunflower (Pearson et al., 2007b; Rath and Pearson, 2004a). Furthermore, given that we were working with transgenic sunflowers, we developed a detailed standard operating protocol for growing transgenic sunflowers in contained environments (Max et al., 2001; Pearson et al., 2008h). Snow and Pearson (2005) also discussed why it is important to confine novel transgenes in field-based research. Moreover, Pearson (2002b) discussed the practical aspects of establishing a new project that involves research with transgenic plants at an off-campus research center.

Laboratory and field experiments were conducted at WCRC-Fruita for several years with sunflower (Rath et al., 2005c; Rath et al., 2004b). Sunflower latex is found mostly in the leaves of young and mature sunflowers. The potential for increasing latex production in sunflower appears possible, given that current natural rubber levels are low and reasonable advances in natural rubber production in sunflower plants through plant breeding and genetic engineering might be achieved (Pearson et al., 2010b; Pearson et al., 2010c).

Sometimes in conducting novel research specialized equipment is lacking. A hydraulic press was designed and fabricated that was needed for extracting fluids from sunflower plants (Pearson and Rath, 2009d). This press was a valuable piece of equipment in conducting our research (Pearson et al., 2013e).

The development of sunflower cultivars suitable for commercial production of natural rubber will require significant improvements in the quantity and quality of natural rubber produced in the plant. Research efforts to further our work to increase natural rubber production in sunflower are being pursued by Edison Agrociences located in Durham, North Carolina (www.**edisonagrosciences**.com).

We also conducted analytical research in our laboratory on another natural rubber-producing crop, guayule. This research effort was conducted in collaboration with colleagues at other institutions and companies and we published a number of refereed journal articles on our work with guayule (Cornish et al., 2013; Pearson et al., 2013a; Pearson et al., 2008f).

Miscellaneous Studies

Hybrid poplars are a valued crop for a number of uses including pulp, dimension lumber, oriented strand board, plywood, conservation and ornamental plantings, phytoremediation, and as a renewable feedstock for energy to replace fossil fuels including as a source of cellulose for ethanol production. As an agronomic crop, hybrid poplar could be grown by various landowners including small landowners or part-time producers or in irregular-shaped fields that do not lend themselves for efficient production of many agronomic crops. We conducted a hybrid poplar study at WCRC-Fruita for 6 years to evaluate eight hybrid clones under short-term, intensive culture conditions (Pearson et al., 2003a; Pearson, 2001b; Pearson, 2001c). Several insect species infested hybrid poplars over the course of the production cycle and caused various levels of damage depending on the clone. Of the eight hybrid poplar clones tested, OP367 was the most adapted and productive in the short-term, intensive culture system in the arid environment of the Grand Valley of western Colorado (Pearson et al., 2010d).

Teff, (*Eragrostic tef*, Zucc.), is a warm-season annual grass promoted as a forage crop in recent years in the United States. Teff has potential use in several applications including – as an annual hay, pasture, or silage crop; as an emergency hay, pasture, or silage crop for planting in mid-summer; as a summer annual crop for erosion control; as a green manure crop; or for use in crop rotation as part of a cropping system.

Teff was evaluated as a potential alternative crop in western Colorado during 2008. Forage yields in the first and second cuttings averaged 1.8 and 1.2 tons/acre, respectively. Application of 40 lbs N/acre after each cutting resulted in a higher total 2008 yield of 3.4 tons/acre. Forage quality of teff was similar to that of other grasses that have been grown at Fruita. Forage yields at Fruita were similar to those obtained in other locations around the country where teff has been grown. Based on one year of data this crop may have potential in western Colorado when grown to meet specific production objectives (Pearson and Brummer, 2009).

Edamame soybean is a popular food in Japan and its popularity as a specialty food is increasing in the United States. Pods of edamame soybean are harvested with partially developed seeds similar to when gardens peas are ready for harvest. Soybean pods are prepared for eating by cooking them in boiling salt water for a short time. Following cooking, pods are opened and seeds are eaten. Edamame soybean is considered to be a healthy, tasty snack food.

Edamame soybean seed for planting is expensive, costing as much as $12.00 per pound. Seed costs are high because of the difficulty encountered when producing seed crops. The primary difficulty for seed production is severe seed shattering that occurs when plants approach maturity. Currently, seed production in North America is limited to a few locations were higher humidity helps reduce seed shattering, although seed losses can still often exceed 20% in many years. Furthermore, these higher humidities often promote disease development in edamame soybean.

Preliminary research was conducted on the seed production of edamame soybean (Pearson, 2001d) and if additional funding would have been available we felt confident we could have learned how to manage or at least mitigate the seed shattering problem. However, there are additional challenges for edamame soybean production. Obtaining uniform and adequate plant populations is often difficult. Early seedling mortalities can be high in some years as a result of disease. Germination and emergence of edamame soybean is slow. The time from planting to seedling emergence generally takes several days longer than most other field crops. At Fruita, Colorado the time from planting to emergence can take up to two weeks. Seedlings planted too deep or soil crusting during emergence can reduce plant stands significantly. However, with careful management at planting and during seedling emergence, adequate plant stands can often be achieved. Overcoming crop production constraints of edamame soybean, mainly seed shattering, could provide farmers in western Colorado with a profitable, alternative crop.

Sugarbeets were first produced in 1883 in western Colorado and were an important agronomic crop on the West Slope for almost a century. Sugarbeets had a strong reputation as a reliable cash crop, but were also important for crop diversity and crop rotation needs for farmers in western Colorado; however, in 1976 the Great Western Sugar Company abruptly ended the production of sugarbeets in western Colorado. Sugarbeets have not been produced in western Colorado since that time. However, interest in sugarbeets was rekindled when discussions about the possibility of growing sugarbeets were held between local growers and businesses, and the Great Western Sugar Company.

One of the outcomes of that discussion was to plant sugarbeet variety trials in 1999 to ascertain how newer varieties would perform in western Colorado since more than twenty years had elapsed since sugarbeets were produced on the West Slope. Two experiments were conducted in western Colorado in 1999, one in the Grand Valley and one in the Uncompaghre valley. The site in the Grand Valley was at WCRC-Fruita, and in the Uncompaghre Valley at the Steve Shea Farm in Delta. The same twenty-five sugarbeet varieties were evaluated at both locations. The data from 1999 indicated that several varieties of sugarbeet should be highly productive in western Colorado. Some weeds persisted at both locations but were not considered to have a significant adverse impact on yield. Great Western Sugar needed growers to collectively commit to the production of 10,000 acres of sugarbeets between the Grand Valley and the Uncompaghre Valley. For various reasons, growers were unable to meet that commitment. Thus, sugarbeets did not make a return to commercial production in western Colorado (Pearson and Cooley, 2000).

Kenaf (*Hibiscus cannabinus* L.) is an annual fiber crop native to east-central Africa where it has been grown for thousands of years for food and fiber. Kenaf was introduced into the United States when jute imports were affected by World War II. Potential uses for kenaf include paper and newsprint, animal feed, clothing/textile fabrics, thermoplastic composites, animal bedding/litter, phytoremediation and other environmental services, and plant growth media. Research on kenaf since its introduction into the U.S. has been sporadic. A kenaf cultivar performance test was conducted in a field study at WCRC-Fruita during 1998 and 1999. Dry matter yields averaged 5.0 tons/acre in 1998 and 3.0 tons/acre in 1999 (Pearson, 2000a; Pearson, 2000b; Pearson, 2000c).

Other new and novel alternative crops and cropping systems have been evaluated to determine their potential for production in western Colorado and to provide basic information for future inquiries including native plants (Pearson, 2016; Pearson et al., 2005c) and a pea/oat mixture (Pearson, 2015b). A biostimulant product was evaluated for its performance in grass pasture over multiple years and was found to have efficacy (Pearson, 2013a).

Years ago at the USDA-ARS Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho, polyacrylamide (PAM) was found to be efficacious in reducing soil erosion and improving infiltration in irrigated furrows (Trout et al., 1995). The performance of PAM was evaluated at WCRC-Fruita on how it would perform under the furrow-irrigated conditions of western Colorado (Pearson, 1999d). We have been using PAM for many years at the research center. PAM is applied in each furrow prior to irrigations whenever new furrows are formed or soil in the field is subject to erosion during an irrigation event.

Western whorled (*Asclepias subverticillata*) is a common plant native to the western U.S. and Mexico. This weed becomes troublesome when it invades pastures, hay fields, orchards, gardens, ditchbanks, roadsides, fence rows, and other sites. Western whorled milkweed contains mostly uncharacterized neurotoxic compounds that are toxic to livestock. It can be highly toxic to many species of livestock and is found in the lower elevations of Colorado and surrounding states. A fact sheet was prepared that describes how to manage western whorled milkweed in western Colorado (Hammon and Pearson, 2014).

Improvements at WCRC-Fruita

A variety of improvements at WCRC-Fruita have enhanced our ability and capacity to carrying out our mission and to provide a safe and productive work environment for CSU employees and visitors.

Numerous farm improvements have occurred over the years including creating farm roads for access around all fields. A new irrigation system was installed over a 3-year period from

1993-1995. The new irrigation system included buried mainline throughout the research center with risers for irrigating with gated pipe and surge irrigation technology. With the installation of the new irrigation system we were able to include the land area across 19 Road that was historically irrigated with water from the Enterprise Ditch. Our irrigation shares serviced by the Enterprise Ditch were not sufficient to allow us to irrigate many furrows at a time. By installing buried mainline along with gated pipe and using irrigation water from the main part of the farm and with good management we are able to irrigate the entire 80-acre research center much more efficiently and conveniently.

A modest subsurface drip system was installed at the research center in spring 2012. We also have the ability to sprinkle irrigate small areas that are located close to the office building. The subsurface drip and the sprinkler systems are valuable tools for conducting experiments when small cropping areas are needed.

Over a 30-year period we have had three signs located next to L Road that were intended to inform the public that we are an agricultural research facility with Colorado State University. In 2011, a new sign was made. We built a sturdy metal frame, poured a substantial concrete pad and anchored the sign in the concrete pad in the middle of the lawn area next to the fence on L Road. The sign is attractive and very visible to those who pass by it.

It is worth mentioning given it was not covered in previous WCRC-Fruita histories. It wasn't until June 1994 that L Road from 19 to 20 Road was paved. Prior to that time, this mile was an all-weather gravel country road.

A considerable amount of sediment is eroded from fields during irrigation and transported in the tailwater off our farms and into various rivers systems of western Colorado. In 2014, we initiated planting grass filter strips at the end of fields to reduce the amount of sediment lost in tailwater. In 2016, we planted another larger filter strip all along the bottom of the fields at the north section of the research center.

Over the years, we have made a dedicated effort to beautify the area around the office and main entrance by planting trees, shrubs, and flowers. We have developed flower beds around the office and yard areas with an emphasis on using native plants in many situations. We have been fortunate to have a senior citizen volunteer who has interest in yard work. She has been instrumental in caring for the flower gardens, mowing the lawn each week during the summer months, and providing general maintenance of the lawn and flower gardens at the research center throughout the year.

A wind storm destroyed our metal, garden tool shed and we were able to replace it with a larger, much stronger wooden tool shed (circa 2007). We store a riding lawnmower, roto-tiller, numerous hand tools, and various other items in the shed.

For many years pesticides were stored inside cabinets in our sample processing building. Recognizing the health concerns with this situation, the Agricultural Experiment Station purchased stand-alone pesticide buildings (1996) for research centers around the state including WCRC-Fruita.

Major equipment purchases and acquisitions in recent years have enhanced research and bulk farming operations. These include farm tractors, strip tiller, equipment trailers, tandem disk, grain drill, flail, pickup truck, farm truck, moldboard plow, chisel plow, forage chopper, ATVs, riding lawnmower, large commercial sprayer, two small plot combines (one for small grain and one for corn grain), and in 2016 auto-steer/auto-trac capabilities were added to our 6140 John Deere tractor and our John Deere 4710 large, self-propelled sprayer.

During 1998-2016, changes and upgrades have occurred to the buildings and the farmyard area at WCRC-Fruita. Years ago (circa 2003) we received one-time funds from campus to improve main door entries into our main sample processing building and we installed metal roofing on two of our buildings. We were also able to improve the restroom in the sample processing building that included upgrading the shower. We moved the washer and dryer into the restroom. This allows employees to shower as needed depending on their work activities and wash their work clothes on site. In 2016, after decades of use, we finally had the asbestos countertop on our work island in the sample processing building professionally removed and replaced with a high density laminate countertop.

Numerous large cottonwood and poplar trees surrounded the lawn and office buildings for many years. These large trees provided wonderful shade during hot summer days, but the trees were old and in decline. Following storms, branches of considerable size were often found lying on or sticking into the ground near the office area. Given the age of these trees and safety concerns, the trees around the yard/office area were removed periodically over a number of years. The most recent tree to be removed was a very large cottonwood that we affectionately called, "Grandfather Tree." This tree icon was in the lawn just north of the office building. Grandfather tree was very old, probably 70-80 years old. Given its size and location it was removed piece-by-piece from the top on down during December 2014 by an experienced tree removal service.

Over the years, we have experienced damage to field research from various external sources. Increased urbanization has likely contributed, or at least added complexity, to some of these problems. Increased problems with livestock have occurred as a result of neighbors not taking proper care (adequate feed and fence repair) of their livestock, resulting in animals crossing onto research property in search of feed.

The increased availability of unmanned aerial vehicles (UAVs) across the country has created concerns about how these flying machines affect numerous aspects of society. Two years ago during harvest we found a small UAV that had crashed in our corn field.

We have experienced a few incidences of vandalism, theft, and trespassing - some by minors. Vandalism and trespassing have included slashed tires, problems with fireworks, super-gluing padlocks, and people in search of asparagus that grows along fencelines and other areas. Thefts have been confined to gasoline.

Over the years, we have had to deploy control measures to prevent damage to research areas caused by dogs and other pets, prairie dogs, ground squirrels, raccoons, and skunks. We have also had periodic damage caused by bears. Summer 2000 was very dry in western Colorado, forcing bears to move out of the mountains and into valley areas in search of food and water.

A deer fence, 8-ft. tall woven wire with barbed wire at the top and bottom, was erected around the entire research center property in 1999 to keep out, not only deer, but also livestock and also to discourage trespassers. Fencing materials were obtained with the assistance of the Colorado Division of Wildlife at a nominal cost. Fencing was erected using inmates from a local prison facility.

As the first line of defense, staff at the WCRC-Fruita have recognized the need to evaluate, develop, and implement solutions to protect and provide security to field research and research facilities (Pearson and Max, 2001). Electric fencing was used in years past to keep raccoons and skunks from entering and damaging sweet corn plots. Raccoons and skunks can cause extensive damage in sweet and field corn in just one night. Live traps have been used to catch pets, specifically dogs and cats that enter research center property. Pets caught in live traps were turned over to county animal control authorities.

With the exception of the weather, damage from these external sources has not resulted in a complete loss of experiments, nonetheless, plots have been damaged and considerable extra time and effort have been expended in dealing with these problems. On one occasion, we had a balloonist set down on research center property. Fortunately, we were close enough that the balloonist shouted to us requesting permission to land in an open field. This incident illustrates the challenge it is to plan for all situations.

Strategies and Remedies Used to Protect Agricultural Field Research at WCRC-Fruita

Protecting agricultural field research from someone who may intentionally or unintentionally cause damage has been actively considered. The items listed below have reduced, deterred, or prevented damage by external sources from occurring at WCRC-Fruita.

The lighting in all the buildings and outside lighting was changed to LED in 2015.

The fencing around research facilities discourages wildlife, livestock, vandals, thieves, and other trespassers from entering the premises.

Entrance gates to the research center have padlocks and have been changed periodically over the years. We close and lock gates after hours and on weekends.

In the late 1990's we developed a WCRC program, operations, and administrative handbook that contains written security procedures and policies at the research center. We appointed a person(s) to be in charge of security to make sure fences are maintained; gates, vehicles, and buildings are locked; security devices are working properly; etc.

As needed we have posted appropriate signs and warnings such as "No Trespassing" and "No Hunting."

When the laboratory was constructed we consciously designed it to appear similar to the rest of the office, giving it the same farmhouse look. We did not want to advertise or attract attention to our research that may incite people to cause damage.

At suitable locations and as warranted, we have posted information with phone numbers, other pertinent information, and the names of the person(s) to be contacted in case of an emergency.

We have made dedicated efforts to project a positive image of the research and activities at the research center in an effort to inform the public and remove mystery and speculation about what goes on at our research facility.

We have actively engaged and attempted to establish friendly relationships with adjacent landowners and others so people become aware of the research center and our mission and research activities.

As a standard operating procedure we have designed and arranged field experiments to include adequate border areas around plots to protect research plots.

We have routinely made fire guards around fields and research areas to create defensible space to prevent fire damage, particularly when crops in field plots become mature and dry and are near roads where they are susceptible to lit materials that could be thrown from vehicles.

Future Research at WCRC-Fruita

In this day and age we live in a global economy. Western Colorado agricultural commodities and products face tough competition from regions around the country and from foreign markets. The overall effect for western Colorado agricultural products is increased competition in the marketplace. Successful competition requires the development of new methods, managements, cropping systems, alternative crops, production technologies, and the rapid adoption of these proven methods and technologies. Research leading toward increased production efficiency, development of new and alternative crops, new varieties, new cropping practices and managements, and improved and unique quality of traditional crops will continue to be important research areas for the future. Additional research will be needed to ensure that agricultural production practices are environmentally safe and sustainable.

Agronomic research conducted under the local conditions of western Colorado has a vital role in shaping and dealing with changes that are and will continue to occur in agriculture and society that will undoubtedly affect agriculture. Future agronomic research aimed at developing new technology for a more profitable and sustainable agriculture in western Colorado is expected to include:

1) Production efficiency and quality improvement of traditional crops.

2) Production and processing practices that ensures the safety of food and feed of agricultural products and commodities.

3) New and improved irrigation practices and increased use of irrigation technology and automation.

4) Development and evaluation of new varieties of traditional crops.

5) Identification and evaluation of new and alternative crops, including those that do not compete with food and feed applications.

6) Conservation tillage, advanced cropping systems, living mulches, cover crops, and other similar research to promote economically and environmentally safe and enhancing practices leading to sustainable intensification of agricultural lands.

7) Impartial testing of proprietary products marketed to farmers including herbicides, insecticides, fungicides, nematicides, bactericides, growth regulators/stimulants, fertilizers, wetting agents, soil erosion control compounds, alfalfa and silage preservatives, inoculants, and others.

8) Integrated pest management, which includes cultural, chemical and biological control of insects, diseases, weeds, and nematodes.

In addition to our past approaches, future research must address the growing number of non-production uses of land that is removed from production as farms are subdivided and managed by people who do not have agricultural knowledge and expertise. These issues include weed management on rural acreage, pasture management for hobby owners, reclamation of disturbed lands, irrigation water management and the use of new technology and automation of irrigation for homeowners.

Educational meetings, field tours, and other various events are sponsored by the University and other agencies and organizations in which Agricultural Experiment Station personnel have the opportunity to inform people about the latest developments in crop production and alert them to production problems and current management situations. Periodic field days and tours are conducted at WCRC-Fruita in which growers, agribusiness representatives, government agencies, colleagues, and friends can tour research in-progress, ask questions, and learn about new techniques for agriculture. Special tours, both at WCRC-Fruita and at off-station locations where farmer-cooperator research is situated, are conducted for growers, clubs, students and faculty, agribusiness representatives, industry groups, college/high school classes, foreign visitors, and others. These tours are designed to meet specific needs, requests, and interests. Community events, such as farmer markets, are popular attractions for the public and provide research center personnel with unique opportunities to interact with non-agricultural people.

Agricultural research findings obtained from our research conducted in the western Colorado region are communicated to broad audiences including scientific and agricultural groups and organizations, governmental and non-governmental agencies, private industry, service organizations, and policymakers by using a diversity of technical and popular media in written, oral, and electronic forms. Specific outreach products depend on the topic and target audience. These outreach products include the following: refereed journal articles, book chapters, proceedings, management guides, abstracts, newsletters, annual reports, technical reports, industry reports, progress reports, Powerpoint presentations, large format posters for technical and general audiences, popular magazine articles, websites (http://aes-wcrc.agsci. colostate.edu), conferences, field tours, workshops, personal consultations, videos, broadcasts, and interviews.

Over the years we have had tours and visitors from all over the world and from around the country and Colorado. We have consciously recognized that the local community watches us closely and we have actively attempted to maintain and improve the appearance and attractiveness of the research center. One year when we grew a block of sunflowers. We had a reporter write a story that was published in the local newspaper. At the end of the article the reporter invited the public to come by the research center to see the sunflowers in full bloom. Numerous people came into the research center while many people drove by on the paved road to have a look at this beautiful field of sunflowers. We had one mom dress her children alike and hired a professional photographer to take Christmas card pictures of her children in front of the flowering sunflowers. Just recently we had another professional photographer take pictures in the canola at full bloom of a mom pregnant with her second child.

The ability to conduct relevant research necessary to meet the future needs of agriculture in western Colorado for the next 50 years will continue to depend largely on support provided by various and numerous entities, research grants, and gifts obtained at the local, state, and federal levels, both public and private.

Agronomic research conducted over the years at WCRC-Fruita has required the efforts of many researchers and station staff. A list of professional staff, listed in the Appendix, acknowledges their service to western Colorado agriculture. Many other persons (summer interns, volunteers, students) not listed also participated and contributed to our mission at WCRC-Fruita.

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APPENDIX

The list of professional staff at the Western Colorado Research Center at Fruita shown below acknowledges their service and contributions to western Colorado agriculture. Numerous other people who worked as summer hourly, temporary employees, students, and interns are not listed, but their efforts toward fulfilling the mission of the Colorado Agricultural Experiment Station and the Western Colorado Research Center at Fruita are acknowledged and appreciated.

Norman Evans	Agricultural Engineer 1949-1957 (campus)
Doral Kemper	CSU/USDA-ARS, Soil Scientist, 1956-1961 (campus)
Forrest M. Wilhite	CSU/USDA-ARS, Soil Scientist, 1949-1970
Earl Cowley	SCS, Irrigation Engineer, 1949-1954
Minour Amemiya	CSU/USDA-ARS, Soil Scientist, 1950-1958
Agnes Crystal	Secretary, 1951-1955
C. L. Horton	USDA-ARS, Agricultural Aide, 1952-1962
Charlie Robinson	Assistant Agronomist-in-Charge, 1953-1974
M. M. Hastings	CSU/USDA-ARS, Irrigation Engineer, 1954-1958
Mrs. McFarland	Secretary, 1955-1956
Annie Ward	Secretary, 1956-1966
Betty Robinson	Secretary, 1957-1959
Sam Little	CSU/USDA-ARS, Soil Scientist, 1958-1959
Bill Pugh	Engineering Aide, 1958-1965
Sterling Davis	USDA-ARS, Irrigation Engineer, 1959-1962
Gilbert Schumaker	USDA-ARS, Soil Scientist, 1959-1964
Harold M. Golus	Associate Professor/Superintendent, 1960-1998
Max Martinez	Technician, 1960-1990
Floyd Bolton	Assistant Agronomist, 1962-1963
Orlando Howe	USDA-ARS, Irrigation Engineer, 1963-1970
Carl Barnes	Assistant Agronomist, 1964-1965
John Hoff	Assistant Agronomist, 1965-1968
Jonni Halman	Secretary, 1967-1968
Sam Shafer	Assistant Agronomist, 1968-1974
Jo Thames	Secretary, 1969
Evelyn Doty	Secretary, 1969-1970
Betty Gardner	Secretary, 1970 -1999
Dan Champion	USDA-ARS, Soil Scientist, 1973 -1989
John Keenan	Assistant Professor/Superintendent, 1974-1983
Woody Gregory	Technician, 1976-1978
Jim Coors	Research Associate, 1977-1978
Barry Furukawa	Research Associate, 1978-1979
Dave Young	Agricultural Engineer, 1979-1983
Bob Jump	Research Associate, 1980-1982
Bob Fox	Research Associate, 1982-1984
Ron Yoder	USDA-ARS, Agricultural Engineer, 1984-88
Calvin H. Pearson	Professor/Research Agronomist, 1984-2016
Dave Schreck	Research Associate, 1984-1985
Phil Miklas	Research Associate, 1985-1987
Robert W. Hammon	Regional Entomologist, 1988-2003

Fred Judson	Research Associate II, 1988 to present
Keith Berger	Coordinator, 1989
Bruce Majors	Coordinator, 1990
Lot Robinson	Research Associate, 1990-2005
Donna Rath	Research Associate, 2002-2008
John (Chip) Brazelton	Research Associate, 2005-2008
Greg Irwin	Research Associate, 2008-2012
Kevin Gobbo	Research Associate I, 2013 to present