Technical Report TR08-10

# Agricultural Experiment Station

Colorado State University

College of Agricultural Sciences

Western Colorado Research Center

Extension

# Western Colorado Research Center 2007 Annual Report

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**Funded by Colorado Agricultural Experiment Station and various sponsors.**

**Front Cover Photos clockwise from top left:**
**"Autumn Leaves" – Background photo by Bryan Braddy**
**"Fruita Lab" – Photo by Calvin Pearson**
**"Wheat Harvest" – Photo by Calvin Pearson**
**"NC140 Annual Meeting" – Photo by Harold Larsen**
**Composition by Susan E. Baker**

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# Introduction

Prices for many of the commodities grown in western Colorado were up in 2007 and provided some relief to producers and their business enterprises as they struggle to find ways to cover their increasing input costs. These rising input costs and rising land values continue to encourage farmers to look at new and alternate crops, alternate management approaches (including organic production), and marketing. As a consequence, producers continue to ask for information from researchers to meet these needs. The Western Colorado Research Center (WCRC) continues its mission of planning, implementing, and conducting research and outreach programs to address regional agricultural needs and help farmers find new answers and alternatives. This Annual Report provides information from some of the many research topics under investigation during 2007 (and prior in some cases). These include row and field crops, forage crops, orchard and vine fruit crops, and vegetable crops.

During 2007, the sunflower latex-rubber project grant funding expired and focus in the Fruita laboratory responsible for that work shifted to assessment of rubber content in samples submitted for evaluation; field studies at Fruita included new trials with malting barley, and continuing study of blunt-ear syndrome in corn, living mulch options for field corn production, Foundation Bean breeding program accession evaluations, and winter wheat, sunflower, alfalfa, and field corn variety trials. Work at WCRC-Rogers Mesa (RM) and WCRC-Orchard Mesa (OM) continued on the Uncompaghre revegetation projects, additional new and alternative options for orchard replant problems, alternative control options for Cytospora canker control, and phytoparasitic nematode impacts on virus disease spread and on crop production. Both NC-140 peach rootstock trials at WCRC-OM and WCRC-RM were removed in fall of 2006 due to the rootstock possibly carrying an imported disease. Therefore, no NC-140 coordinated trials remain in Colorado until the next plantings (planned for 2008 and 2009). The viticulture project completed the initial studies on grape rootstocks and removed the bulk of the Chardonnay grape planting; the main grape block at WCRC-OM now consists of Syrah grapes with new variety trials scheduled for planting at WCRC-OM and WCRC-RM for 2008. Winter hardiness and spring hardiness studies were expanded in 2007, as reflected by new information posted on our WCRC viticulture website in 2007. Thus the viticulture program continues to expand, as does the wine grape acreage within the state. The addition of a new Enology (wine making) research position to be based at WCRC-OM was approved in 2007 [and filled in early 2008 by Dr. Steven Menke; we are including some basic information about him in this 2007 Annual Report for our clientele].

We continue to update and expand our web page and link to the Tri-River Extension web pages for other information. This is increasingly important as more farmers adopt computers as an information management tool. We realize they have access to a wealth of free information on the worldwide web, and we are trying to do our part to provide information of value to them in that venue.

I gratefully acknowledge the effort that support staff and faculty have made in ensuring the successful completion of this year's projects. The accomplishments reported herein would not have been possible without their cooperation & effort, as well as that of the Colorado Agricultural Experiment Station and the department heads associated with this center. Funding support has been provided by many sources and are acknowledged in the individual reports by the authors.

Harold Larsen
Interim Manager, Western Colorado Research Center

## Agricultural Experiment Station - Western Colorado Research Center Site Descriptions

***Fruita Location:*** **1910 L Road**
Fruita, CO 81521
(970) 858-3629
(970) 491-0461 *fax*

WCRC - Fruita is an 80-acre property 15 miles northwest of Grand Junction. Site elevation is 4510 feet, average precipitation is slightly more than 8 inches, with an annual frost-free growing season of up to 175 days. Average annual daily minimum and maximum temperatures are 41° F and 64° F respectively. The primary soil types are Billings silty clay loam and Youngston clay loams. Irrigation is by way of gated pipe and furrows with ditch water from the Colorado River. Facilities at the Fruita site include an office building, shop, equipment storage building, field laboratory, tissue culture laboratory, and a dry bean conditioning facility. The Colorado State University Foundation Bean Project operations are managed at WCRC - Fruita. A comprehensive range of agronomic equipment is based at the site to facilitate research on a variety of agronomic crops.

***Orchard Mesa Location:*** **3168 B ½ Road**
Grand Junction, CO 81503
(970) 434-3264
(970) 434-1035 *fax*

WCRC - Orchard Mesa is located seven miles east and south of Grand Junction on B ½ Road. It lies at an elevation of 4,750 feet with Mesa clay loam and Hinman clay loam soil types. High temperatures average 93° F in July and 39° F in January. Lows average 64° F in July and 18° F in January. While the frost-free growing season averages 182 days, spring frost damage is frequent enough to be a production problem. Frost protection is provided by wind machines. Irrigation is by pressurized drip, micro-sprinkler and gated pipe systems supplied by ditch water from the Colorado River. Facilities at the Orchard Mesa site include an office-laboratory building with labs for plant pathology and viticulture research. Other buildings include a conference room, shop, and separate climate controlled and retractable roof greenhouses. Approximately twelve of the center's 80 acres are devoted to experimental orchards, principally apples, and peaches. Three acres are dedicated to wine grape variety trials and research. The balance of acreage is utilized for grass and alfalfa production or small demonstration plantings of other fruits. Additional acreage is also utilized on occasion for dry bean variety trials and seed increases in conjunction with the CSU dry bean breeding project and Foundation Seed Project.

***Rogers Mesa Location:*** **30624 Highway 92**
Hotchkiss, CO 81419
(970) 872-3387
(970) 872-3397 *fax*

WCRC - Rogers Mesa is located 17 miles east of Delta and 3 miles west of Hotchkiss on Colorado Highway 92. Site elevation is approximately 5,800 feet, average annual precipitation is about 12 inches, and the average frost-free growing season is 150 days. The primary soil types are Aquafria and Ultaline stony loams. High temperatures average 88° F in July and 42° F in January. Lows average 57° F in July and 18° F in January. Frost protection is provided by wind machines. Irrigation methods used include drip, micro-sprinklers, and furrow, all supplied from the Fire Mountain canal water. Facilities include an office-laboratoryconference room building, shop, residence, and greenhouse. Experimental orchards occupy approximately 8 acres, approximately half of which is managed organically. A wine grape block was planted in spring 2004 and expanded in 2008. Research plots for seed production of native forages and shrubs were established in 2004. Research efforts on conventional vegetable production began in 1998 and have since expanded to include organic options.

## Acknowledgments

- Dr. Ron Godin was editor. Susan Baker assisted in the editing of this publication. The assistance of all is much appreciated. We would also like to acknowledge the assistance of the following people farmer, cooperators, and staff:

- Bryan Braddy - Research Associate, Colorado State University, Western Colorado Research Center
- John Brazelton - Research Associate, Colorado State University, Western Colorado Research Center
- Canyon Wind Vineyard
- Daniel Dawson – Student hourly – Colorado State University, Western Colorado Research Center
- Derek Godsey – Coors Agronomist
- Fred Judson – Research Associate, Colorado State University, Western Colorado Research Center
- Jim Rohde – Field Manager, New Leaf Farms
- Kim Schultz - Research Associate, Colorado State University, Western Colorado Research Center
- Whitewater Hill Vineyards
- John Wilhelm - Research Associate, Colorado State University, Western Colorado Research Center
- Mike Williams - Farmer cooperator

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- Uncompahgre Plateau Project
- USDA-NRCS
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## Advisory Committee

The Western Colorado Research Center (WCRC) Advisory Committee has two roles - advocacy and advisory. The advocacy role is to actively promote WCRC research and outreach activities with policy makers, producers, and the general public. Advocacy is the primary mission of the Committee. The advisory role is to provide input and feedback on research and outreach activities conducted through the programs of the Western Colorado Research Center.

The members of the WCRC Advisory Committee for 2006 are listed below. Committee members serve voluntarily without compensation. WCRC Advisory Committee meetings are open to the public. For the current membership list please visit our web page (http://www.colostate.edu/programs/wcrc/).

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*Deceased in April 2008

# Value of Agriculture and Conducting Agricultural Research in Western Colorado

Calvin H. Pearson[1,2] and Harold Larsen[3]

## Summary

Colorado State University has been conducting agricultural research in western Colorado for nearly 86 years. The overall purpose of agricultural research is to promote the profitability of agriculture, be environmentally enhancing, and create sustainability for agriculture and society. The mission of the Western Colorado Research Center is to plan, implement, and conduct research and outreach programs to address the needs of western Colorado agriculture. The Western Region of Colorado contains 14 counties in northwest and west central Colorado with a land area of nearly 20 million acres, representing nearly 30% of the total land area of the state. This region of the state contains a large amount of land used for agriculture and the market value of the agricultural products in this region exceeds $260 million annually. Whether crops are sold directly, used for livestock production, or processed into commercial products, supporting agricultural production systems and operations through agricultural research continues to be important. To assist agricultural producers in the western Colorado region to be competitive in the market place and to develop sustainable and environmentally enhancing technology, local adaptive agricultural research must be ongoing.

## Introduction

Colorado State University has been conducting agricultural research in western **Colorado** for nearly 86 years. The overall purpose of agricultural research is to promote the profitability of agriculture, be environmentally enhancing, and create sustainability for agriculture and society. The mission of the Western Colorado Research Center (WCRC) is to plan, implement, and conduct research and outreach programs to address the needs of western Colorado agriculture.

WCRC is comprised of three research centers on the western slope: Fruita; Orchard Mesa at Grand Junction; and Rogers Mesa near Hotchkiss. WCRC scientific staff includes an agronomist, an entomologist, a horticulturist, a soil scientist, a plant pathologist, a viticulturist, and an enologist. These scientists are supported by a manager, five field support staff, an administrative assistant, research project staff, and summer hourly help.

There are various primary audiences we target as outlets for our research results and outreach efforts. As our traditional clientele we provide producers with information to help them in making crop production decisions. It is also important to work with private industry and companies to help them to determine which products and services to market and in which locations their products and services are best adapted and are best in end use applications. Lastly, we as university personnel develop new crop production technology and we use this new information to educate and inform our clientele.

Fred Judson standing in a winter wheat variety trial at Hayden, Colorado.

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WCRC scientists endeavor to meet emerging and recognized needs of the western Colorado agricultural community as the resources of WCRC and the Agricultural Experiment Station permit. Our research efforts are directed by the overarching need to address relevant challenges and issues, solve problems, and create opportunities in agriculture within the region and elsewhere.

The impact of research can depreciate or deteriorate over time and in the absence of ongoing and sustained research a decline in agricultural productivity may occur. Thus, relevant and effective agricultural research must be ongoing to prevent declines in agricultural productivity.

Investing in agricultural research from both private and Federal-State sources results in high, positive economic returns. A large number of scientific studies have shown that the rate of return from public agricultural research ranges from 20 to 60 percent (Fuglie and Heisey, 2007). Supporting agricultural research not only creates high returns on investment for both crop and livestock commodities but has other benefits:

● There are significant social returns associated with agricultural research. Both public and private ag research contribute to improved social factors by creating improved technology such as in manufacturing, chemicals, machinery, biotechnology, farming practices, and many others.

● There are long term benefits from agricultural research. Often there is a lag time before agricultural research results in tangible economic impacts, and new knowledge and technology developed from ag research will continue to contribute to productivity until it becomes obsolete and outdated.

● There are spillover effects from agricultural research across state and national boundaries. Agricultural research conducted in one specific state or region has application and affects productivity in other regions or even other countries.

**Western Colorado Region**

The Western Region of Colorado consists of 14 counties in northwest and west central Colorado (Fig. 1) with a land area of nearly 20 million acres (Table 1), representing nearly 30% of the total land area of the state. Farm/ranch size varies considerably across counties within the region and within some counties as noted by the median farm/ranch size (Table 1).

Donna Rath and Daniel Dawson working in Dr. Pearson's laboratory at WCRC- Fruita, Colorado.

The agriculture in these 14 counties varies considerably in the amount and type of agriculture that occurs in each county as evidenced by the amount and kind of cropland and whether the land is used to produce crops or livestock (Tables 2, 3). In total, this region of the state contains a large amount of land used for agriculture and the market value of the agricultural products in this region exceeds $260 million annually (Table 2).

The western Colorado region is unique, not only in geographic location, but also in agricultural production systems with opportunities, challenges, constraints, and limitations. High water alkalinity, desert vegetations, heavy soils, variable precipitation, seasonal water availability, and cold injury are some of the challenges. In some areas of the region such as the Craig/Hayden area, producers are mainly limited to wheat and forages, and this limits cropping options. Producers in the Craig/Hayden area and in other locations in the region are also isolated from many of their markets.

Due to rapid urbanization and energy exploration, land values are increasing, which, in

turn, affects agriculture in many ways. Thus, WCRC has a major role to play in developing and delivering agricultural production technology to address these challenges and create new options and opportunities for western Colorado agriculture.

When viewed as a region, there is a large diversity of crops grown in the western Colorado, making it unique in many aspects compared to the rest of the state. Throughout the region there is a wide range of agronomic crops along with a range of vegetable and fruit crops grown in specific locations within the region.

Non-animal agricultural production in the western Colorado regions is concentrated in

Strip tillage equipment operating in a living mulch study at WCRC-Fruita, Colorado.

Chaffee, Delta, Garfield, Mesa, Moffat, Montrose, Rio Blanco, and Routt counties. Traditional farm producers are coming under increasing pressure as urban sprawl, rural subdivisions, recreation, and energy exploration encroach on and impact farming areas.

An aging farmer population, unpredictable agricultural commodity prices, increasing production input costs, and high land values are prompting farmers to sell their properties in many areas. Consequently, both farm and the percentage of farmers solely reliant on agriculture for their livelihood are decreasing. While it is difficult to predict changes in land use patterns as a result of external changes that apply pressure to agriculture, it is likely that growers will need to develop alternative agricultural practices and operations that offer higher gross margins per acre.

## Research in the Western Colorado Region

Agronomic

To support western Colorado agriculture we have, in recent years, conducted and are currently conducting agronomic research on various crops, cropping systems, and related research. A broad research approach has been taken in order to address as many needs and create as many opportunities as possible.

Small grain variety performance testing has been ongoing in northwest Colorado for many years (Pearson et al., 2007; Pearson, 2006b; Pearson, 2005b; Pearson et al., 2004a; Pearson, et al., 2003b; Berrada et al., 2002; Golus et al., 1997). Small grain variety performance tests are conducted in northwest Colorado to identify varieties adapted for commercial production in the region.

Data 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 (Smith and Pearson, 2004; Brick et al., 2004). 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 will be profitable for seed production. Variety yield performance data 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 in western Colorado for many years (Pearson et al., 2006; Pearson, 2005c; Pearson, 2004g; Pearson et al., 2004b; Pearson et al., 2003a; Johnson et al., 2003a).

A considerable amount of forage research has been conducted at several locations for several years (Pearson, 2004a; Pearson, 2004b; Pearson, 2004c). Reports that summarize this forage

research have been widely distributed to ag producers, industry representatives, and various public agency personnel.

We have had a long history of conducting yield performance trials for alfalfa varieties (Pearson, 2007b; Pearson, 2004d; Pearson, 2004f) and other alfalfa production related topics (Pearson and Brummer, 2004; Pearson, 2004e). We have also worked cooperatively with industry representatives, particularly Forage Genetics Int'l, to test advanced alfalfa germplasm for its performance in western Colorado and to provide adaptation data to assist the alfalfa breeder at Forage Genetics to make selections for new alfalfa varieties. These varieties are subsequently sold to seed companies and made available to western Colorado growers for planting. Because selections are made under western Colorado field conditions, the varieties are well adapted to our local conditions.

Nighttime chilling study conducted in corn at WCRC-Fruita, Colorado.

Commercial acreages of soybean were grown in the Grand Valley of western Colorado in the 1980s. Because of yield variations, marketing problems, and low crop prices for soybean, commercial production of this alternative crop in the Grand Valley dwindled. In the intervening years since soybean production research was conducted in western Colorado, numerous new soybean cultivars have been developed. Roundup-Ready® soybean cultivars have been developed and are now widely used in commercial agriculture throughout the USA. Commercial production using Roundup-Ready cultivars allows considerable timing application flexibility and ease for controlling weeds during the growing season. In 2004, we conducted a soybean performance trial in which soybean cultivars from a broad range of maturity groups were evaluated at Fruita (Pearson, 2005a).

Corn hybrid performance trials have been conducted each year for many years in western Colorado (Johnson, et al., 2003b; Johnson et al., 2005, Johnson et al., 2006). We solicited corn seed companies each year and they chose the entries they wanted us to test. The companies paid a fee for each entry tested in each trial. Our testing program in western Colorado was part of a state testing program coordinated from campus by Dr. Jerry Johnson. 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 Delta. Over the past several years, the number of entries in these tests in western Colorado has been decreasing. We made the decision to end commercial corn hybrid testing in 2006. However, Grand Valley Hybrids, a corn hybrid breeding and seed company located in Grand Junction, proposed that we cooperate with them to do some corn grain hybrid testing in western Colorado. In 2007, we had three large trials at Fruita and another smaller yield trial at Delta, Colorado. Additionally, we conducted hybrid evaluation with Golden Harvest brand corn hybrids at the request of the JC Robinson Company (Pearson, 2008b).

Soft white winter wheat was grown in the valley areas of western Colorado for many years, but in the 1990s production dwindled. Growers have expressed interest in growing winter wheat again. In response to that interest, we conducted a winter wheat cultivar performance trial in 2007 and have planted a repeat trial in 2008 to identify winter wheat cultivars that are adapted to western Colorado. Given the new winter wheat cultivars that have been released in recent years and interest in market classes other than soft white wheat, we planted 18 winter wheat entries including soft white, hard white, and hard red winter wheat

cultivars. Data obtained from this study will aid growers and industry representatives to determine which cultivars and market classes could be produced in western Colorado in 2008.

Soil erosion and the high cost of fuel and fertilizers are critical issues that threaten the sustainability of agriculture. Integrating "living mulches" with no-till crop production practices can potentially offset these 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. The objectives of this research project on conservation tillage of corn in a kura clover living mulch are to: 1) determine methods of establishing various perennial plant species potentially adapted for use as living mulches under irrigation, 2) evaluate methods of suppressing living mulches that both conventional and organic producers can use to avoid reduced yields of associated crops, 3) quantify the environmental and economic benefits of using living mulch systems under irrigation. This project was initiated at Fruita, Colorado in 2006 and will continue for the next several years depending on our success in obtaining competitive grants (Pearson, 2006a).

In recent years, we have conducted studies on alternative crops that could be produced in western Colorado including native plants (Pearson et al., 2005) and hybrid poplar. We completed a 6-year study in 2005 on the performance of hybrid poplar when grown under an intensive, short-term rotation (Pearson et al., 2003c).

Currently, a biodiesel production facility in southwest Colorado is under construction by the San Juan Biodiesel Cooperative and is projected to be completed sometime mid-2008. The crops targeted for use in this facility are safflower, sunflower, and canola. Production of biodiesel in western Colorado will open the possibility of growing alternative crops such as sunflower and canola in western Colorado to supply vegetable oil for the biodiesel facility. We have conducted field trials with canola for three years (2005, 2006, 2007). Results from the 2005 and 2006 trials have been published (Pearson, 2006c; Pearson 2007c). In 2006 and 2007, we conducted field trials with thirty-two sunflower

Transplanting sunflowers in a fitness study at WCRC-Fruita, Colorado.

varieties for seed and oil yield and other agronomic characteristics to determine the potential for commercial production of sunflower under irrigation in western Colorado (Pearson, 2008b: Pearson, 2007a).

A collaborative research project was initiated in 2001 to transform sunflower into a rubber-producing crop. The overall objective of this research project on sunflower was to insert genes into sunflower to optimize rubber synthesis (Cornish et al., 2005). 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. Sunflower is notoriously recalcitrant to genetic transformation and regeneration when subjected to tissue culture. We have conducted various studies in an attempt to improve the regeneration success in sunflower (Rath and Pearson, 2004).

Alternatives to traditional corn/wheat/forage production will be an important research topic if the land currently in production is to remain in

agriculture. This research will address not only production, but also marketing, and social issues. Production research must include evaluating and integrating new technology into production practices and evaluating the cost/benefit relationship of such alternatives. Examples of the new technologies include genetically-altered crops such as Roundup-Ready corn, soybeans and alfalfa, geographic information systems for increasing production efficiency, or polyacrylamide additives to irrigation water to increase efficiency and decrease erosion.

Horticulture

Horticultural crops have been grown within the Grand Valley of western Colorado since the construction of the first irrigation canals in 1882 (Sexton, 1987). The potential for production of horticultural crops in western Colorado is considerable and diversified because of the area's mild climate and abundant irrigation water. High levels of solar radiation and warm daytime temperatures combined with cool nights and diverse microclimates result in outstanding nutritional and flavor qualities as well as excellent appearance for many fruit and vegetable crops. Disease and insect pressures are relatively low and new and alternative pest control technologies can often be introduced into the region.


Retractable roof greenhouse at WCRC-Orchard Mesa, Grand Junction, Colorado.

Needs of the horticultural industry include research on cropping consistency, preharvest and postharvest factors affecting fruit quality, insect and disease problems, and issues related to co-existence of agricultural and residential areas. Peach production has been highly profitable and its acreage is increasing and shifting to higher elevation sites. The apple industry has suffered from competition and oversupply of domestic and worldwide markets. To remain competitive, apple growers need to maximize efficiency and develop a stronger marketing program. With increasing consumer interest in organically-produced food crops, western Colorado producers have moved in recent years toward greater adoption of organic production, and needs for assistance in identifying and implementing organic production methods have stimluated interest in organic production research.

Colorado State University research response to these and earlier needs began in 1922 with the establishment of a fruit research station at Austin in that year. That facility was moved to Rogers Mesa and a sister facility opened at Orchard Mesa in Grand Junction in 1962. Yu et al. (1988) provide a summary of this extensive fruit research program across all sites for the period between 1922 and 1988. Hatch, Luepschen, and Bulla (1975) provide an overview of the research at the Orchard Mesa Research Center for the period 1962-1974. Retractable roof greenhouses were added in 2002 at WCRC-Orchard Mesa to facilitate horticultural research (Rogoyski et al., 2004).

Tree Fruit Crops

The majority of the tree fruit crops in Colorado are grown in Mesa and Delta counties. The principal tree fruit crops are peaches, apples, and pears along with some tart and sweet cherries. The value of fruit crops in Colorado, recognizing that most of this production is in Mesa and Delta counties, was estimated at $16.90 million in 2004 and $19.2 million in 2005.

Demand for Colorado fruit continues to be excellent and the region has enjoyed a long reputation for the quality of its fruit. However,

fruit production in western Colorado is impacted by a variety of challenges from year to year that include crop losses caused by freeze damage, pests, and disease. Other challenges for fruit production in the region are sufficient labor for producing fruits, competition from other fruit production areas outside the state, lack of profit from growing fruit crops, and urbanization pressure on fruit growing acreages.

Methods to manage risk of freeze or frost damage to fruit crops have been addressed through the years by numerous CSU researchers. Ure and Weimer (1972) reported on environmental factors affecting response to orchard heating. Orchard wind machines, which draw air from warm layers up above during temperature inversions, were examined by Doesken, McKee, and Renquist (1989) and by Renquist (1985). Methods to delay bud break were studied by Larsen, Stushnoff, and Rogoyski (2001). Wind machines and heaters are the predominant means of frost protection used at present, but grower interest in delaying bud break remains high if it can be worked out.

Rootstock can affect tree productivity and longevity, fruit size and quality, and labor availability and costs. Thus, it is important that growers select the appropriate rootstock that is adapted for the local climate, soils, and cultivars that are grafted to them. Twelve peach rootstocks were evaluated for five years at WCRC – Orchard Mesa and nine peach rootstocks were evaluated for four years at WCRC – Rogers Mesa as part of nationally coordinated (NC-140) trials (Pokharel et al., 2007a). The trials were terminated in 2006 because of a virus contamination of one rootstock. Similarly, a sweet cherry rootstock trial was planted in 1998 to evaluate thirteen rootstocks at WCRC – Rogers Mesa and was completed in 2006 (Pokharel et al., 2007b). Earlier rootstock trials have included peach (Reighard et al., 2004), apple, and pear. Other earlier studies looked at the use of plant growth regulators for peaches (Yu, 1989). And fruit variety trials were carried out for many years (e.g., Renquist, 1993) and referred to extensively by growers.

Hoarfrost on sweet cherry buds, WCRC-Orchard Mesa, Grand Junction, Colorado.

Crop load management is critical in managing fruit size and quality. Pruning is the first step in reducing crop size and establishing appropriate placement of the flower buds for needed light exposure, but chemical thinning has long been the mainstay for reducing labor required to thin apples. Rogoyski and Renquist (1992) described a computerized system for apple crop load management that used available chemical materials, but few options have been available for organic growers. Rogoyski and Renquist (2000) addressed this need with their two-step method for organic thinning of apples.

Irrigation management has been another area of study for tree fruits in western Colorado (Renquist, 1987 and 1989). Caspari and associates have looked at partial root zone drying as a means to manage water while keeping tree stress to a minimum (Caspari, 2006; Caspari et al., 2002a, b; Einhorn and Caspari, 2003; Einhorn et al., 2005a, b; Green et al., 2002, 2003; Lieb et al., 2002, 2006; Lombardini et al., 2002). Results of these studies have supported the idea that irrigation water may be far more efficiently used for tree fruit crops than previously thought without reducing fruit size and quality. Further studies are needed to confirm that there are minimal carry-over effects on tree productivity.

Disease control research has included many facets of study: pesticide efficacy studies for apple powdery mildew and Coryneum blight (shothole) of stone fruit, Cytospora canker (gummosis of stone fruits) control, study of phytoparasitic nematodes associated with fruit-

producing soils of western Colorado (Larsen and Nigh, 1986; Pokharel and Larsen, 2007c). Fungicide testing for apple powdery mildew control demonstrated the efficacy of newer fungicides and fungicide/adjuvant combinations as well as the impact of poor control (Larsen, 1987, 1988a, b, 1989a, b, 1990b, 2000a-d). The work on Cytospora canker of stone fruits developed new approaches to control (Larsen, 2000e, f); it currently is being extended to look at organic control options by pathology program personnel at WCRC.

Work on orchard replant problems began in 1985 and it took until 1995 to define the problem, assess the comparative efficacies of available control options, and assess their impact on tree growth and fruit production through Year 6 (Larsen, 1990a, 1995). The research demonstrated that proper site preparation and soil fumigation cumulatively increases peach production by 1,800 to 1,870 bushels per acre for Years 3 to 7 (when annual fruit production of trees planted in non-fumigated sites catches up with that for trees planted in fumigated sites). The value of this cumulative increased production provided by pre-plant fall soil fumigation (based on a conservative $18 / bu sale value for peaches) less the $2,600 - $6,400 / acre cost for site preparation, fumigant, and application is $27,000 - $31,000 per acre. Grower adoption of the resulting recommendations increased rapidly from 1990; in the fall of 1994, a total of 14,250 tree sites were treated (Fig. 2). Use of soil fumigation has decreased since 2000 due to decreased availability of methyl bromide (no longer available) and increased cost for the chloropicrin (tear gas, another effective material identified in early work) alternative despite its unpleasant characteristics and cost. Loss of methyl bromide has stimulated the search for other control options, including those acceptable for organic producers (Pokharel and Larsen, 2007a, b).

Work by Larsen on peach mosaic virus from 1987 to 1990 showed that yellow-fleshed freestone nectarines infected with peach mosaic virus exhibit similar symptoms to those exhibited by yellow-fleshed freestone peaches (Larsen, 1990c, 1996, 1997, 1999; Larsen and Oldfield, 1995; Larsen, Hatch, and Yu, 1997). This finding enabled modification of the quarantine against importation of yellow-fleshed freestone nectarines into Mesa County to allow their importation and provided opportunities for Mesa County fruit growers to grow yellow-fleshed freestone nectarines as an alternative crop to peaches. Collaboration with a researcher in British Columbia, Canada facilitated a definitive identification of the causal agent of peach mosaic as a virus closely related to, but distinct from, cherry mottle leaf virus (James et al., 2006).

Research on tree fruit insect pests has

Basin application of peach replant study treatments in a grower-cooperator orchard, 2004.

focused on insecticide and miticide efficacy trials, application timing, and identification of new pests as they emerged (Bulla, 1987; Doles, Zimmerman, and Moore, 2001; Cranshaw, Larsen, and Zimmerman, 2008; Nelson, 1987; Zimmerman, 1997-2006, 1999a, 1999b, and 1999d). Current research is being focused on the application of mathematical models to predict pest pressure based upon the insect's life cycle (Larsen, 2004) and the use of pheromone-based mating disruptors. Integrating the use of selective, rather than broad spectrum, pesticides into the spray program based upon insect life cycles has the potential to reduce costs to the grower and lessen the environmental impact of such practices. Novel technologies and organic approaches are also being examined as pest control options (Godin et al., 2006)

Nutrition and weed control in fruit orchards continue to be important topics of research. This includes work on different types of mulch and

impact on nutrition and weed control (Davis et al., 2001; Gaus, 1999). Two types of thermal weed control have been evaluated by Zimmerman (2005), and other alternatives for weed control and ground cover management have been studied by Godin et al. (2006).

Vegetables

Research for the vegetable industry is likely to be driven by producers searching for more profitable alternatives. The vegetable industry in western Colorado does not speak with one voice and tends to be opportunistic in the selection of crops to grow. The importance of green industries in western Colorado has been growing. This may require additional research support to address the unique challenges posed by the climate and growing conditions encountered on the west slope.

Vegetables are an important economic crop for western Colorado growers. Past research has looked at irrigation management options for Kubocha squash (Alam and Zimmerman, 2002, 2003; Zimmerman, 1999c), evaluation of pumpkin cultivars (Rogoyski, 1999), and evaluation of tomato and pepper varieties suited to western Colorado production (Zimmerman, unpublished). Horticultural and pest management research efforts are being increased in these areas by research center staff as programs are underway with a variety of crops to examine pest management strategies and identify conventional and organic approaches that can be implemented on a commercial scale.

Examples of sweet, chili, and paprika peppers in 2007 pepper variety trial at WCRC-Rogers Mesa, Hotchkiss, Colorado.

Research in fruit and vegetables is being directed toward developing strategies and programs that will assist growers in the transition from programs dependent upon broad-spectrum pesticides to programs utilizing a mix of narrow-spectrum management tools. Future pest management systems will have to be compatible with urban interfaces, especially if fruit production is to continue at its current level. Future pest management of secondary pests will have a strong emphasis on control by natural enemies, while control of primary pests will be dependent upon a mix of behavioral (i.e., mating disruption), biological and narrow-spectrum insecticides (insect growth regulators, viruses, bacteria and novel chemistries). Successful implementation will depend on both field and laboratory studies of pest populations, which will assist in developing information needed to economically and efficiently utilize new pest management tools.

Grapes

Wine grapes have been grown on a small number of acres in western Colorado during most of the 20th century, but over the last 20 years grape acreage has increased substantially. This is largely due to research in western Colorado over the last 20+ years (Mielke et al, 1980; Hammon, 1993; Hamman and Renquist, 1985). The largest growth industry in Colorado agriculture is grapes, although there are relatively few acres involved compared to other crops. Most grape acreage is concentrated in Mesa County and, according to the Colorado Fruit Tree/Vineyard Survey of 2002, more than 86% of the grape acreage is located within the western Colorado region. Wine grape acreage in Colorado was estimated to be 900 to 1,000 acres in 2007, with production demand exceeding supply.

With strong marketing and research support, the wine grape/winemaking industry is likely to continue to prosper in the coming years. Wine grape acreage is expected to exceed apple acreage within the next two years to become the second largest fruit crop in the state only exceeded by peaches.

Primary production concerns for the wine grape industry in western Colorado are winter

freeze damage, hail damage, disease control, and irrigation impact on fruit quality and vine survival. Cold hardiness studies and bud burst delay studies have been done in the last several years (Caspari et al., 2006; Caspari, Montano, and Larsen, 2007; Larsen and Caspari, 2002, 2004). A study of simulated hail damage to Chardonnay grape documented the impact of different timings and severity of hail injury to wine grapes (Caspari et al., 2003). Recent studies have been done to examine the relationship of crop load with grape quality and vine hardiness (Caspari et al., 2006). Caspari (2006) has also examined grapevine water requirements and irrigation scheduling.

Grape powdery mildew is the primary disease of Vitis vinifera grapes in Colorado. Although a study of biological control with a powdery mildew eating mite was less than successful (Norton, Larsen, and Caspari, 2005), other options have been developed (Larsen, 2005). As an alternative to a calendar-based spray program that many grape growers were using, an integrated disease management program was investigated over a 5-year period from 2002-2006 (Caspari and Larsen, 2007). Findings from this study indicated that growers can effectively control grape powdery mildew using a spray program that is reactive and treats only infection hotspots plus a buffer rather than blanket applications that are preventative. The reactive spray program can significantly reduce the number and amount of spray applications and associated costs for these applications.

Test of narrow (3 ft) vineyard tractor and sprayer for use in ultra-high density vineyards. WCRC-Orchard Mesa, Grand Junction,

Industry adoption of the resulting recommendations has been strong (Caspari and Larsen, 2007).

Grape pest problems in western Colorado have been relatively few. Leafhoppers, grape berry moth, and mites are the primary pests, with sphinx moth and flea beetles among the occasional problems. These have been studied by several researchers (Kondratieff and Cranshaw, 1994; Zimmerman et al., 1997) and solutions provided in the Colorado Grape Pest Management Guide (Larsen, 2006).

Ecological

Many other topics and issues related to agronomic and horticultural research are of importance beyond agriculture and have considerable impact off the farm. On farm production practices can affect the ecology of the surrounding region and have spillover effects that occur long distances from the farm. Some of these research topics are:

- Irrigation water management.
- Water quality.
- Proper fertilizer placement and application rates.
- Crop protection product evaluation and proper use.
- Crop residue management.
- Tillage and soil quality.
- Crop rotations and living mulches.
- Disease and insect control and management.
- Weed control and management.

These and other topics have been studied at WCRC over the years and will undoubtedly be studied in the future.

## Conclusion

Whether crops are sold directly, used for livestock production, or processed into commercial products, it continues to be important to conduct research on traditional, alternative, and novel agricultural production systems and operations. Local, adaptive agricultural research must be ongoing to assist agricultural producers in the western Colorado

region to be competitive in the market place and to develop sustainable and environmentally enhancing technology.

Agricultural research findings 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 depends on the topic and target audience and 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 (www.colostate.edu/programs/wcrc), conferences, field tours, workshops, personal consultations, videos, broadcasts, and interviews.

In addition to our traditional 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 an agricultural background. These issues include weed management on rural acreage, pasture management for hobby owners, reclamation of disturbed lands, irrigation water management and novel approaches to irrigation, and sustainable low input land uses.

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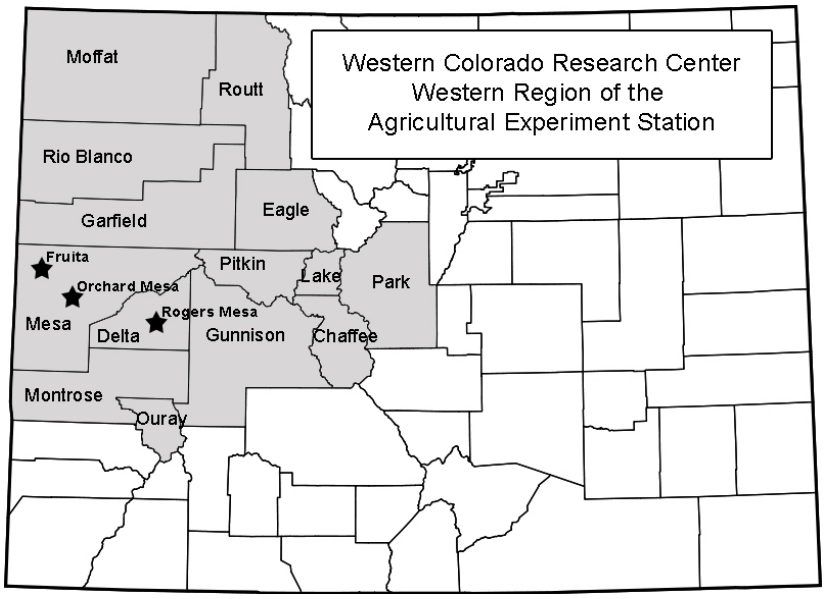


Fig. 1. The Western Region of the Agricultural Experiment Station and the three Research Center site locations at the Western Colorado Research Center.

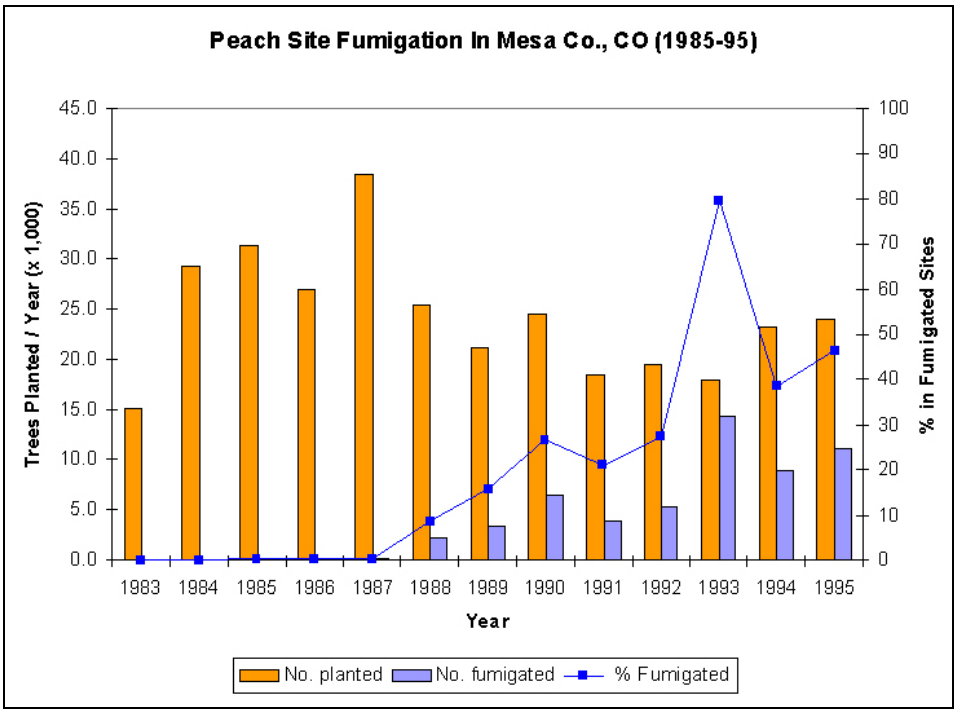


Fig. 2. Adoption of soil fumigation for peach orchard renovation in western Colorado, 1983-1995.

Table 1. The 14 counties served by the Western Colorado Research Center and their total land area, land in farms and ranches, number of farms, average size of farms/ranches, and median size of farms/ranches (Colorado Department of Agriculture, 2006).

| County | Land area (acres) | Land in farms and ranches (acres) | Number of farms (acres) | Average size of farms/ranches (acres) | Median size of farms/ranches (acres) |
|---|---|---|---|---|---|
| Chaffee | 649,035 | 71,188 | 212 | 336 | 110 |
| Delta | 735,644 | 262,443 | 1,063 | 247 | 50 |
| Eagle | 1,088,485 | 115,998 | 114 | 1,018 | 181 |
| Garfield | 1,893,267 | 404,335 | 499 | 810 | 110 |
| Gunnison | 2,085,900 | 165,488 | 186 | 890 | 320 |
| Lake | 245,475 | 17,253 | 34 | 507 | 268 |
| Mesa | 2,141,239 | 385,255 | 1,599 | 241 | 24 |
| Moffat | 3,043,751 | 1,017,612 | 443 | 2,297 | 400 |
| Montrose | 1,437,712 | 334,747 | 915 | 366 | 73 |
| Ouray | 347,075 | 108,088 | 96 | 1,126 | 200 |
| Park | 1,413,990 | 298,286 | 217 | 1,375 | 288 |
| Pitkin | 621,036 | 23,872 | 84 | 284 | 75 |
| Rio Blanco | 2,064,791 | 376,509 | 245 | 1,537 | 305 |
| Routt | 1,511,750 | 450,239 | 593 | 759 | 188 |
| Total/Ave | 19,279,150 | 4,031,313 | 6300 | 842 | 185 |

Table 2. The 14 counties served by the Western Colorado Research Center and their total cropland, irrigated land, market value of ag products, value of all crops sold, and value of all livestock sold (Colorado Department of Agriculture, 2006).

| County | Total cropland (acres) | Irrigated land (acres) | Market value of ag products sold ($) | Value of all crops sold ($) | Value of all livestock sold ($) |
|---|---|---|---|---|---|
| Chaffee | 26,257 | 8,818 | 8,536,000 | 2,195,000 | 6,342,000 |
| Delta | 79,134 | 54,184 | 39,077,000 | 14,413,000 | 24,664,000 |
| Eagle | 16,639 | 9,306 | 3,749,000 | 302,000 | 3,447,000 |
| Garfield | 76,277 | 34,217 | 22,771,000 | 7,077,000 | 15,694,000 |
| Gunnison | 58,608 | 41,219 | 9,139,000 | 982,000 | 8,157,000 |
| Lake | 3,936 | 516 | 365,000 | | |
| Mesa | 119,920 | 66,052 | 59,224,000 | 29,554,000 | 29,667,000 |
| Moffat | 161,643 | 22,629 | 20,179,000 | 1,102,000 | 19,077,000 |
| Montrose | 106,613 | 75,459 | 57,991,000 | 21,039,000 | 36,952,000 |
| Ouray | 15,342 | 10,548 | 3,234,000 | 394,000 | 2,840,000 |
| Park | 45,649 | 10,827 | 4,198,000 | 229,000 | 3,969,000 |
| Pitkin | 4,913 | 6,374 | 754,000 | 218,000 | 536,000 |
| Rio Blanco | 73,167 | 23,239 | 12,921,000 | 1,111,000 | 11,810,000 |
| Routt | 136,211 | 35,844 | 25,161,000 | 2,141,000 | 23,021,000 |
| Total | 924,309 | 399,232 | 267,299,000 | 55,788,000 | 127,872,000 |

Table 3. Market value of all hay, market value of corn for grain, market value of wheat, and the total of all three for 14 counties in western Colorado in 2005 (Colorado Department of Agriculture, 2006).

| County | Market value of all hay ($) | Market value of corn for grain ($) | Market value of wheat ($) | Total value of hay, corn for grain, and wheat ($) |
|---|---|---|---|---|
| Chaffee | 2,180,000 | - | - | 2,180,000 |
| Delta | 7,240,000 | 1,552,500 | 170,850 | 8,963,350 |
| Eagle | 2,900,000 | - | - | 2,900,000 |
| Garfield | 9,410,000 | - | 33,500 | 9,443,500 |
| Gunnison | 2,270,000 | - | - | 2,900,000 |
| Lake | - | - | - | - |
| Mesa | 11,080,000 | 607,500 | 1,366,800 | 13,054,300 |
| Moffat | 7,110,000 | - | 994,950 | 8,104,950 |
| Montrose | 11,190,000 | 2,925,000 | 73,700 | 14,188,700 |
| Ouray | 1,140,000 | 906,750 | - | 2,046,750 |
| Park | 860,000 | - | - | 860,000 |
| Pitkin | 760,000 | - | - | 760,000 |
| Rio Blanco | 6,340,000 | - | 77,050 | 6,417,050 |
| Routt | 5,930,000 | - | 569,500 | 6,499,500 |
| Total | 68,410,000 | 5,991,750 | 3,286,350 | 77,688,100 |

# Small Grain Variety Performance Test at Hayden, Colorado 2007

Calvin H. Pearson, Scott Haley, and Jerry J. Johnson[1]

## Summary

Each year small grain variety performance tests are conducted at Hayden, Colorado to identify varieties that are adapted for commercial production in northwest Colorado. Nineteen varieties were evaluated in the 2007 winter wheat variety performance test conducted at Hayden. Growing conditions during the 2007 cropping season in Hayden were favorable for winter wheat production. Grain yield in the winter wheat variety performance test averaged 3200 lbs/ac (53.3 bu/ac). The highest yielding entry was TAM 111 at 3573 lbs/acre (59.6 bu/ac). Many winter wheat varieties were high yielding, with thirteen varieties having higher yields than the other six. Protein concentration averaged 9.5% and ranged from a high of 10.8% for the variety Hayden to a low of 8.3% for Ripper.

## Introduction

Small grain variety performance testing has been ongoing in northwest Colorado for many years (Pearson et al., 2007; Pearson et al., 2005; Pearson et al., 2004; Pearson et al., 2003; Golus et al., 1997). Small grain variety performance tests are conducted in northwest Colorado each year to identify varieties adapted for commercial production in the region. The 2007 winter wheat variety performance test was conducted at Hayden, Colorado.

## Materials and Methods

Nineteen winter wheat varieties and breeding lines were evaluated during the 2007 growing season at the Mike Williams Farm near Hayden (Fig. 1). The experimental design was a randomized complete block with four replications. Plot size was 4-ft. wide by 40-ft. long with six seed rows per plot. The seeding rate was 680,000 seeds/ac and planting occurred on 28 Sept. 2006. The elevation at the plot location was 6483 feet above sea level. No fertilizer, herbicides, or insecticides were applied to the plots. Harvest occurred on 10 Aug. 2007 using a small plot combine. Grain samples were cleaned in the laboratory using a small Clipper cleaner to remove plant tissue that remained in the grain sample following combining. Grain moistures and test weights were determined using a DICKEY-john GAC2100b™ Grain Analysis Computer[2]. Grain yields were calculated at 12% moisture content. Protein concentration was determined by whole grain near infrared reflectance spectroscopy with

Fig.1. Calvin Pearson measuring plant height and Arielle Koehler recording the data. These data were collected from the winter wheat variety performance test plots at Hayden, Colorado just prior to harvesting wheat on 10 Aug 2007. Photo by Fred Judson.

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a Foss NIRSystems 6500 (reported on a 12% moisture basis).

## Results and Discussion

The 2006-2007 growing season in the Craig/Hayden area was favorable for winter wheat production. The average maximum temperature for July 2007 at Hayden, Colorado was 89.9EF (Fig. 2). Precipitation at Hayden during the 2006-07 winter/spring growing season (September 2006 through July 2007, 11-month period) totaled 16.83 inches. Winter moisture in the Hayden area was good. During September 2006 through February 2007 a total of 11.19 inches of precipitation was received, and from March through July 2007 a total of 5.64 inches of precipitation was received at Hayden (Fig. 3).

Precipitation in the Craig/Hayden area varies considerably from month to month and year to year and is a critical factor affecting crop production. If timely precipitation occurs, grain yields of winter wheat can be increased significantly as occurred in 2006 (Pearson et al., 2007). If precipitation does not occur in a timely fashion, grain yields of wheat can be low. Because precipitation is so variable during the growing season in the Craig/Hayden area, wheat yields often vary considerably from year to year.

Grain moisture in the winter wheat variety performance test at Hayden averaged 9.1% (Table 1). Grain moisture content ranged from a high of 9.6% for Danby to a low of 8.6% for Juniper.

Grain yield for the winter wheat varieties averaged 3200 lbs/acre (53.3 bu/acre). Grain yield ranged from a high of 3573 lbs/acre (59.6 bu/acre) for TAM 111 to a low of 2662 lbs/acre (44.4 bu/acre) for Hayden. Many winter wheat varieties were high yielding, with thirteen varieties having higher yields than the other six.

Test weights averaged 59.9 lbs/bu. Test weights ranged from a high of 62.9 lbs/bu for Danby to a low of 57.5 lbs/bu for Gary.

There was no lodging in the winter wheat variety performance test in 2007 (Fig. 1).

Plant height averaged 29.0 inches. Plant height ranged from a high of 37.2 inches for Juniper to a low of 25.4 inches for NuDakota.

Protein concentration averaged 9.5% and ranged from a high of 10.8% for the wheat variety Hayden to a low of 8.3% for Ripper. Three varieties (Hayden, Darwin, and UT9325-55) had protein concentrations above 10%. It is well known that there is a significant negative correlation between grain yield and grain protein. Grain yield and grain protein data clearly showed that relationship in 2007 at Hayden.

## Acknowledgments

The farmer-cooperator for this trial was Mike Williams. We thank Mike for his willingness to participate with us year after year in conducting this research. We also thank Fred Judson, Chip Brazelton (Western Colorado Research Center staff), and Daniel Dawson (part-time hourly employee) who assisted with this research. Appreciation is also extended to the Colorado Wheat Administrative Committee for funding this research.

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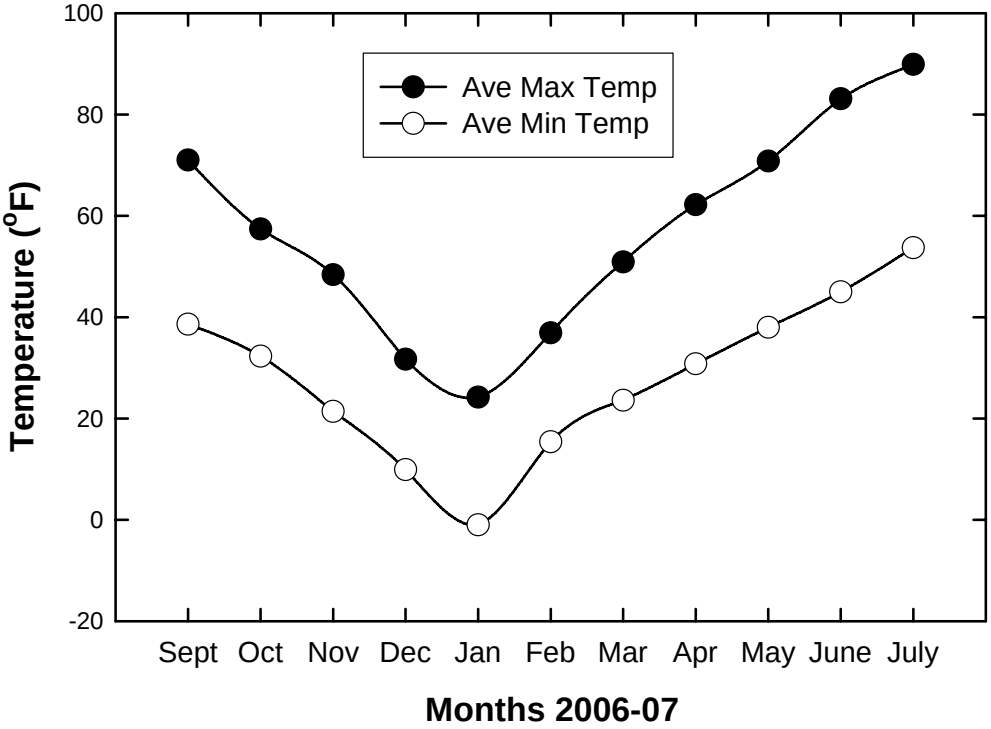
Table 1. Winter wheat variety performance test at Hayden, Colorado 2007. Farmer-Cooperator: Mike Williams.

| Variety | Market class[1] | Grain moisture | Grain yield | | Test weight | Plant height | Protein |
|---|---|---|---|---|---|---|---|
| | | (%) | bu/acre | lbs/acre | lbs/bu | in. | (%) |
| TAM 111 | HRW | 9.5 | 59.6 | 3573 | 60.4 | 29.1 | 9.2 |
| Ripper | HRW | 9.1 | 59.0 | 3538 | 59.8 | 25.9 | 8.3 |
| Ankor | HRW | 9.3 | 58.6 | 3515 | 59.9 | 29.2 | 9.3 |
| Hatcher | HRW | 8.8 | 57.6 | 3458 | 59.3 | 26.1 | 8.7 |
| IDO641 | HWW | 9.1 | 57.6 | 3456 | 59.2 | 27.6 | 9.3 |
| Gary | HWW | 9.0 | 57.0 | 3418 | 57.5 | 29.5 | 9.5 |
| Avalanche | HWW | 9.2 | 55.7 | 3340 | 61.3 | 27.5 | 9.5 |
| Darwin | HWW | 9.4 | 55.2 | 3312 | 61.4 | 31.1 | 10.5 |
| Bond CL | HRW (CL) | 9.2 | 55.2 | 3311 | 59.3 | 29.6 | 8.8 |
| Above | HRW (CL) | 9.0 | 52.0 | 3119 | 59.8 | 26.8 | 9.2 |
| Juniper | HRW | 8.6 | 51.9 | 3117 | 60.8 | 37.2 | 9.8 |
| NuDakota | HWW | 9.1 | 52.0 | 3116 | 58.6 | 25.4 | 9.7 |
| UT9325-55 | HRW | 8.9 | 51.6 | 3100 | 58.7 | 30.7 | 10.4 |
| Deloris | HWW | 9.1 | 50.5 | 3033 | 59.3 | 30.8 | 9.7 |
| Golden Spike | HWW | 8.7 | 50.4 | 3024 | 57.9 | 30.1 | 9.2 |
| UT9508-88 | HRW | 9.3 | 49.8 | 2990 | 59.6 | 29.4 | 9.8 |
| Jagalene | HRW | 9.1 | 48.7 | 2923 | 60.9 | 26.8 | 9.2 |
| Danby | HWW | 9.6 | 46.5 | 2790 | 62.9 | 26.3 | 9.7 |
| Hayden | HRW | 9.2 | 44.4 | 2662 | 60.8 | 32.0 | 10.8 |
| Ave. | | 9.1 | 53.3 | 3200 | 59.9 | 29.0 | 9.5 |
| LSD (0.05) | | 0.3 | 9.0 | 540 | 0.8 | 1.6 | |
| CV (%) | | 2.1 | 11.9 | 11.9 | 0.9 | 4.0 | |

[1] HRW = hard red winter wheat; HWW = hard white winter wheat; CL = Clearfield* wheat.




Temperatures for Sept 2006 through July 2007 at Hayden, Colorado.

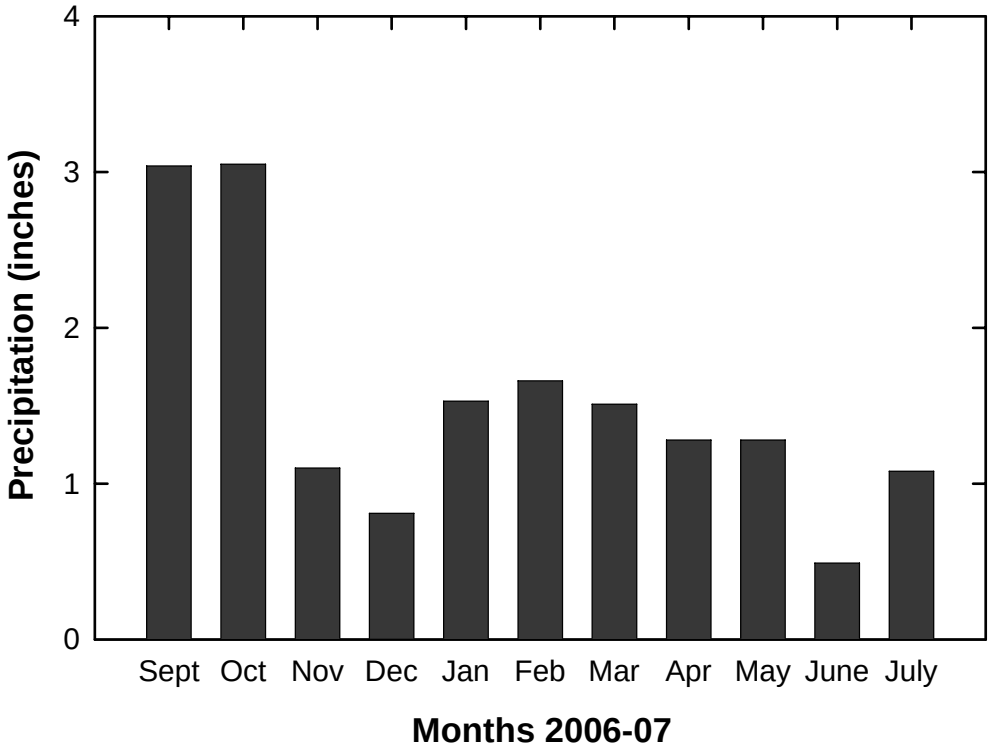



Fig. 3. Monthly precipitation for Sept. 2006 through July 2007 at Hayden, Colorado.

# Winter Wheat Variety Performance Trial at Fruita, Colorado 2007

Calvin H. Pearson, Scott Haley, and Jerry Johnson[1]

## Summary

After years of limited production, producers in the area have again become interested in growing winter wheat. Because of the limited commercial production of winter wheat it has been several years since we have conducted a winter wheat variety performance trial in the Grand Valley. During 2007 we evaluated 18 winter wheat varieties comparing those that have been recently developed to those that have been traditionally grown in Western Colorado. Grain yields of the winter wheat varieties averaged 7361 lbs/acre (122.7 bu/ac). Grain yields ranged from a high of 8526 lbs/ac (142.1 bu/ac) for Bond CL to a low of 5833 lbs/ac (97.2 bu/ac) for Hayden. Grain moisture averaged 10.7% and test weights averaged 60.1 lbs/bu. Protein concentration averaged 9.4% and ranged from a high of 10.9% for Juniper to a low of 8.9% for Golden Spike. Some of the new varieties had grain yields that were comparable to or greater than those of varieties that have been traditionally grown in the Grand Valley.

## Introduction

Commercial production acreage of irrigated winter wheat in western Colorado has varied over the years. After years of limited production, producers in the area have again become interested in growing winter wheat. Furthermore, it has been several years since we have conducted a winter wheat variety performance trial in the Grand Valley (Pearson et al., 2000).

Various factors influence producers in deciding what crops to plant on their farm. The recent increases in the price of wheat have been an encouragement for growers to plant winter wheat. Other factors that may encourage producers to plant wheat are: 1) winter wheat often works well into crop rotations in western Colorado, 2) growing winter wheat may spread out growing season workloads, and 3) growing winter wheat may free up irrigation water that may be needed later in the growing season for other crops such as alfalfa and corn.

Production technology is continually changing and this creates a need to evaluate winter wheat varieties, particularly those that have been recently developed in the intervening years and compare them to winter wheat varieties that were popular in past years.

Variety yield performance data can be used by various farmers when selecting varieties to plant on their farms, seedsmen in knowing which varieties to grow and nuances about growing the varieties, companies, to determine which varieties to market and in which locations

Figure 1. Harvesting winter wheat plots at the Western Colorado Research Center at Fruita on 25 July 2007. Photo by Calvin Pearson.

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varieties are best adapted and are best in end use applications, and university personnel, in developing new wheat production technology and in educating people about the varieties researchers have tested.

During 2007, we evaluated 18 winter wheat varieties comparing those that have been recently developed to those that have been traditionally grown in Western Colorado.

### Materials and Methods

Eighteen winter wheat varieties were evaluated at the Western Colorado Research Center at Fruita during 2007. The trial location was at N 38° 10.826', W 108° 42.046'; and at an elevation of 4583 feet. The experiment was a randomized, completed block with four replications. Prior to winter wheat, the field was a hybrid poplar plantation for six years.

Planting occurred on 3 Nov 2006 at 120 lbs seed/ac. Urea at 75 lbs N/ac was applied topdress on 3 March 2007. Harmony Extra2 at 0.6 oz/ac plus 10 oz/A of 2,4-D amine was applied by ground in 22 gal water/ac at 22 psi on 3 Apr 2007.

The experiment was furrow-irrigated using gated pipe. Winter wheat plots were harvested on 25 July 2007 using a plot combine. Grain moistures and test weights were determined using a Dickey-John GAC 1200B seed analyzer. Protein concentration was determined by whole grain near infrared reflectance spectroscopy with a Foss NIRSystems 6500 (reported on a 12% moisture basis).

## Results and Discussion

Weed control was excellent during the growing season. Adequate irrigation water was available during the growing season and was not a limiting factor for crop production. Seven irrigations were applied to the winter wheat beginning with the germination irrigation in fall 2006 and ended with the last irrigation during mid-June 2007 (Table 1).

Grain moisture in the winter wheat variety performance trial at Fruita averaged 10.7% (Table 2). Grain moisture content ranged from a high of 11.3% for Darwin to a low of 9.9% for Juniper.

Grain yields of the winter wheat varieties averaged 7361 lbs/acre (122.7 bu/ac). Grain yields ranged from a high of 8526 lbs/acre (142.1 bu/ac) for Bond CL to a low of 5833 lbs/acre (97.2 bu/ac) for Hayden. Many winter wheat varieties were high yielding with eleven varieties having higher yields than the other seven.

Stephens is a soft white winter wheat and has been grown traditionally in the area for many years. Tubbs 06 is also a soft white winter wheat and is considered to be the replacement variety for Stephens. Tubbs 06 yielded 18.8 bu/ac more than Stephens.

Test weights averaged 60.1 lbs/bu. Test weights ranged from a high of 62.9 lbs/bu for Danby to a low of 57.6 lbs/bu for Lambert and Stephens.

Days to flowering averaged 136 days. Seven varieties began flowering at approximately 133 days while Simon and UI 99-22407 required 141 days to reach flowering.

Plant height averaged 39.3 inches. Plant height ranged from a high of 53.2 inches for Juniper to a low of 29.8 inches for Tubbs 06.

Some lodging occurred in the trial. The variety with the most lodging was Hayden (4.0). Despite Juniper being the tallest variety it did not lodge near as much as Hayden. There was a small amount of lodging (less than 1.5) for other varieties as compared to Hayden.

Protein concentration averaged 9.4% and ranged from a high of 10.9% for Juniper to a low of 8.9% for Golden Spike. Five varieties (Darwin, Gary, Juniper, Akron, and Stephens) had protein concentrations at 10% or higher.

## Acknowledgments

Appreciation is extended to Fred Judson and Chip Brazelton (Western Colorado Research Center staff), and Daniel Dawson (part-time hourly employee) who assisted with this project.

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Table 1. Irrigations for winter wheat grown at Fruita, Colorado during the 2007 growing season.

| Irrigation number | Date | Set time (hours) |
|---|---|---|
| 1 | 11/3/06 | 16 |
| 2 | 4/16/07 | 17 |
| 3 | 4/30/07 | 24 |
| 4 | 5/12/07 | 12 |
| 5 | 5/24/07 | 16 |
| 6 | 6/2/07 | 6 |
| 7 | 6/18/07 | 13 |

Table 2. Agronomic characteristics of winter wheat varieties evaluated at Fruita, Colorado during 2007.

| Variety | Market class* | Grain moisture | Grain yield** | | Test weight | Days to flower† | Plant height | Lodging | Protein |
|---|---|---|---|---|---|---|---|---|---|
| | | (%) | lbs/ac | bu/ac | lbs/bu | no. | in. | 0.2-9.0 | (%) |
| Bond CL | HRW | 10.5 | 8526 | 142.1 | 62.0 | 133 | 38.9 | 1.3 | 9.8 |
| Tubbs 06 | SWW | 10.6 | 8395 | 139.9 | 58.1 | 140 | 29.8 | 0.2 | 9.1 |
| UI 99-22407 | SWW | 11.1 | 8297 | 138.3 | 58.5 | 141 | 39.2 | 0.2 | 9.6 |
| Bill Brown | HRW | 11.1 | 8255 | 137.6 | 61.2 | 133 | 33.9 | 0.9 | 9.6 |
| Gary | HWW | 10.6 | 7688 | 128.2 | 59.5 | 136 | 44.4 | 1.3 | 10.0 |
| Simon | SWW | 10.3 | 7600 | 126.7 | 58.9 | 141 | 38.1 | 0.2 | 9.8 |
| Danby | HWW | 11.1 | 7426 | 123.8 | 62.9 | 133 | 36.8 | 1.1 | 9.2 |
| Golden Spike | HWW | 10.2 | 7364 | 122.8 | 60.4 | 140 | 42.7 | 0.6 | 8.9 |
| Fairview | HRW | 10.0 | 7313 | 121.9 | 60.8 | 136 | 42.0 | 1.1 | 9.6 |
| Hatcher | HRW | 11.0 | 7292 | 121.5 | 60.8 | 133 | 37.1 | 0.5 | 9.6 |
| Stephens | SWW | 10.4 | 7269 | 121.1 | 57.6 | 137 | 36.1 | 0.4 | 10.1 |
| Brundage | SWW | 10.7 | 7197 | 120.0 | 60.2 | 133 | 33.2 | 0.2 | 5.0 |
| Akron | HRW | 10.8 | 7187 | 119.8 | 61.2 | 133 | 38.2 | 1.3 | 10.5 |
| Darwin | HWW | 11.3 | 7173 | 119.5 | 61.5 | 139 | 42.8 | 0.6 | 10.5 |
| Alice | HWW | 10.9 | 6969 | 116.1 | 60.0 | 133 | 33.1 | 0.2 | 9.9 |
| Lambert | SWW | 11.0 | 6560 | 109.3 | 57.6 | 137 | 38.5 | 0.2 | 9.1 |
| Juniper | HRW | 9.9 | 6162 | 102.7 | 59.7 | 139 | 53.2 | 1.4 | 10.9 |
| Hayden | HRW | 11.0 | 5833 | 97.2 | 60.4 | 139 | 48.5 | 4.0 | 9.1 |
| Ave | | 10.7 | 7361 | 122.7 | 60.1 | 136 | 39.3 | 0.9 | 9.4 |
| LSD (0.05) | | 0.4 | 1278 | 21.3 | 0.9 | 0.5 | 6.4 | 1.4 | |
| CV (%) | | 2.8 | 12.2 | 12.2 | 1.1 | 0.3 | 11.6 | | |

* HRW = hard red winter wheat; HWW = hard white winter wheat; SWW = soft white winter, CL = Clearfield wheat.
** Table is arranged by decreasing grain yield.
† Determined from 1 January.

# Plant Parasitic Nematodes Associated with Fruit Crops in Western Colorado

R. R. Pokharel[1] and H.J Larsen[2]

## Summary

Western Colorado fruit growers are increasingly concerned about reduced crop yield caused and mediated by plant parasitic nematodes (PPN). PPN predispose plants to soilborne pathogens, some vector plant viruses, and often go unnoticed. To find out the incidence and the importance of these PPN, surveys were conducted in grapes, cherry, peach, apple, pear, apricot and prune orchards throughout western Colorado. The PPN were extracted, identified and counted. Prune and apricot orchards followed by apple had the highest densities of PPN. High densities and frequency of dagger nematode and associated nepovirus infections indicated a need for further work. Endo-parasitic nematodes like root-knot nematode in prunes and apricots, root-lesion in apples and grapes, and citrus nematode in prunes also warrant further study. The density and genera of PPN varied with location, crop and varieties sampled. To evaluate the reaction of 14 cherry rootstocks, PPN were assessed in a 5 year-old rootstock evaluation experiment. Observed PPN population densities from these rootstocks were highly variable and no rootstock had extremely low population densities of the major PPN genera.

## Introduction

Fruit production in the Western Colorado is important and is concentrated in the valleys and drainages of the Colorado, Gunnison and Uncompaghre Rivers with some additional fruit cultivation scattered in other parts of the state. Commercial fruit production includes peach, grape, cherry, apple, apricot, plum, prune and other minor fruit crops. Although fruit acreage, especially apples has declined since 1985, peach acreage has held steady at 2000 acre and grape acreage has increased twenty-fold to over 800 acres (USDA, 2007). Colorado-grown fruits are known for their unique taste, color and luster. The climate is also unique with hot summer days to snowy winters with low rainfall. The Colorado River and tributaries are the only water source for irrigation and contribute to increasing soil alkalinity and/or salinity, a major issue to the fruit growers. Pest (insects, weeds and diseases) pressure in these fruit orchards is lower than in other fruit growing areas of the US, but does occur and varies with localities, crops and varieties grown because of microclimate differences over short distances.

Growers' main need for pest control is identification of efficient, cost effective and easy management options as well as appropriate treatment timing. Monitoring and spraying with insecticide as needed help growers to manage the insects, and regular sprays of herbicide help to manage the weed pressure. However, some diseases are rather difficult to manage because they have few management options available; these include plant virus and virus-like diseases, nematodes and some bacterial diseases. Though growers get certified planting materials, they still face problems of virus and virus-like disease. Some of these diseases are well managed by strict quarantine and management of clean plant

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materials. Most of the virus diseases are difficult to manage, especially the ones that with poorly known causes, origins or transmission of these diseases. Nematode borne viruses could be managed by managing nematode vectors, but adequate information on both the nematode vector and the viruses is required. Because management of these nematodes is expensive with decreasing alternatives available, most go untreated. In addition to this, limited information is available on these PPN in the western Colorado fruit orchards. Most of these PPN produce no specific symptoms in the foliage, and it is difficult to observe them in roots or see root symptoms as these roots are buried deep in the soil. There is very little or no attention paid to these plant parasitic nematodes by the growers.

Presence of these nematodes associated with different fruit crops is already reported through a survey in the State of Colorado (Niles and McIntyre, 1997). However, information on their importance in different crops, localities and soil types is limited. Moreover, information on nematodes associated with minor crops is lacking and the impact of nematodes like root-knot, root lesion and dagger in these fruit orchards is not clear. Based on the results of other locations, above mentioned genera could be important, the first two as endopasites and the latter one as virus vector. Tomato ring spot, cherry rasp leaf, Prunus necrotic ring spot virus and peach latent mosaic viroid in fruit trees are the most common virus and virus-like diseases prevalent in the Western Colorado fruit orchards/vineyards along with some sporadic incidence of the grape leaf roll virus, prune dwarf virus, apple mosaic virus, cherry mottle leaf, peach wart and transmissible internal bark necrosis viruses (Larsen, personal observation). Out of these, tomato ring spot virus (causing apple union necrosis, stem pitting in Prunus and cherry, and peach yellow bud mosaic) and cherry rasp leaf virus (causing cherry rasp leaf and flat apple disease) are transmitted by dagger nematodes and cause significant negative impact in fruit industries, by decreasing productivity and life span of trees, especially the cherry industry. The only management option for these nematode-borne viruses available to the growers would be managing the nematode vector to these nematode borne viruses. However, knowledge on the distribution, diversity and density of these nematodes would be very helpful for their management and for enhancing profitability of these industries. Moreover, the effective nematode management strategies and practices differ with the genera and the numbers of the PPN present in an area, and with potential of the crop to harbor the nematode genera or species. Work on PPN in other areas in different crops have indicated that these PPN could be problematic based on the crops grown, varieties and soil types. Thus surveys were carried out in fruit orchards to understand the distribution patterns of PPN. In addition to this, because use of rootstocks resistant to these nematodes could help manage the nematode-borne virus diseases, sampling was done from a NC-140 sweet cherry rootstock evaluation trial at Rogers Mesa to examine the level of PPN associated with these different rootstocks.

## Materials and Methods

Surveys were carried out in Orchard Mesa, East Orchard Mesa, the Redlands area of the Grand valley, Dominguez Canyon, Rogers Mesa and Pinion Mesa in different seasons but mostly in the Spring of 2007. During these surveys, soil samples were collected from different fruit orchards of peach, grape, sweet cherry, chokecherry and tart cherry, apple, pear, apricot, plum and prunes, to determine the importance of plant parasitic nematodes in different crops, soil types and localities by examining their diversity and densities with soil types (coarse versus fine textured), locations and crops. In addition to this, samples from Colorado Spring were also collected from different crops as well as from wild chokecherry, tart cherry, hawthorn (wild relative of apple) and some abandoned 50 year-old apple trees mostly from the Grand Mesa plateau above the Grand Valley. One sample, consisting of five sub-samples (except few locations) from 5 random trees covering

an area of up to 5 acres, was collected from each crop in each location. In each sub-sampling, 18" soil cores were collected within the root zone whenever possible and attempts were made to include some root/rootlets in the samples. Each sub-sample was placed in a labeled plastic bag, brought to the lab and kept in a cool room until processed. Each sub-sample was processed separately.

**Screening of cherry rootstocks for PPN**: Twelve rootstocks grafted to Bing cherry scion were planted in 1998 in at the Western Colorado Research Center- Rogers Mesa (WCRC-RM) to evaluate their performance using a completely randomized block design with eight replications. Only four replications were used for this nematode study because of prior tree mortality. Association of PPN with these rootstocks was studied by taking soil samples from these rootstocks during winter 2006. Soil samples of 250 to 500 cc per tree were collected to a depth of 18" via a 1" diameter soil probe, placed in a plastic bag with a field label, and kept in a cold room until processed. Each sample was processed separately as described below. The nematode numbers are reported as the average of four replications.

**Extraction of nematodes from soil**: Field soil samples were mixed well in the laboratory, clods broken-up and a 100 cc representative sample taken. Five samples per orchard were collected. Milk filter papers were placed on top of stainless steel wire screen (6.5" diameter) and covered with two layers of facial quality tissue papers. The 100 cc soil sub-samples were then spread uniformly over the tissue paper and the screen, filters, tissue paper and soil sample was placed in the pie pan (7" diameter), and sufficient water was added to ensure the submergence of soils. Each was then covered on top by another aluminum foil pie pan to minimize evaporation. After 72 hours, the tissue, milk filter and soil were discarded. The remaining nematode suspension from the pie pan (clear water with nematodes) was collected in a beaker and put in a cold room until the nematodes were counted. The nematode suspension was reduced to 250 cc, a 20 cc aliquot sample taken, and the nematode genera identified and counted under a inverted compound microscope scope with 10x ocular and 4x, 10x, and 20x objectives. An average was calculated for the five samples per orchard and presented. Data was analyzed using SAS 8.1 statistical software and means compared with LSD separation at P= 0.05 level (SAS, 1990)

## Results and Discussion

The PPN genera and their numbers varied with locations, crops, varieties and soil types. However, some genera were specific to some locations and/or crops and/or soil types (Tables 1-5). In peach, central and East Orchard Mesa (COM+ EOM) soils had the greatest diversity of PPN and EOM had the highest PPN density. Dagger nematode (*Xiphinema*) was the most common nematode genus whereas spiral nematode (*Helicotylenchus)* had the highest densities in the EOM and Dominiguez Canyon locations (Table 1). In pear, the Redlands area soils had the greatest diversity of PPN and EOM had the highest density. Spiral (*Helicotylenchus*), root-knot (*Meloidogyne*) and dagger nematodes (*Xiphinema*) were the most common PPN genera observed whereas *Helicotylenchus* and *Paratylenchus* had the highest densities (Table 1). In sweet cherry, the highest densities and diversities of PPN were observed in the Fruitvale area of Grand Junction (Table 2). The most common genera of plant parasitic nematodes were *Xiphinema* and *Meloidogyn*e followed by *Helicotylenchus* and *Pratylenchus. Criconemoides* had higher numbers in Fruitvale. To find out the distribution in native soil and host preference of dagger nematode, we sampled tart cherry and chokecherry (cultivated and wild) in and around the sweet cherry growing area. No dagger nematode was observed in these crops except for one sample in cultivated chokecherry (Table 2); one explanation for this could be that dagger nematode might have come from outside Colorado. In grapes, Palisade had the highest densities, but EOM had the highest diversity of PPN (Table 3). *Helicotylenchus*, *Meloidogyne*, *Paratylenchus,*

*Trichodorus* and *Xiphinema* were the most common PPN genera in grapes; *Pratylenchus* had the higher numbers in EOM. In apple, the red sandy soil from Redlands had the highest densities of PPN, and the fine textured Orchard Mesa soils had the highest diversity of PPN. *Xiphinema* and *Tylenchulus* were the most common PPN genera observed in apples in different locations surveyed whereas *Helicotylenchus* in Colorado Springs and *Xiphinema* in Orchard Mesa had the higher numbers (Table 3). To study the distribution of the dagger nematode, we also surveyed abandoned $50^{+}$ year-old apple trees and hawthorn, the wild relatives of apples, no dagger populations were found (Table 4). In plum, prune and apricot, the highest diversity was observed in plum and the highest densities observed in prune, both from the Redlands. Dagger nematode was the most common PPN genus out of the PPN observed in these crops and location surveyed whereas *Meloidogyne* in Redlands in plum and apricot had the higher numbers (Table 5).

Aerial feeder nematodes, *Ditylenchus*, (a very common nematode in alfalfa in this locality) and *Aphlenchoides* were both observed in fruit orchard soils sampled; the exact role of these nematodes in fruit orchards is not known. These nematodes might have come either from irrigation water and/or some weeds or alfalfa grown/self seeded in between fruit trees. *Criconemoides,* another ectoparasite genus, was present in pear of Redlands, sweet-cherry of Fruitvale and Colorado Springs, grape of EOM locations, and all but one sample for plum, apricot and prune. This difference might be due to difference either in management and/or variety of fruits grown. Their exact role in these fruit crops in the western Colorado is not known, but they often are reported to cause economic yield loss in other fruit growing areas (Brown et. al, 1993). *Hemicycliophora* was present only in Redlands area regardless of the crops surveyed; this might be due to a preference of this nematode for sandy soil rather than crop as Redlands has sandy soils. *Pratylenchus* and *Meloidogyne* were observed in most of the crops except in few locations. However, they were not consistently present in all samples in each location across the samples. Low populations of these nematodes in soil might be either due to low populations present in the locality, crop or variety and or being present inside the roots as they remain inside the roots feeding and few populations come out in the soil. But it was very difficult to get feeding roots in these orchards, especially in heavy soil. Since these nematodes were common in distribution with variable populations, their role might be different with crops, variety and climatic condition. *Tylenchulus*, a semi-endo parasite was not observed in grape and prune. In other crops also, it was absent in many location; wherever present, the number might not be at a damaging level, and the economic threshold of this nematode in these fruit crops is not known. Among endoparasites, *Meloidogyne* and *Pratylenchus* are important in stone fruits and grapes; whereas *Xiphinema* and *Criconemella* are important among ectoparasites. (Nyczpir and Halbrendt, 1993)

Among the ectoparasitic nematodes observed, dagger (*Xiphinema* spp.) was most commonly observed irrespective of locations, crops, variety and soils. However, their densities varied from locations and crops, and that might be related to the orchard management, especially the irrigation pattern and types. Sites sampled were mostly non-fumigated orchards of 15+ years age (Table 5). In apple, the dagger nematode densities (18-152 per 100 cc soil) observed in most of the orchards were above the economic threshold level (10-100 nematodes/100 cc soil) there might be economic impact of this nematode on fruit production. However, in other crops, their damage threshold is not known. Densities (15-70 nematodes per 100 cc soils) in sweet cherry are very high, it is a virus vector of cherry rasp leaf virus, and (one nematode per 100 cc soil is enough to transmit cherry rasp leaf virus). This nematode is present in all the orchards where rasp leaf virus was found and rasp leaf virus is very common in cherry orchards in this area. We also looked at wild relatives and old abandoned apple trees, but no dagger nematode was observed in these soil samples. Absence of this nematode in these crops and locations could be explained if this nematode

arrived with the trees and colonized those and surrounding soils; further investigations are under way to examine this hypothesis. This nematode is important in this area primarily as a virus vector rather than a potential yield reducer because the potential impact on yield by this nematode in sweet cherry is unknown, but viruses transmitted by this nematode including the cherry rasp leaf virus are already present. Very recently, grape fan leaf virus, another deadly disease of grape transmitted by another species of dagger was reported in one vineyard. Whether either of the known Colorado species of dagger nematode (X. *thorneii* and X. *utahensis*) can serve as a vector for this virus is unknown. At the same time, other species of dagger reported as vectors of viruses, especially the cherry rasp leaf virus, have not been reported from Colorado. Thus, attempts are being made to establish the identity of dagger species present in Colorado using molecular tools since there are controversies in the identification of this nematode using morphometric data. Nevertheless, other genera of plant parasitic nematodes observed in this survey and known as virus vectors might be important to this region as viruses are already present and are very difficult to eradicate once they become established in an area.

**Evaluation of cherry rootstocks for PPN:** Nine PPN genera were found in soils beneath the study trees; these varied from rootstock to rootstock (Table 6). High numbers of root-knot nematode (*Meloidogyne*) were observed with W10 followed by Edabriz and the lowest with W13. Similarly, higher numbers of root lesion nematodes (*Pratylenchus* spp.) were observed with W 153 and GI 148-2, but lower with GI 148-8 and Edabriz. Numbers of citrus nematode (*Tylenchulus)* were highest with GI 148-2 and lowest with W13.

The above endoparasitic PPN genera (feed internally and cause physical damage to the roots) were observed in almost all rootstocks in relatively high densities and thus, might have a negative role on the tree health and yield potential of these rootstocks. Highest numbers of dagger nematodes (*Xiphinema* spp.) were observed with W 158 followed by W 10; W 72 and Edabriz had the lowest number of dagger nematodes (Table 6).

Endoparasitic nematodes, *Meloidogyne* and *Pratylenchus* were common in most of the crops, varieties and localities. They could be problematic but not in all crops, varieties and locations. Of the ecto-parasitic nematodes, Dagger seems to be problematic, especially for the cherry industry as virus vector as cherry rasp virus is very common in this area. Evaluation is needed of cherry rootstock/ nematode associations, especially for the dagger nematode.

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Table 1. Plant parasitic nematodes populations associated with peach and pear in different locations during spring of 2007.

| | Peach | | | Pear | | |
|---|---|---|---|---|---|---|
| Plant Parasitic nematode genera | COM* | DC | EOM | COM | RL | DC |
| *Aphelenchoides* | 3 | 0 | 2 | 0 | 35 | 0 |
| *Criconemiodes* | 0 | 0 | 0 | 0 | 36 | 0 |
| *Ditylenchus* | 0 | 0 | 34 | 0 | 0 | 0 |
| *Helicotylenchus* | 125 | 0 | 200 | 417 | 18 | 256 |
| *Hemicycliophora* | 0 | 18 | 0 | 0 | 0 | 0 |
| *Hoplolaimus* | 3 | 13 | 0 | 3 | 22 | 0 |
| *Longidorus* | 0 | 0 | 0 | 3 | 0 | 0 |
| *Meloidogyne* | 47 | 0 | 60 | 44 | 56 | 88 |
| *Paralongidorus* | 0 | 13 | 0 | 0 | 0 | 0 |
| *Paratrichodorus* | 10 | 0 | 0 | 0 | 18 | 0 |
| *Paratylenchus* | 21 | 37 | 0 | 51 | 102 | 6 |
| *Pratylenchus* | 0 | 0 | 60 | 0 | 0 | 0 |
| *Trichodorus* | 0 | 18 | 15 | 0 | 0 | 0 |
| *Tylenchorhynchus* | 0 | 47 | 0 | 0 | 0 | 0 |
| *Tylenchulus* | 0 | 0 | 60 | 0 | 0 | 0 |
| *Xiphinema* | 53 | 13 | 120 | 58 | 23 | 6 |
| Total parasitic | **263** | **159** | **549** | **582** | **327** | **263** |
| Free living | **356** | **100** | **320** | **525** | **250** | **356** |
| Total parasitic geenra | 8 | 7 | 8 | 7 | 8 | 4 |

* COM = Central Orchard Mesa, DC= Dominguez Canyon, RL = Redlands, EOM = East Orchard Mesa.

Table 2. Plant parasitic nematode populations associated with Sweet cherry, chokecherry and tart cherry in different locations including the wild plants during spring of 2007.

| | Sweet-Cherry | | | | | Choke cherry | Tart-cherry | |
|---|---|---|---|---|---|---|---|---|
| Plant Parasitic nematode genera | FV | CS | DC | PM | RM | Wild | C | C |
| *Aphelenchoides* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 5 |
| *Criconemiodes* | 345 | 60 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Ditylenchus* | 0 | 15 | 53 | 0 | 0 | 10 | 46 | 44 |
| *Helicotylenchus* | 315 | 0 | 15 | 25 | 35 | 13 | 20 | 13 |
| *Hoplolaimus* | 45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Longidorus* | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Meloidogyne* | 60 | 15 | 15 | 13 | 140 | 35 | 0 | 133 |
| *Paralongidorus* | 0 | 0 | 15 | 0 | 0 | 0 | 20 | 0 |
| *Paratylenchus* | 0 | 0 | 15 | 23 | 0 | 18 | 0 | 3 |
| *Pratylenchus* | 90 | 45 | 38 | 0 | 35 | 13 | 0 | 3 |
| *Tylenchorhynchus* | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| *Tylenchulus* | 105 | 15 | 0 | 25 | 70 | 0 | 0 | 0 |
| *Xiphinema* | 15 | 15 | 38 | 30 | 70 | 0 | 7 | 0 |
| *Psilenchus* | 105 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| *Hemicriconemiodes* | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| *Trichodorus* | 30 | 0 | 0 | 5 | 0 | 0 | 0 | 25 |
| *Belonolaimus* | 0 | 0 | 0 | 17 | 0 | 0 | 45 | 0 |
| Total parasitic | **1125** | **165** | **189** | **140** | **350** | **113** | **138** | **226** |
| Free | 750 | 930 | 128 | 397 | 0 | 0 | 0 | 0 |
| Total Genera | 9 | 6 | 7 | 8 | 5 | 8 | 5 | 4 |

Note: RM = Rogers Mesa, DC= Dominguez Canyon, FV = Fruitvale, CS= Colorado Springs, PM= Pinion Mesa, C = Cultivated.

Table 3. Plant parasitic nematodes population associated with grapes in different growing locations during spring of 2007.

| Nematode genera | COM* | DC | PS |
|---|---|---|---|
| *Aplenchus* | 6 | 0 | 0 |
| *Criconemoides* | 15 | 0 | 18 |
| *Ditylenchus* | 71 | 0 | 66 |
| *Helicotylenchus* | 98 | 55 | 106 |
| *Hoplolaimus* | 0 | 0 | 9 |
| *Meloidogyne* | 73 | 13 | 75 |
| *Paratrichodorus* | 0 | 0 | 0 |
| *Paratylenchus* | 6 | 14 | 171 |
| *Pratylechus* | 160 | 0 | 6 |
| *Trichodorus* | 100 | 13 | 123 |
| *Xiphinema* | 36 | 26 | 39 |
| *Paralongidorus* | 0 | 13 | 0 |
| Total parasitic | **564** | **134** | **613** |
| Free living | 338 | 130 | 330 |
| Total Genera | 11 | 7 | 10 |

* COM = Central Orchard Mesa, DC= Dominguez Canyon, PS = Palisade.

Table 4. Genera and their numbers of plant parasitic nematodes associated with apple and its wild relative (Hawthorn) in different locations during Spring of 2007.

| Plant Parasitic nematode | Apple | | | | Haw-thorn[d] |
|---|---|---|---|---|---|
| | COM*[a] | RL[b] | CS[c] | MP | M |
| *Aphelenchoides* | 0 | 0 | 18 | 3 | 0 |
| *Criconemiodes* | 0 | 0 | 36 | 0 | 0 |
| *Criconemella* | 0 | 0 | 0 | 0 | 18 |
| *Ditylenchus* | 0 | 0 | 52 | 61 | 0 |
| *Helicotylenchus* | 0 | 0 | 202 | 0 | 0 |
| *Hemicycliophora* | 0 | 360 | 0 | 0 | 0 |
| *Hoplolaimus* | 0 | 0 | 0 | 2 | 0 |
| *Longidorus* | 9 | 0 | 0 | 0 | 0 |
| *Meloidogyne* | 47 | 60 | 0 | 30 | 210 |
| *Paralongidorus* | 0 | 0 | 0 | 0 | 18 |
| *Paratrichodorus* | 0 | 0 | 0 | 0 | 28 |
| *Paratylenchus* | 61 | 0 | 18 | 25 | 0 |
| *Pratylenchus* | 35 | 0 | 0 | 0 | 0 |
| *Tylenchorhynchus* | 32 | 0 | 0 | 0 | 0 |
| *Tylenchulus* | 23 | 45 | 18 | 0 | 180 |
| *Xiphinema* | 152 | 18 | 36 | 0 | 0 |
| Free Living | | | | | |
| Total papasitic | **359** | **483** | **380** | **121** | **454** |
| Total Genera | 7 | 4 | 7 | 5 | 5 |

* COM = Orchard Mesa, DC= Dominguez Canyon, RL = Redlands, CS = Colorado Spring, M = Mesa, MP = Mesa Plateau, [a] Gala, [b]Macintosh , [c]Red delicious, [D] wild relatives of apple.

Table 5, Genera and their numbers of plant parasitic nematodes associated with plum, prunes and apricot in different growing locations during spring, 2007.

| | Plum | | | Prune | Apricot |
|---|---|---|---|---|---|
| Plant Parasitic nematode genera | RL* | CS | PS | RL | RL |
| *Aplenchoides* | 23 | 15 | 0 | 45 | 19 |
| *Criconemoides* | 20 | 0 | 18 | 50 | 9 |
| *Ditylenchus* | 192 | 150 | 66 | 30 | 4 |
| *Helicotylenchus* | 0 | 15 | 106 | 0 | 0 |
| *Hemicyclophora* | 37 | 0 | 0 | 60 | 0 |
| *Hoplolaimus* | 0 | 15 | 9 | 0 | 16 |
| *Longidorus* | 0 | 0 | 0 | 0 | 4 |
| *Meloidogyne* | 369 | 0 | 75 | 596 | 230 |
| *Paratrichodorus* | 0 | 0 | 0 | 0 | 0 |
| *Paratylenchus* | 40 | 0 | 171 | 0 | 18 |
| *Pratylenchus* | 29 | 0 | 6 | 45 | 32 |
| *Rotylenchus* | 20 | 0 | 0 | 60 | 0 |
| *Trichodorus* | 0 | 0 | 123 | 93 | 0 |
| *Tylenchorhynchus* | 55 | 15 | 0 | 130 | 43 |
| *Tylenchulus* | 29 | 0 | 0 | 95 | 21 |
| *Xiphinema* | 148 | 15 | 39 | 21 | 21 |
| Free living | 647 | 0 | 330 | 980 | 462 |
| Total parasitic | **962** | **225** | **613** | **1225** | **417** |
| Total genera | 11 | 5 | 8 | 10 | 10 |

* RL = Redlands, CS= Colorado Springs, PS = Palisade

Table 6. Genera and average numbers of plant parasitic nematodes / 100 cc soil associated with 13 sweet-cherry rootstocks at the Western Colorado Research Center - Rogers Mesa, Hotchkiss, CO.

| Rootstock | Meloid* | Helico | Pratyl | Tylen | Xiph | P-tyl | Ty-chul | Dityl | P-trich | Free | TP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 148/1 | 141.3 ab** | 11.3 | 37.5 ab | 0.0 | 19.4 b | 26.3 | 73.8 ab | 5.0 | 0.0 | 407.5 | 314.4 b |
| 148/2 | 108.1 ab | 55.0 | 86.3 a | 3.8 | 33.8 ab | 56.9 | 69.4 ab | 12.5 | 0.0 | 274.4 | 425.6 ab |
| 148/8 | 118.5 ab | 37.0 | 10.3 b | 13.5 | 33.3 ab | 36.3 | 126.5ab | 5.5 | 2.8 | 520.5 | 383.5 ab |
| 195/20 | 148.1 ab | 35.6 | 36.3 ab | 22.5 | 21.9 b | 81.3 | 106.3ab | 36.3 | 3.1 | 364.4 | 491.3ab |
| 209/1 | 118.8 ab | 48.4 | 62.1 ab | 20.6 | 22.2 b | 49.1 | 90.1 ab | 17.8 | 1.6 | 312.3 | 430.6ab |
| Edabriz | 235.6ab | 11.9 | 20.6 ab | 12.5 | 16.9 b | 110.6 | 126.3ab | 45.6 | 3.1 | 474.4 | 583.1ab |
| Mahaleb | 71.1 b | 39.8 | 61.6 ab | 0.0 | 42.9 ab | 14.1 | 74.9 ab | 7.9 | 25.0 | 423.1 | 337.3 b |
| Mazzard | 183.3 ab | 26.7 | 53.3 ab | 0.0 | 20.0 b | 56.7 | 173.3a | 6.7 | 3.3 | 465.0 | 523.3 ab |
| W10 | 316.3a | 56.3 | 28.8 ab | 30.0 | 55.0 ab | 25.0 | 188.8a | 35.0 | 61.3 | 323.8 | 796.3 a |
| W13 | 52.5 b | 13.8 | 60.0 ab | 3.8 | 22.5 b | 22.5 | 27.5 b | 3.8 | 0.0 | 225.0 | 206.3b |
| W158 | 133.6 ab | 46.8 | 94.9 a | 0.0 | 108.3a | 113.6 | 68.3 ab | 11.3 | 36.8 | 348.8 | 630.1a |
| W53 | 81.3 b | 28.0 | 31.9 ab | 0.0 | 20.6 b | 18.8 | 50.6 ab | 2.5 | 0.0 | 375.1 | 236.1b |
| W72 | 108.8 ab | 22.5 | 26.3 ab | 6.3 | 13.8 b | 11.3 | 78.8 ab | 0.0 | 8.8 | 375.0 | 276.3 b |

* Genus code: Meloid = *Meloidogyne* spp., Helico = *Helicotylenchus* spp., Pratyl = *Pratylenchus* spp., Tylen = *Tylenchorhynchus* spp., Xiph = *Xiphinema* spp., P-tyl = *Paratylenchus* spp., Ty-chul = *Tylenchulus* spp., Dityl = *Ditylenchus* spp., P-trich = *Pratrichodorus* spp., Free = Free living species, and TP = Total parasitic nematode counts per sample.

** Means within a column with different letters differ at the p=0.05 level (by LSD test).

# Effect of Season and Soil Solarization on Nematode Populations in Western Colorado Peach Orchards

Ramesh R Pokharel[1], Harold J. Larsen[2]

## Summary

A western Colorado peach orchard was sampled from Nov, 2006 to Sept 2007 to understand the variability and winter survival of plant parasitic and free living nematodes in the soil. The highest nematode populations of both free living and plant parasitic nematodes were observed in December when the soil temperature was low 7.3 o C (45 o F) and seasonal soil moisture was at its highest. Large numbers of nematodes survived sub-zero temperature of -0.4 o C (30 o F) in January (average of 31 days). Lower numbers of plant parasitic nematodes were observed in April and May; this may be an unsuitable time for sampling to assess nematodes from the soil in this area. Plant parasitic nematode populations, but not free living nematode populations, increased again in June to August when there is maximum crop growth. Another field experiment was conducted in a similar soil with four treatments using plastic mulch in winter and summer months where a single layer of clear plastic, a double layer of clear plastic and a single layer of black plastic were compared with no plastic (control) in winter months (Nov, 2006 to Feb, 2007) and summer months (June 18 to August 18, 2007) Soil temperature at 15 cm (6 in) depth in winter months beneath a double layer of clear plastic was higher than under a single layer of black plastic, but it was reversed in summer months. In summer months, minimum temperatures were 42.3 C (108 o F), 36.6 (98 o F) and 35.0 (95 o F) under black plastic, double layer and single layer of plastic, respectively, enough for successful soil solarization. In addition, soil solarization either with clear or black plastic mulch reduced nematode populations within the top 45 cm (18 inches) soil by 80% of that in non-solarized soil. This demonstrates the potential for soil solarization to address at least this aspect of the peach orchard replant problem. Further studies to enhance the efficacy of soil solarization are in progress.

## Introduction and Objectives

Plant parasitic nematodes (PPN), Cytospora canker, replant problems and rasp leaf virus are important challenges in fruit production in western Colorado. The diversity and densities of PPN vary with seasons, locations, crops, soil types and other management practices and knowledge of these interactions is important for their management. Moreover, the limited choice of chemicals due to their availability and environmental impacts often makes crop pest/disease management difficult. Often management decisions fail due to inadequate understanding of species present, their population densities, seasonal visibility and virulence levels; such information is critical for effective management decisions. However, limited information on PPN and their management options is available to fruit growers. Surveys done in the past indicated association of 8-11 genera of PPN with different fruit crops in Colorado (Niles and McIntyre,1997). Later detailed surveys of western Colorado fruit orchards indicated that *Helicotylenchus*, *Xiphinema* and *Meloidogyne* were the predominant genera (Pokharel and Larsen, 2007). However, the need for information on their seasonal variability and

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winter survival, especially with very cool temperatures, created interest for this study.

Chemicals to control plant parasitic nematodes are expensive and have environmental risks. Thus, it is important to explore other approaches to manage nematodes and increase fruit production, especially for organic settings. Soil solarization, the solar heating fo moist soil beneath a clear plastic mulch, might provide a more environmentally friendly means to manage soil-borne nematode problems. Heating the surface soil over a period of several weeks helps to control pathogenic fungi, and phytoparasitic nematodes and weeds. The soil solarization also increases soil nutrient availability and increases populations of known beneficial bacteria and fungi (Elmora et. al., 2003). Soil solarization may also have several indirect effects on the soil biota. Many plant pathogenic organisms, such as oomycetes, may be weakened by heat stress, while saprophytic and/or antagonistic organisms may be less adversely affected; these may then out-compete hemophilic pathogens. A temperature threshold of about 37° C (98.5 ° F) is critical for hemophilic organisms. However, temperature and time of exposure required are inversely related; so the higher the temperature, the less the time required to reach lethal combinations of times and temperatures. For example, at 37°C (98.5 ° F), a killing temperature ($LD_{90}$ for many themophilic fungi) exposure may require from 2-4 weeks. Soil solarization involves the interaction between temperatures and soil moisture; daily temperature changes bring about cycling of water during this process. The upper soil layers (upper 5 cm) have a marked diurnal fluctuation in temperature, cooling at night and heating to high temperature during sunlight hours. As the soil solarization deepens on different factors of the soil, the movement of moisture becomes more pronounced, and changes the distribution of soil salts and improves the tilth of the soil. A reduction in soil salinity resulting from soil solarization was reported (Cullman et al, 2006).

Mineral nutrients whose availability is increased following soil solarization are particularly those tied up in organic fraction, such as $NH_4$-N, $NO_3$-N, P, Ca, and Mg; primarily as a result of the death of the microbiota (Stapleton and Heald 1991). Extractable P, K, and Ca, Mg sometimes have been found in greater amounts after soil solarization (Stapleton and Heald 1991). The liberation of N compounds (vapor and liquid) also is a component of the mode of action. The resulting increased concentration of reduced N would then nitrify after termination of soil solarization to provide $NO_3$ for increased crop growth (Stapleton and Heald, 1991). High temperatures during soil solarization in soil high in organic matter may kill much of the microbiota, including nitrifying microorganisms, and thus favor the accumulation of the ammonical form ($NH_4$-N) of N. Soil solarization is commonly practiced in California and Florida to manage soil borne pathogens. In California, the solarization treatments were equally effective in providing weed management, with a reduction in weed number by 86 to 94% and weed bio-mass by 94 to 99% over the control. In addition, efficacy of solarization is also influenced by soil type, soil color and structure, soil moisture, thickness and light transmittance of the mulching material (plastic film), organic matter content, air temperature, length of day, intensity of sunlight, extent of heating, sensitivity of pathogens and pest species to heat, cropping history, and other components of soil ecology (Katan, 1987).

The potential of soil solarization in western Colorado has not been studied previously despite high temperatures in summer months. Thus, to understand the potential of soil solarization and its impact on PPNs, field experiments were carried out at the WCRC-Orchard Mesa site.

## Materials and Methods

**Seasonal Variability of Plant Parasitic nematodes**: A plot (15 ft x 8 ft) in an orchard block previously planted to peach was selected for the study of seasonal variability of plant parasitic nematodes, and five soil samples were collected randomly each month from Oct. 2006 to Sept. 2007. These samples were processed immediately and separately in the laboratory. The presence of enough moisture was insured in each sampling. The soil moisture dropped below field capacity in late Feb. and April, soil,

moisture was supplemented by an artificial irrigation with sprinklers for 18 hours set. Nematode populations were assessed by processing soil samples as described at the end of materials and methods section.

**Plastic mulching in winter and summer (Soil solarization)**: Another field experiment was started in November, 2006 at WCRC-OM after removal of Berenda Sun peach trees due to Cytospora canker. The experiment examined winter survival and the effect of mulches in winter and summer (soil solarization) on PPN populations and was replicated three times in split-plot design with four treatments: a single layer of clear plastic, a double layer of clear plastic, a single layer of black plastic, and no plastic as control. Plots were plowed and irrigated with micro-sprinkler for 18 hours before start of the experiment. Soil in plastic mulch plots was kept covered with plastic sheet (6 mm thick transparent, covering an area of 16.5 foot x 8 foot). The plastic was made airtight, sealed from all sides by burying the edges of the plastic. The plastic sheets were replaced once in the winter. Soil probe samples of 18" depth (3 per plot) were collected every month from Nov, 2007 to Feb, 2008, placed in a Ziploc plastic bags and kept in a cool room until processed/ or processed immediately or next day. All three samples per plot were processed separately. Weather resistant transparent tape was used to seal the holes made in the plastic sheet by soil probe. The plastic eventually weathered and was shattered by the environmental conditions.

Again in the same plot, the same type of plastic was emplaced from June 18$^{th}$ to August 18, 2007 and made air tight as before. The soil samples were collected at the beginning of treatment application and after removing the plastic and processed separately. In all treatments, two temperature probes were inserted at a depth of 6". The temperatures were recorded by the computer program at 6 hours intervals and daily average was calculated.

**Extraction of nematodes from Soil**: Field soil samples were mixed well in the laboratory, clods broken and a 100 cc representative sample taken. Five samples from each orchard were collected and processed. Milk filter papers were placed on top of stainless steel wire screen (6.5" diameter) and covered with two layers of facial quality tissue papers. The 100 cc soil sub-samples were then spread uniformly over the tissue paper and the screen, filters, tissue paper and soil sample was placed in the pie pan (7" diameter) and water was added to ensure submergence of soils. Each was then covered on top by another aluminum foil pie pan to minimize evaporation.

After 72 hours, the tissue, milk filter and soil were discarded. The remaining nematode suspension from the pie pan (clear water with nematodes) was collected in beaker and refrigerated at 40$^{o}$ F put in a cold room until the nematodes were counted. The nematode suspension was reduced to 250 cc, 20 cc aliquot sample was taken, and the nematode genera identified and counted under a inverted compound microscope scope with 10x ocular and 4x, 10x, and 20x objectives. An average of the samples per orchard was calculated and is presented in the data as one sample.

## Results and Discussion

**Seasonal variability of nematodes in orchard soils:** Populations of free living nematodes were highest in December and then declined until May. Lower nematode populations and higher soil temperatures were observed from May to August than during the winter months. That might be due to greater sensitivity of nematodes to temperature than moisture. PPN populations reached a maximum in December, and then declined until April, and increased again in May until August (Fig.1). Due to lower PPN numbers in soil in April-May, these months do not appear to be suitable for sampling for plant parasitic nematodes. The higher PPN populations in December and from May to August might be due to preference of low temperature, high soil moisture and/or plant growth. The winter months in this area are cool and get occasional snow, soil is mostly below freezing. The average air temperatures during the 2006-07 winter months were 31, 20, 16 and 27$^{o}$ F in November, December, January and February, respectively. A Similar trend in soil temperatures was observed in different depths of

soil (Fig. 2). In winter the soil mostly remains moist due to snow and from May to August the soil is irrigated by external water supply. However, lower populations of free living nematodes during May-August in the field might be due to higher temperature. This indicates that nematode populations were unaffected by near freezing temperature or snow.

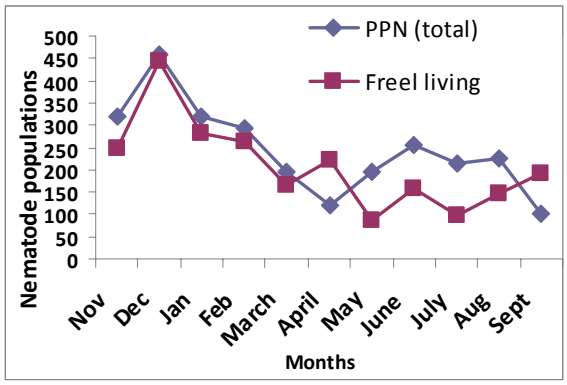



Fig. 1 Seasonal variability of total PPN (plant parasitic nematodes) and free living nematodes in western Colorado orchard soil 2006-2007.

However, increases in nematode populations seem to be related with soil moisture which decreased in April-May and increased again. After July, rainfall may have been enough to maintain the soil moisture required by the nematodes in the soil. The lower PPN populations in April-May might be due to lower soil moisture content before the start of regular irrigation. Among the PPN genera, spiral nematode (*Helicotylenchus)* populations were highest before April, declined and again increased in July.

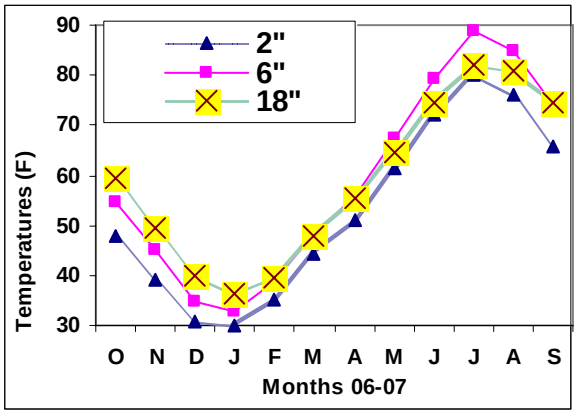



Fig 2 Monthly soil temperatures at 6, 12 and 18 inches depth in Orchard Mesa Research Center, 2006-2007.

Similarly, dagger nematode (*Xiphinema)* populations increased in December and then declined from February until May; populations increased again in July and August and then declined. Similar trends in population changes were observed for other plant parasitic nematode genera (Fig. 3).

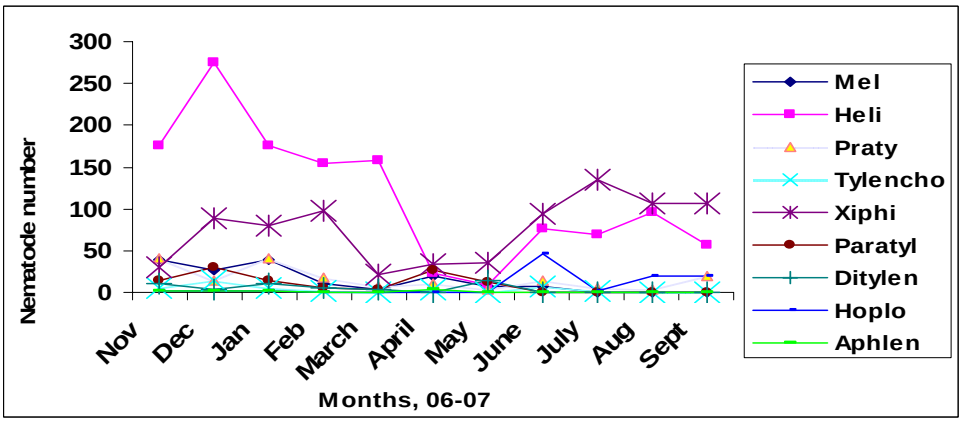



Fig. 3. Seasonal variability in the populations of plant parasitic nematodes (Mel = *Meloidogyne,* Heli = *Helicotylenchus,* Praty = *Pratylenchus, Xiphi* = *Xiphinema,* Tylencho = *Tylenchorhynchus,* Paratyl = *Paratylenchus,* Ditylen = *Ditylenchus,* Hoplo = *Hoplolaimus* and Aphlen = *Aphlenchoides*) in the orchard soils, Western Colorado Research Center- Orchard Mesa, 2006-2007.

This indicates that soil moisture might be the major factor for nematode populations change.

Similar results was obtained in Brazil in soybean. Annual population patterns of the five genera were related to seasonal changes in soil water content and to soybean growth and fallow periods. Populations of *Acrobeles* spp. and *Pratylenchus* spp. were higher in wet soils, *Cephalobus* spp. and *Meloidogyne* spp. adapted well in dry soils, and *Helicotylenchus* spp. survived abundantly in wide ranges of soil moisture where three plant parasite genera dominated the observed nematode communities (Gomes et al., 2003). PPN population fluctuation was connected with plant growth in fields. This result suggests that PPN population densities might be driven by soil moisture and free living nematode populations densities by soil temperature. Jordan and Mitkowski, (2006) also reported that temperature may not have played a role in the differences in populations of nematodes during the 2003 and 2004 seasons in a New England golf course. However, average and extreme temperature readings do not take into account the duration of freezing and thawing periods that may have occurred in either year; these may have impacted the ability of nematodes to successfully overwinter in the 2003 season.

Fig. 4. Soil temperature at 6' dept (15 cm) under Black= Black plastic, Single = Single layer of clear plastic, Double = Double layers of clear plastic) and control = No plastic from June 18 to Aug.18 of 2007 Western Colorado Research Center, Orchard Mesa, Grand Junction, Co.

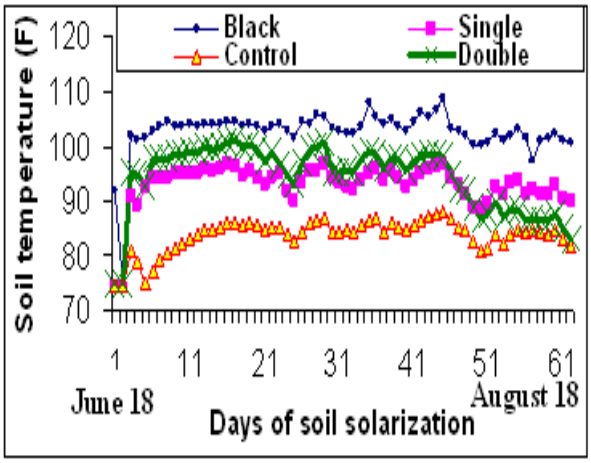
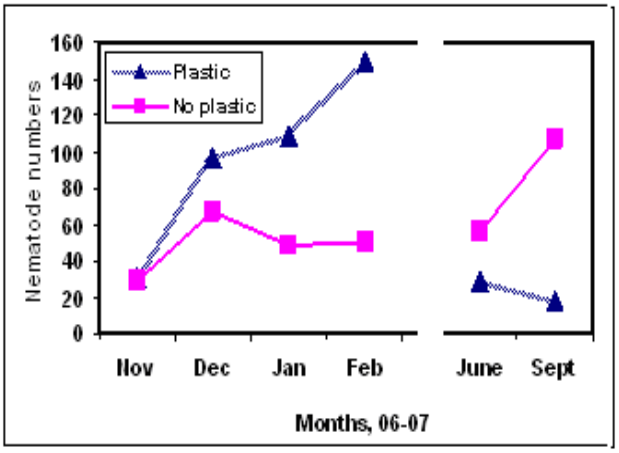



Fig. 5. Change in total plant parasitic nematode populations from November to March and again June-September in uncovered and plastic covered soils



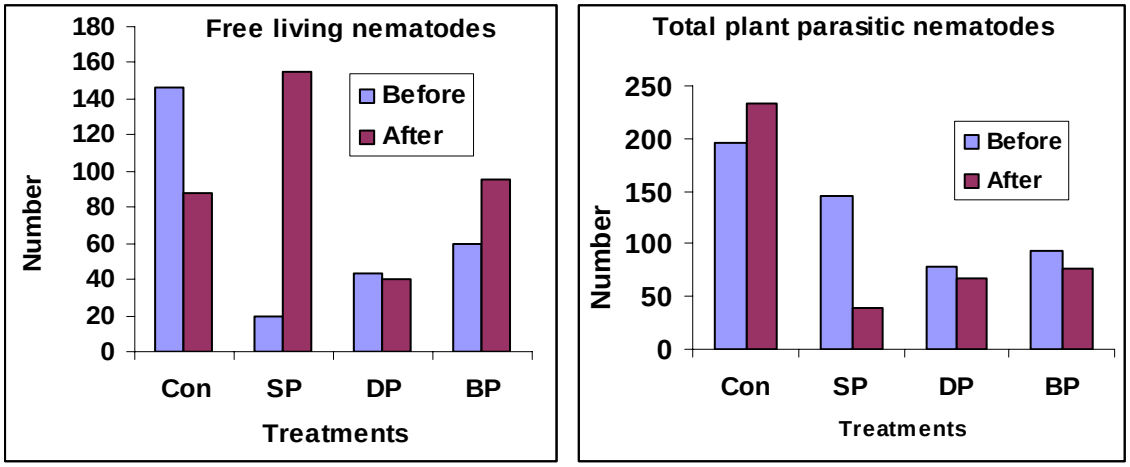



Fig. 6. Populations of free living nematodes and total plant parasitic nematodes before and after treatments in soils under DP = double layer of clear plastic, BP = black plastic, SP = single layer of clear plastic and Con = control treatments at Western Colorado Research Center- Orchard Mesa, 2007.

**Potential of soil solarization under western Colorado conditions**

The soil temperature beneath a double layer of clear plastic was higher than beneath a single layer of black plastic during winter months, December, January and February, by -1.2, -1.8, and -0.6$^{o}$ C (26, 23, 29.0 $^{o}$ F ), respectively. In summer, with some exceptions however, soil temperatures at 6 inches (15 cm) depth were highest beneath the single layer of black plastic, followed by the double layer of clear plastic and single layer of clear plastic followed by those in the non-covered control plots. (Fig. 4). In this experiment, black plastic increased soil temperatures (24.4%) over the control over single layer of clear plastic (18.8 %). This result indicated that black plastic was efficient to raise soil temperature and was more resistant to environmental degradation as compared to clear plastic.

The higher soil temperatures observed beneath black plastic were similar to findings of other researchers (Locher et al., 2003). In a cotton field, soil solarization with clear plastic increased soil temperature by 16 to 18% in F against black plastic (24%) as compared to control (Locher et al., 2003). The soil temperature beneath the plastic reached more than 35 $^{o}$ C (95 $^{o}$ F) from June 18 to September 18. This provided 4-6 weeks for effective soil solarization and clearly indicates a potential for soil solarization in this area. The temperature inside plastic in this area is less than in California, where the maximum soil temperature through soil solarization is usually from 108° to 131°F (42° to 55°C) at a depth of 2 inches (5 cm) and from 90° to 99°F (32° to 37°C) at 18 inches (45 cm). Soil temperatures above 95$^{o}$ F for 2-4 weeks are enough to control soil-borne pathogens with an inverse relation of time and duration.

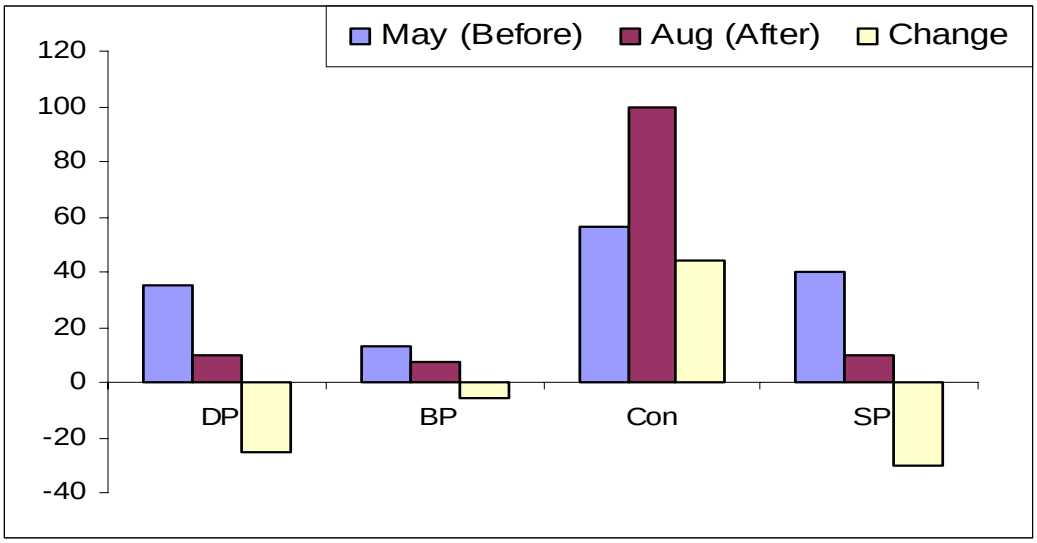



Fig. 7. Changes in dagger nematode populations under DP = double layer of clear plastic, BP = black plastic, SP = single layer of clear plastic as compared to Con = control treatments at Western Colorado Research Center - Orchard Mesa, 2007.

Soil temperatures beneath a double layer of clear plastic were slightly higher (5$^{o}$ F) on average than a single layer of clear plastic. This result was similar to that of California where higher soil temperatures and deeper soil heating were achieved inside greenhouses or by using a double layer of plastic sheeting (Elmore et al, 1993). Solar irradiation intensity, air temperature, and plastic color and other factors all play roles in determining the extent of soil heating via solarization. (Stapleton, 2000).

We were not able to analyze the change in nutrient content in soil due to funding limitations However, studies done elsewhere indicate that concentrations of ammonium- and nitrate-nitrogen are consistently increased across a range of soil types after solarization. Results of a study in California showed that, in soil types ranging from loamy sand to silty clay, N concentration ($NH_4$–N and $NO_3$–N) in the top 15 cm soil increased to 26–177 kg/ha. Concentrations of other soluble mineral nutrients, including calcium, magnesium, phosphorus, potassium, and others also increased sometimes, but less consistently. Increases in available mineral nutrients in soil can be a major contribution to increased plant health, growth, and reduced fertilization requirements resulting from soil solarization (Elmore et. al., 2003).

Moreover, use of UV resistant plastic sheet in combination with, soil amendments of organic manure like compost, chicken manure and canola meal could further increase the benefit of soil solarization by increasing soil temperature, mineralization, controlling weeds and supporting better plant growth as soil solarization was found to increase the soil mineralization in California (Elmore et al., 2003). Further investigations exploring the use and increasing the effectiveness of soil solarization are under way.

**Effect of plastic mulch during winter and summer (soil solarization) months on nematode populations.**

PPN populations increased in the plots covered by plastic in winter months, but decreased in summer months. The opposite was observed in the non-covered soil (Fig. 5).

The increase in nematode populations in covered soil during winter months (Nov. to Feb.) might be due to protection of nematodes from adverse environmental

conditions by plastic mulch. The decrease in nematode populations inside the plastic mulch during summer month (June to Sept) might be due to effect of soil heat and gases. This indicates a potential of soil solarization for reduction in nematode populations. A greater increase in free living nematode populations was observed in the soil covered by single clear plastic followed by black plastic, but total plant parasitic nematode populations decreased in the soils covered by plastic. Free-living nematodes are very important and beneficial in the decomposition of organic material and the recycling of nutrients in soil. The presence and feeding of these nematodes accelerate the decomposition process. Their feeding recycles minerals and other nutrients from bacteria, fungi, and other substrates and returns them to the soil where they are accessible to plant roots. The highest nematode decrease was observed with single layer of clear plastic (Fig.6). Moreover, the nematode populations in control plots increased over the initial nematode populations. The increase in PPN populations in control plots might be due to reproduction, and decrease observed in the soil covered with plastic might be due to effect of heat and gases.

More than 80% reduction in dagger nematode populations was observed in soils treated by soil solarization (June 18- August 18) as compared to control. However, the increase in dagger population (final vs initial) observed in the control plots (Fig. 7) might be due to hatching of the eggs present in soil that synchronize with tree fruit growth. Fruit trees grow from April until October when they enter dormancy. Greater reduction in dagger nematode populations was observed under clear plastic mulch (whether single or double layers) followed by black plastic as compared to control (Fig. 7).

One hundred percent reduction in *Pratylenchus* and *Meloidogyne* populations in soil under the single or double layers of clear plastic, but not in black plastic, was observed (data not shown). However, the final populations of these nematodes in control plots (without plastic mulch) increased over initial (data not presented). The smaller reduction in these populations under black plastic might be due the fact that the black plastic is resistant to UV penetration; less soil exposure to UV might impact in nematode populations as well as other soil-borne pathogens. This clearly indicates that, while black plastic might help increase soil temperature, it may have less impact on plant parasitic nematode populations.

Soil solarization, a process of covering moist soil with plastic for 5 to 6 weeks during summer months (mid- June to Mid August), has potential in western Colorado. This can increase soil temperature more than 95$^{o}$ F to manage nematode populations, especially the dagger populations and possibly other soilborne pathogens. However, studies integrating organic matter such as *Brassica,* chicken manure, compost, green manuring with different crops, and using different color and layers of plastic are warranted .to look at ways to increase the efficacy of soil solarization

**Acknowledgments**

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# Effects of Irrigation and Spacing on Native Seed Production under Cultivation

Kim Schultz[1] and Ron Godin[2]

**Summary**

Restoration efforts on public lands in western Colorado, specifically on the Uncompahgre Plateau, have placed a high demand on the limited supply of native seed. This project was undertaken to determine the best production practices, in terms of irrigation and plant spacing to optimize seed yields. This information will assist local growers in producing seed of perennial native species in order to supply local, state and federal agencies with native seed for rehabilitation and revegetation of the Uncompahgre Plateau.

## Introduction

Located in western Colorado, the Uncompahgre Plateau (Plateau) encompasses 607,000 ha (1.5 million acres) of mostly public and some private lands, includes five counties, and is bordered by the cities of Montrose, Delta, Grand Junction, Ridgway, Olathe, Norwood, Naturita, Nucla and Gateway. In the past 120 years, the Plateau has been severely impacted by human activity, including grazing, logging, recreation, fire suppression and road construction. Livestock grazing and fire suppression have allowed the pinyon-juniper woodlands and shrublands to increase in size and density, decreasing elk and mule deer habitat and winter-feeding grounds.

The Native Seed Productions for Crop Diversification project (Project) was undertaken to determine what cultivation practices (i.e. irrigation practices and plant spacing) could be employed to optimize native seed production. The results of this research would enable local growers to profitably produce native plant seed, reducing the need for wild-collected seed and increase the supply available for restoration projects.

The native seed produced would then be used to increase native grass and forb populations in the pinyon and juniper under-story, used for habitat and winter forage by deer and elk, and generally benefit the ecosystem health of the Plateau. The Uncompahgre Plateau Project (UP Project), which is a new and experimental method for managing public/private lands through a collaborative, community based process, is attempting to understand the impacts of human activity on the Plateau and begin the process of ecosystem restoration on the Plateau in a manner that involves and best serves the interests of the local communities.

The final outcomes of this Project are new insights into the establishment and cultivation of native seeds and improved methods of production that will enable local producers to grow the native seed needed by the UP Project and associated partners to revegetate the Plateau. Local producers will benefit from crop diversification and ready markets for their native seed production, increasing their economic sustainability and viability while contributing to environmental improvement in the region.

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## Materials and Methods

### Project Design

The native plants selected for this project are listed in Table 1. The species were selected by state and federal agency botanists and scientists. The species that were selected are considered critical native plant species for improving mule deer and elk habitat and are classified as perennial native plants. Transplants were used to establish plantings due to low volumes of seed collected because of the drought conditions that occurred during the first year of wild seed collection.

Table 1. Native plant names and codes of native plants grown for seed for the Project.

| Common Name | Latin Name | Code |
|---|---|---|
| **Grasses** | | |
| Muttongrass | *Poa fendleriana* | POFE |
| Prairie Junegrass | *Koeleria macrantha* | KOMA |
| **Forbs** | | |
| Blue Flax* | *Linum Lewisii* | LILE |
| Bluestem Penstemon | *Penstemon cyanocaulis* | PECY |
| Sulfur Buckwheat | *Eriogonum umbellatum* | ERUM |
| Milkvetch* | *Astragalus eastwoodiae* | ASEA |

* =did not survive past second year and had a poor stand and no seed yield.

This study was conducted at Colorado State University's Western Colorado Research Center at Rogers Mesa (Research Center), elevation 1690 m (5500 ft.) and grew both native grasses and forbs on 35 $m^2$ (375 $ft^2$) replicated plots. The soil is an Agua Fria Clay Loam (fine-loamy, mixed, mesic Typic Haplargid) on a 3.8% slope. Two research blocks were established and designed to examine the effects of irrigation and plant spacing on native seed production as well as observing and detailing the plant's life history, or stages of development, in an effort to devise best management practices for optimizing native seed production.

In the year seedlings were transplanted into the fields, approximately 95% of the plants in all of the species remained in a vegetative growth stage until dormancy in the fall. The remaining 5% did flower, however, the flowering was very late compared to following years and little or no seed was produced. The results for the replicated studies were analyzed using analysis of variance (SAS, 1998). Significance is reported at the $p < 0.10$ level.

## Research Methods

### Pre-plant weed control

At the outset of the project it was understood that weed control would be the biggest challenge to the success of the Project and the native species grown. Weed eradication methods consisted of bi-monthly furrow irrigations followed by disking and/or herbicide applications on a monthly basis. The weed eradication was done to reduce spring, summer and fall weed seeds from the soil weed seed bank, in order to minimize competition with the native plants once they were established. Weed eradication was conducted from spring to fall of 2004.

### Planting

Native plant seedlings were greenhouse propagated from seed collected on the Plateau for all plants listed in Table 1. Native grasses and forbs were transplanted into the replicated randomized complete blocks for the irrigation and spacing studies in late spring of 2005. The row spacing was 0.76 m (30 in.) to coincide with the spacing on grower fields. The irrigation used was sub-surface drip installed at approximately 10 cm (4 in) below the surface.

### Irrigation

The length of the irrigation season in western Colorado is dependent on the specific irrigation company and available water supply from snow melt. At the Research Center, transplants were irrigated

with pressurized drip tape every five to ten days, depending on climate and soil moisture content, from the time of transplanting until September 15th in 2005. In 2006 and 2007, the plots were irrigated from April 15th until September 15th except for the partial irrigation treatment of irrigation study (detailed below) where irrigation was shut off for seed maturation (approximately June 15th in 2006 and 2007.

**Weed Control**

Following plant establishment, weed control consisted of pre and post-emergent herbicides and mechanical cultivation as needed. Hand hoeing was also used extensively in the forb plots as no post emergent herbicides are available for use in broadleaf crops.

**Replicated Studies**

Two replicated studies were conducted, an irrigation study and a spacing study. Both studies were randomized complete block designs with six species and three replications for each treatment (see Table 1). Seed was harvested using a handheld "Prairie Habitat Seed Stripper", (Prairie Habitat Inc., P.O. Box 10, Argyle, Manitoba, Canada R0B0C0, http://www.prairiehabitats.com/hand.html), or by hand, depending on whether the seed matured sporadically or simultaneously on all the plants within each plot.

**Irrigation Study**

The irrigation study examined yield differences between partial and full season irrigations. The two treatments in the irrigation study included: a) full season irrigation, typically April 15th to September 15th, except the plots were not irrigated from the onset of seed maturation until seed harvest each year (approximately June 15th to August 15th), and b) partial season irrigation, where plots were irrigated only until the onset of seed maturation. Plants were spaced 0.6 m (24 in.) apart within rows and 0.76 m (30 in.) apart between rows. The seedlings were transplanted into the plots in the spring of 2005. Yield data collection was done in 2006 and 2007. There were 18 plots (six species x three replications) for each of the irrigation treatments for a total of 36 plots. All irrigations for both partial and full season irrigations were simultaneous, except for the partial season irrigation as mentioned above. The plots were irrigated for the same duration of time on the same days from the beginning of the irrigation season until the partial irrigation treatment was shut off each year. All plots received irrigation every five to ten days depending on climatic and soil moisture conditions

**Spacing Study**

The spacing study examined yield differences between three different plant spacings, 0.45, 0.60 and 0.76 m, (18, 24, and 30 in.) by six species by three replications for a total of 54 plots. The seedlings were transplanted into the plots in the spring of 2005. Yield data was collected in 2006 and 2007. All plots received irrigation every five to ten days depending on climatic and soil moisture conditions.

## Results and Discussion

**Irrigation Study**

The results for the irrigation study can be found in Table 2. The irrigation study showed significant yield differences between years, therefore, each year was evaluated separately. Neither the ASEA nor LILE survived long enough to provide meaningful harvest data. For the KOMA, the results show that the full season irrigation treatment yielded significantly higher each year compared with the partial season irrigation. A possible explanation is that continuing the irrigation until mid-September allowed the plants to store more nutrients for over-wintering and seed production in subsequent years. The yields in 2007 were much lower than in 2006, suggesting that KOMA may be a short-lived perennial in cultivated fields and that the stand may be in decline. The POFE did not have seed yield in 2006 due to the early, rapid onset of hot weather at the initiation of seed fill which caused the plant to stop all seed production. This may suggest that the

elevation of the Research Center may be too low to have consistent POFE production due to warmer climatic conditions compared to higher elevations. In 2007, the POFE yielded significantly higher in the partial season irrigation treatment than the full season treatment. This may be because prolonging the irrigation season in this cool season plant, rather than allowing the plants to go dormant, also prolongs growth later into the fall and the plant may be too vigorous during the onset of cold weather and suffer cold damage. The ERUM showed no significant difference between treatments in either year; however, seed yields in 2007 were approximately seven times larger than in 2006. These results match our observations that the plants are getting larger each year and appear to be getting more vigorous each year thus producing higher yields. In both 2006 and 2007, the PECY showed significantly higher yields in the partial season irrigation treatment versus the full season irrigation, although yields declined in both treatments in 2007 from 2006, it appears the partial season irrigation benefits subsequent year seed production.

**Spacing Study**

Results of the spacing study show decreasing yields from year to year, except for the ERUM (Table 3). The spacing study examined the possibility that plants might yield more as in-row spacing increased, possibly allowing the plants to grow larger and produce more seed. However, wider spacing also reduces the number of plants on a per hectare basis so the results are mixed and inconclusive as to the spacing effect at this time. The KOMA yielded significantly higher in the closest spacing in 2006 and in the closest and middle spacing in 2007 (Table 3). The reason for this difference is not known. In 2007, the POFE yielded significantly higher at the middle spacing. As with the irrigation study, the ERUM yielded significantly higher in 2007 than in 2006 with significantly higher yields at the narrow spacing in 2007. Yield results varied in the PECY each year with higher yields in the narrow spacing in 2006 and higher yields in the middle spacing in 2007. This may be due to crowding as the plants begin to compete for resources. Yields were markedly lower in 2007 than in 2006, the reason for this decline is not known (Table 3).

Table 2. Irrigation study seed yields.

| Species | KOMA | | POFE | | ERUM | | PECY | |
|---|---|---|---|---|---|---|---|---|
| | Yield – kg ha$^{-1}$ (lbs ac$^{-1}$) | | | | | | | |
| Irrigation | 2006 | 2007 | 2006 | 2007 | 2006 | 2007 | 2006 | 2007 |
| Partial Season | 48 b* (43) | 35 b (31) | 0 | 21 a (19) | 15 a (13) | 108 a (96) | 97 a (86) | 51 a (45) |
| Full Season | 57 a (51) | 41 a (37) | 0 | 9 b (8) | 13 a (12) | 96 ab (86) | 87 b (77) | 48 ab (43) |

* Letter followed by a different within a column indicates significant difference between treatments ($p < 0.10$).

Table 3. Spacing study seed yields.

| Species | KOMA | | POFE | | ERUM | | PECY | |
|---|---|---|---|---|---|---|---|---|
| | Yield – kg ha$^{-1}$ (lbs ac$^{-1}$) | | | | | | | |
| Spacing m (in) | 2006 | 2007 | 2006 | 2007 | 2006 | 2007 | 2006 | 2007 |
| 0.45 (18) | 55 a* (49) | 31 ab (27) | 0 | 6 b (5) | 19 a (17) | 125 a (111) | 128 a (114) | 39 b (35) |
| 0.60 (24) | 49 ab | 35 a | 0 | 21 a | 15 ab | 109 b | 97 b | 51 a |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (43) | (31) | | (19) | (13) | (98) | (87) | (45) |
| 0.76 (30) | 19 c (17) | 23 c (20) | 0 | 4 b (4) | 18 a (16) | 79 c (71) | 64 c (57) | 23 c (21) |

* Letter followed by a different in the same column indicates significant difference between treatments ($p < 0.10$).

## Conclusion

Our increased understanding of the growth and development of native plants under cultivated conditions and the timing of seed production based on regular observations over the three years of the study has greatly improved management. Seed produced by the project has begun to be used in research areas on the Plateau under natural conditions. The Research Center has also developed protocols for handling and cleaning the native seed, each protocol being species specific. And finally, the extensive knowledge and information gained through this study has been made available through the Native Plant Program webpages (http://www.upproject.org/cpnativeplant_program/native%20plant_main.htm) on the UP Project website (http://www.upproject.org).

The knowledge gained from the experiences of this project is being used to overcome the challenges faced at the Research Center and with cooperator/growers. The understanding of early harvest times for cool season species and how dramatically the climate affects plant growth and development has been a key step to improving management practices. As mentioned earlier, weed control during the year prior to planting and during the growing season was the main challenge for of this project and its impact cannot be underestimated.

## Acknowledgements

Richard Graff, George Osborn, Jim Rohde, and Jon Wedekind provided assistance with the plot establishment maintenance, and harvest. The work was supported by grant funding from the Uncompahgre Plateau Project.

# Spring-Planted Malting Barley at Fruita, Colorado 2007

Calvin H. Pearson[1]

## Summary

Performance testing of malting barley varieties has been conducted for several years in western Colorado. The objective of this project was to evaluate three Coors malting barley varieties when spring-planted in the Grand Valley of western Colorado during the 2007 growing season. Planting occurred on April 11, 2007 and harvest occurred in late July 2007. Overall, grain yields were low but were quite typical for spring-planted wheat and barley in the Grand Valley; however, M-37 yielded substantially higher than the other two barley varieties. Grain yields for M-37, C-84, and M-69 were 53, 37, and 27 bushels per acre, respectively. All three varieties had acceptable malting quality characteristics. Based on previous research conducted in the Grand Valley, fall-planted barley would be expected to yield substantially higher than spring-planted malting barley.

## Introduction

Performance testing of malting barley varieties has been conducted for several years in western Colorado. Malting barley variety trials were conducted in Montrose with a farmer-cooperator during a four-year period from 1995 through 1998. Average grain yields for these spring-planted trials were 108, 113, 129, and 130 bu/ac for 1995, 1996, 1997, and 1998, respectively. All of these trials were sponsored by the Coors Brewing Company.

Variety yield performance data can be used by various farmers, when selecting varieties to plant on their farms, seedmen, in knowing which varieties to grow bests under certain conditions and nuances about growing the varieties, companies, to determine which varieties to market and in which locations varieties are best adapted and are best for end use applications, and university personnel, in developing crop production technology and in educating people about the varieties that have been tested. The objective of this project was to evaluate three Coors malting barley varieties when spring-planted in the Grand Valley of western Colorado.

[1] Professor/Research Agronomist, Dept of Soil & Crop Sciences, Agricultural Experiment Station, Western Colorado Research Center at Fruita.Contact information: Colorado State University Agricultural Experiment Station, Western Colorado Research Center-Fruita, 1910 L Road, Fruita, CO 81521. Ph. 970-858-3629; Fax 970-858-0461; email: calvin.pearson@colostate.edu.

## Materials and Methods

Three malting barley varieties were evaluated at the Western Colorado Research Center at Fruita during 2007. The trial location is at N 39° 10.810'; W 108° 41.917'; and at an elevation of 4604 feet. As per Coors protocol, the experiment was arranged in the field in three 1.03 acre blocks. Each barley variety was planted in one of the 1.03 acre blocks. The previous crop was soybean. No fertilizer was applied during the growing season.

Planting occurred on 11 April 2007 at 100 lbs seed/acre. On May 14, 2007 a tank mix of Warrior insecticide at 3.84 oz/ac plus 0.6 oz/ac of Harmony plus 12 oz/ ac of 2,4-D amine plus 1 qt of Activator 90 in 100 gallons of water was applied to the malting barley. The application was made with 20 gallons of water per acre at 30 psi. On May 31, 2007 another application of Warrior insecticide was applied at 3.84 oz/ac in 22 gallons of water per acre at 25 psi using a ground sprayer. The two applications of Warrior were made in an attempt to control Russian wheat aphids; however, these applications did not completely control this insect.

The experiment was furrow-irrigated with 1¼ inch siphon tubes from a concrete ditch. Irrigation water was from the Colorado River delivered through a canal system.

Malting barley was harvested with an International 1440 combine. C-84 and M-69 were harvested on July 20, 2007. Because M-37

took longer to mature it was harvested a week later on July 27, 2007. Grain for each of the three malting barley varieties was augered into separate steel bins. The bins were weighed separately and weights were subtracted from a tared bin weight. Grain moistures and tests weight were determined using a DICKEY-John GAC2100B seed analyzer. Grain yields were corrected to 12% moisture.

## Results and Discussion

Weed control across the plot area was excellent during the growing season until close to harvest. Green foxtail and barnyardgrass became visible in the mature barley and more of these two weeds was present in M-69 than in the other two varieties. M-37 headed on May 30, 2007 and C-84 and M-69 both headed on June 3, 2007.

Adequate irrigation water was available during the growing season and was not a limiting factor for crop production. Eight irrigations were applied to the malting barley beginning on April 16, 2007 with the last irrigation occurring on July 6, 2007 (Table 1).

Grain moisture, grain yield, and test weight for the three malting barley varieties are shown in Table 2. The M-37 variety out-yielded the other two varieties by a substantial amount. Grain moisture for M-37 was slightly higher than the other two varieties probably because it was slower to mature than the other two varieties. Test weight for M-37 was lower than those of C-84 and M-69. Grain characteristics for malting barley are shown in Table 3. All three varieties had acceptable malting quality characteristics.

Overall, grain yields were low but were quite typical for spring-planted wheat and barley in the Grand Valley. Grain yields of spring-planted malting barley in the Montrose area were higher than what we observed in the Grand Valley in 2007. Fall-planted barley would be expected to yield much higher than spring-planted malting barley in the Grand Valley. Malting barley variety trials conducted over several years are important to more fully assess the performance of barley varieties when grown in various environments and under different production conditions.

Fig. 1. Spring-planted, malting barley at the Western Colorado Research Center at Fruita. July 17, 2007. Photo by Harold Larsen.

**Acknowledgments**

We thank Coors Brewing Co. and Derek Godsey (Coors agronomist) for their support of this research activity. Appreciation is also extended to Fred Judson and Chip Brazelton (Western Colorado Research Center staff), and Daniel Dawson (part-time hourly employee) who assisted with this project.

Table 1. Irrigations for malting barley grown at Fruita, Colorado during the 2007 growing season.

| Irrigation number | Date | Set Time (hours) |
|---|---|---|
| 1 | 4/16/07 | 18 |
| 2 | 5/1/07 | 16 |
| 3 | 5/21/07 | 15 |
| 4 | 6/3/07 | 12 |
| 5 | 6/10/07 | 11 |
| 6 | 6/18/07 | 13 |
| 7 | 6/26/07 | 15 |
| 8 | 7/6/07 | 15 |

Table 2. Agronomic performance of three Coors malting barley varieties grown at Fruita, Colorado during the 2007 growing season.

| Variety | Grain moisture at harvest (%) | Grain yield (lbs/ac) | Grain yield (bu/ac) | Test weight (lbs/bu) |
|---|---|---|---|---|
| M37 | 12.0 | 2565 | 53 | 47.8 |
| C84 | 10.0 | 1792 | 37 | 49.2 |
| M69 | 10.2 | 1304 | 27 | 48.6 |

Table 3. Malting quality characteristics of three Coors malting barley varieties grown at Fruita, Colorado during the 2007 growing season. Quality analyses were performed by Coors Brewing Company.

| Variety | Grain moisture when quality analyses performed (%) | Screening (%) | Color | Protein (%) |
|---|---|---|---|---|
| M37 | 12.5 | 5 | 53 | 13.1 |
| C84 | 11.4 | 8 | 37 | 11.7 |
| M69 | 10.4 | 19 | 27 | 12.0 |

## Dr. Ronald Godin

**2007 Research Projects**

Native Seed Production for Crop Diversification (WSARE, Public Lands Partnership, USFS, USBLM, Uncompahgre Plateau Project)*

Irrigation research and demonstration project in alfalfa using furrow, sprinkler, and sub-surface drip (Delta Conservation District)

Investigating native grass production (USFS, Medicine Bow Routt National Forest)

Native plant seed production (USBLM, Gunnison office)

The use of sanfoin in organic soil fertility improvement (Abundant Life Organic Farms, Herz Farms)

Organic brewing hops production and variety trials (Larry Sheer)

**2008 Research Projects**

Irrigation research and demonstration project in alfalfa using furrow, sprinkler, and sub-surface drip (Delta Conservation District)

Investigating native grass production (U.S. Forest Service, Medicine Bow Routt National Forest)

Native plant seed production (U.S. Bureau of Land Management, Gunnison office)

Organic brewing hops production and variety trial (Allison Hamm, graduate student, CSU; Larry Sheer, Glen Fuller)

Sunflower variety trials for biodiesel (Bob Hammon, CSU Extension / San Juan Biodiesel)

Organic cover crops for vegetable fertility

Organic vegetable rotations for sustainable production

*Cooperators / sponsors are noted in parentheses.

**2007 Publications**

Godin,R.; K. Schultz and J. Rohde. 2007. Investigation of organic weed control methods. In: Colorado State University Agricultural Experiment Station Technical Report TB07-01. Fort Collins, Colorado.

Godin, R. and Kim Schultz. 2007. Colorado State University Native Plant Program Update. http://www.upproject.org/cpnativeplant_program/csu_site/csu_index.htm

## Dr. Harold J. Larsen

**Research Projects**

2007:

Viticulture and enology programs for the Colorado wine industry (H. Caspari, R. Zimmerman, R. Pokharel / Colorado Wine Industry Development Board)

Remediation of stone fruit replant problems in Colorado Orchards (R. Pokharel / Arysta Corp., Eden Research)

Nematode control materials (R. Pokharel / Eden Research)

Resistance to cherry rasp leaf virus infection in Bing sweet cherry on Zee interstem on Citation rootstock (3-yr pot-in-pot study at WCRC-OM; R. Pokharel / Dave Wilson Nursery & Talbott Farms, Inc.)

2008 -- New or Continuing:

Peach Split-pit / Soft-suture management study (M. Rogoyski & N. Guard/ fruit growers, WCHS, COCMA)

Viticulture and enology programs for the Colorado wine industry (H. Caspari, R. Zimmerman, R. Pokharel / Colorado Wine Industry Development Board)

Remediation of stone fruit replant problems in Colorado Orchards (R. Pokharel / Arysta Corp., Eden Research)

Management options for Cytospora canker (R. Pokharel / Eden Research)

Nematode control materials (R. Pokharel / Eden Research)

Resistance to cherry rasp leaf virus infection in Bing sweet cherry on Zee interstem on Citation rootstock (3-yr pot-in-pot study at WCRC-OM; R. Pokharel / Dave Wilson Nursery & Talbott Farms, Inc.)

*Cooperators/collaborators/sponsors are noted in parentheses.

**2007 Publications:**

Refereed:

Pokharel, R.R. and Larsen, H.J. 2007. Efficiency of some new chemical pesticides on replant problem of stone fruits on western Colorado. Phytopathology 97(7):S93. (abstr.)

Pokharel, R.R. and Larsen, H.J. 2007. The importance and management of phytoparasitic nematodes in western Colorado fruit orchards. J. Nematology 39(1):96. (abstr.)

Technical Reports / Other Publications / Written Works:

Caspari, H.W. and Larsen, H. J. 2007. Application of crop modeling for sustainable grape production. pp. 6 – 13 in Western Colorado Research Center 2006 Annual Report. TR07-08. Colo. Agric. Exp. Sta. 44 p. (on the web at: *http://www.colostate.edu/programs/wcrc/annrpt/06/Caspari&Larsen.pdf*)

Larsen, H. 2007. Fruit industry outlook -- 2007-2008. Colo. Ag-Forum. 1 p + abstract.

Pokharel, R.R., Godin, R., and Larsen, H.J. 2007. Evaluation of sweet cherry rootstocks in western Colorado (NC 140). Pp. 18-21 in Western Colorado Research Center 2006 Annual Report. TR07-08. Colo. Agric. Exp. Sta. 44 p. (on the web at: *http://www.colostate.edu/programs/wcrc/annrpt/06/Caspari&Larsen.pdf*)

Pokharel, R.R. and Larsen, H.J. 2007. Efficacy of chloropicrin, methyl iodide and terpene-blend materials on replant problem of stone fruits in western Colorado. Pp. 22-28 in Western Colorado Research Center 2006 Annual Report. TR07-08. Colo. Agric. Exp. Sta. 44 p. (on the web at: *http://www.colostate.edu/programs/wcrc/annrpt/06/Caspari&Larsen.pdf*)

Pokharel, R.R., Godin, R., and Larsen, H.J. 2007. Performance of selected peach rootstocks in western Colorado. Pp. 29-32 in Western Colorado Research Center 2006 Annual Report. TR07-08. Colo. Agric. Exp. Sta. 44 p. (on the web at: *http://www.colostate.edu/programs/wcrc/annrpt/06/Caspari&Larsen.pdf*)

Non-Refereed WEB Publications:

Caspari, H., Montano, A., and Larsen, H. Fruit (and grape) bud cold hardiness, western Colorado, 2007. *http://www.colostate.edu/programs/wcrc/pubs/viticulture/fruitcoldhardiness07.pdf*

Larsen, H. Code-A-Phone Message (weekly update during growing season). *http://www.colostate.edu/programs/wcrc/infopages/codemessages07.pdf*

Larsen, H. Crop phenology program output data report for Cedaredge, CO. (weekly update during spring) *http://www.colostate.edu/programs/wcrc/infopages/budscedge.pdf*

Larsen, H. Crop phenology program output data report for WCRC-Orchard Mesa, Grand Junction, CO. (weekly update during spring) *http://www.colostate.edu/programs/wcrc/infopages/budswcrcom.pdf*

Larsen, H. Crop phenology program output data report for WCRC-Rogers Mesa, Hotchkiss, CO. (Weekly update during spring) *http://www.colostate.edu/programs/wcrc/infopages/budswcrcRM.pdf*

Larsen, H. Western Colorado temperature records (for WCRC-Orchard Mesa & WCRC-Rogers Mesa). (updated quarterly). *http://www.colostate.edu/programs/wcrc/infopages/temperaturerecords.htm*

Newsletter articles:

Larsen, H. 2007. WCRC – Fruita hosts tour for an Agro-Ecology class from the University of Wyoming. Western PhytoWorks, Spring 2007:1.

Larsen, H. 2007. Colorado River Salinity Control Program approves funding for WCRC – Rogers Mesa irrigation system. Western PhytoWorks, Spring 2007:1.

Larsen, H. 2007. WCRC hosts annual meeting of national / international fruit tree rootstock and breeder horticulturists. Western PhytoWorks, Fall 2007:1.

Larsen, H. 2007. WCRC reports daily weather observations to National Weather Service since 1963. Western PhytoWorks, Fall 2007:2-3.

## Dr. Calvin H. Pearson

### 2007 Research Projects

Winter wheat cultivar performance test – Hayden (Mike Williams, Dr. Scott Haley)
Winter wheat cultivar performance test – Fruita
Malting barley cultivar evaluation and demonstration – Fruita (Coors Brewing Co.)
Alfalfa variety performance test (2005-2007) – Fruita (Dr. Jerry Johnson, seed companies, breeding companies, private industry)
Alfalfa germplasm evaluations 2007-2009 – Fruita (Dr. Peter Reisen, Forage Genetics)
Evaluation of alfalfa genetic material 2005-2007 – Fruita (Forage Genetics and Monsanto)
Canola cultivar performance test – Fruita (Dr. Jerry Johnson, Kansas State Univ.)
Nuna advanced breeding line yield trial – Fruita (Dr. Mark Brick and Barry Ogg)
Volunteer sunflower seed longevity study – Fruita (Dr. Allison Snow, Ohio State University)
Sunflower cultivar performance test – Fruita (seed companies)
Evaluation of corn hybrid breeding material evaluation – Fruita (Grand Valley Hybrids)
Corn grain variety performance test – Delta (Grand Valley Hybrids)
Evaluation of corn hybrids for blunt ear syndrome – Fruita (Golden Harvest)
Effect of nighttime chilling of aerial phytomass of corn on blunt ear syndrome – Fruita (Golden Harvest Seed Company)
No-till crop production using a kura clover living-mulch system – Fruita (Dr. Joe Brummer, Dr. Neil Hansen)
Establishment of legume species for use in living mulch crop production systems – Fruita (Dr. Joe Brummer, Dr. Neil Hansen)
Pollen movement and outcrossing of sunflower confined in pollination cages – Fruita and Ames, IA (Drs. Candace Gardner and Laura Marek, USDA North Central Regional Plant Introduction Station)
Transforming sunflower into a natural rubber-producing crop (Drs. Maureen Whalen and Colleen McMahan, USDA-ARS, Albany, CA; Dr. Katrina Cornish, Yulex Corporation)

*Cooperators/collaborators/sponsors are noted in parentheses.

### 2007 Publications

Pearson, C.H. 2007. An updated, automated commercial swather for harvesting forage plots. Agron. J. 99:1382-1388.
Pearson, C.H. 2007. Letter from the Editor. Agron. J. 99:320-321.
Pearson, C.H. 2007. Letter from the Editor. Agron. J. 99:1726-1727.
Pearson, C.H., S.M. Ernst, K.A. Barbarick, J.L. Hatfield, G.A. Peterson, and D.R. Buxton. 2007. *Agronomy Journal* turns one hundred. Pp. 61-68. *In*: The American Society of Agronomy: 100 Years of History (L.E. Moser, ed.). American Society of Agronomy, Inc. Madison, WI.
Pearson, C.H., K. Cornish, C.M. McMahan, M. Whalen, D.J. Rath, N. Dong, and S. Wong. 2007. The rationale for transforming sunflower into a rubber-producing crop. Pp. 72-77. *In*: Issues in New Crops and New Uses (J. Janick and A. Whipkey, eds.). Proceeding of the Sixth National Symposium: Creating Markets for Economic Development of New Crops and New Uses. ASHS Press, Alexandria, VA.
Pearson, C.H., K. Cornish, C.M. McMahan, M. Whalen, D.J. Rath, N. Dong, and S. Wong. 2007. Using peat pellets in liquid media to root sunflower tissue culture plants. Pp. 78-81. *In*: Issues in New Crops and New Uses (J. Janick and A. Whipkey, eds.). Proceeding of the Sixth National Symposium: Creating Markets for Economic Development of New Crops and New Uses. ASHS Press, Alexandria, VA.

Johnson, Jerry J., Alicia Davisson, James P. Hain, Abdel Berrada, Cynthia Johnson, Calvin Pearson, and Ron Meyer. 2007. Making Better Decisions: 2006 Colorado Soybean Variety Performance Trials. Colorado State University, Agricultural Experiment Station and Extension, Technical Report TR07-02. Fort Collins, Colorado.

Johnson, Jerry J., Alicia Davisson, James P. Hain, Calvin Pearson, and Ron Meyer. 2007. Making Better Decisions: 2006 Colorado Sunflower Variety Performance Trials. Colorado State University, Agricultural Experiment Station and Extension, Technical Report TR07-03. Fort Collins, Colorado.

Pearson, Calvin. 2007. 2006 National winter canola variety trial. M Stamm and Cynthia La Barge (senior authors). Report of Progress 973. Kansas State Univ., Agricultural Experiment Station and Cooperative Extension Service. Manhattan, KS. (I conducted a variety trial at Fruita and the data were published in this report along with numerous other locations around the country.)

Pearson, Calvin. 2007. New Regional Water Management Specialist Hired for Western Colorado. *In*: Western PhytoWorks (Ramesh Pokharel, ed.). Fall 2007. Newsletter of the Western Colorado Research Center, Agricultural Experiment Station, Colorado State University.

Pearson, Calvin. 2007. A Diversity of Tours and Visitors This Summer at WCRC. *In*: Western PhytoWorks (Ramesh Pokharel, ed.). Fall 2007. Newsletter of the Western Colorado Research Center, Agricultural Experiment Station, Colorado State University.

Pearson, Calvin. 2007. WCRC Employees Participate in Bike-to-Work Day. *In*: Western PhytoWorks (Ramesh Pokharel, ed.). Fall 2007. Newsletter of the Western Colorado Research Center, Agricultural Experiment Station, Colorado State University.

## Dr. Ramesh Pokharel

**2007 Research Projects***

Cytospora Management

"Incidence and severity of cytospora in western Colorado fruit orchards". (Harold J. Larsen)

"*Brassica* byproducts and plant oils for the management of cytospora disease of stone fruits" (Harold J. Larsen)

"Study of carrier materials on the efficacy of chemicals for the management of cytospora diseases of stone fruits" (Harold J. Larsen)

Nematode management

"Study of plant parasitic nematode and virulence of major species associated with Alfalfa in western Colorado" funded through Forage Genetics, Idaho, USA.(Robert Hammon / Forage Genetics, USA.

"Study on the efficacy of Terpene-based materials on plant parasitic nematodes (PPN) and their phytotoxocity to peach" funded through Eden Research Inc. UK. (Harold J. Larsen / Eden Research International, UK).

"Diversity, density and importance of plant parasitic nematodes associated with fruit crops in western Colorado orchards".

Plant parasitic nematodes associated with onion in Colorado funded through Colorado Onion growers Association (new, Robert Hammon).

Increase efficacy of biofumigation by soil solarization and integrating with *Brassica* meal cake and poultry manure to manage soil-borne problem in onion (Harold Larsen, Bob Hammon and Jerry Han / funded through PESP- EPA, new).

Replant management

"Efficacy of Chloropicrin, Methyl Iodide and Terpene -Blend Materials on Replant Problem of Stone Fruits" (on-going). (Continued, Harold J. Larsen / Partially funded through Arysta Corp.).

"Effect of soil solarization, mustard green manure, chicken manure, compost and mustard meal cake for the management of replant problem in peach"

Rasp leaf virus and dagger complex

"Study of rasp leaf virus and dagger nematode (vector) relationship of cherry." (Harold J. Larsen and Allen Szalanski, University of Arkansas )

" Study on rootstock, scion and virus relationship in cheery and rasp leaf virus"(Harold Larsen)

Alternative crops

"Study on adoptive performance of alternatives fruit crops (Goji berry and edible honeysuckles) to western Colorado." (Harold J. Larsen)

Vegetable production

"Varietal evaluations of okra; outbreak of insect and diseases as well as yield potential in Orchard Mesa and Roger Mesa condition of Western Colorado" (Rick R. Zimmerman).

Efficacy of soil solarization with red and blue color plastic mulch integrated with canola mill cake, chicken manure and compost on plant nutrients, weed intensity, nematode populations, arthropods and onion yield (Rick Zimmerman).

*Cooperators/collaborators/sponsors are noted in parentheses.

**Publications**

Peer reviewed Journals

Pokharel, R. R. and H.J. Larsen. 2007. Efficiency of some new chemical pesticides on replant problem of stone fruits on Western Colorado. Phytopathology 97(7): S93

Pokharel, R. R. and H.J. Larsen. 2007. The importance and management of phytoparasitic nematodes in western Colorado fruit orchards. Journal of Nematology 39(1): 96.

Pokharel, R. R., G. S. Abawi, J. M. Duxbury, N. Zhang and C. Smart. 2007. Characterization of root-knot nematodes from rice-wheat production fields in Nepal. Journal of Nematology 39 (3): 221-230 (Publication from Ph.D. dissertation at Cornell University)

Reports

Pokharel, R. Ron Godin, and H. J. Larsen. 2007. Evaluation of sweet-cherry rootstocks in western Colorado (NC 140). WCRC, Annual Report 06-07 pp. 18-21 http://www.colostate.edu/programs/wcrc/pubs/publications/researchreports.htm

Pokharel, R. Ron Godin, and H. J. Larsen. 2007. Performance of selected peach rootstocks. WCRC, Annual Report 06-07 pp. 29-32 http://www.colostate.edu/programs/wcrc/pubs/publications/researchreports.htm

Pokharel, R. and H. J. Larsen. 2007. Efficacy of chloropicrin, methyl iodide and terpene-blend materials on replant problem of stone fruits. WCRC, Annual Report 06-07 pp 22-28 **http://www.colostate.edu/programs/wcrc/pubs/publications/researchreports.htm**

Newsletter articles:

Pokharel, R.R. Grapevine Fanleaf virus found in Colorado vineyard. Western Phytoworks, Spring 2007:3.

Pokharel, R, R, 2007. Natural and bio-fumigants: Potential options for disease management in western Colorado. Western Phytoworks, Fall 2007:3-4.

## Denis Reich

### Peach Irrigation Study

Denis Reich and Wayne Guccini [1]

A small group of peach growers, among them the Talbott family from the Palisade area of the Grand Valley, have been pioneering micro sprinkler irrigation in the upper Grand Valley. One of their orchards transitioned from flood irrigation to micro sprinkler as early as 1987 and other fields have been following as resources allow. While the Talbotts generally express a high degree of satisfaction with micro sprinkler irrigation, there has been concern over salts buildup in the root zone of trees due to the lower degree of percolation provided by micro sprinkler irrigation.

Under the guidance of Randy Kramer of Delta Conservation District, and working closely with the Talbotts and their managers, a study was designed that combines soil salt mapping and irrigation moisture sensing. The goal is to determine if salt buildup is occurring due to lack of deep percolation associated with furrow irrigation.

The project has included the use of the mobile irrigation lab for the Western Slope provided by NRCS that allows digital mapping of salt layers at one and three foot depths. To compliment the digital mapping, Bob Rayer of NRCS assisted with some soil cores for laboratory soils testing.

Bob Rayer (NRCS) takes a soil core.

Randy Kramer, right (Delta CD) Assists Wayne Guccini (Mesa CD) with salt mapping.

[1]CSU water resource speicialist Mesa Conservation District irrigation specialist, respectively.

## Onion Irrigation Study

Dave Seymour (Shavano Conservation District) and Denis Reich (CSU-WCRC-Fruita)

An Onion growing workgroup has been established for Onion growers in the Uncompaghre Valley area. Sub-surface drip irrigation in the tri-river area has struggled to produce profitable yields of storable onions over recent years and producers are frustrated.

Randy Kramer of Delta Conservation District collected soil moisture data from a small group of producers' fields during the 2007 growing season. The results suggested that producers were following a spectrum of protocols for growing drip irrigated onions, with mixed success. A workgroup was formed with representatives from Netafim Irrigation Company, Grand Junction Pipe and Supply, Delta and Shavano Conservation Districts, ex-NRCS, and CSU Extension to formalize a protocol to produce healthy, marketable stands of onions.

Two neighboring producers on the California Mesa on the edge of Montrose County agreed to host a test of the protocol in 2008, with one producer's field acting as the control plot. Stringent soil, water and petiole testing will be performed in combination with a tightly monitored fertilizer and pest control regime. Results will provide a baseline for successful onion production in the Tri-River area.

## Corn Crop Modeling

Allan Andales (Soil and Crop Sciences, Fort Collins), Calvin Pearson (Soil and Crop Sciences, WCRC-Fruita) and Denis Reich (CSU, WCRC- Fruita).

Allan Andales was hired as a new Professor in September of 2007 with the Soil and Crop Sciences Department, based in Fort Collins. Allan brings a wealth of irrigation and water science experience to his new role, which includes outreach responsibilities. Allan has worked in a post-doctorate role at CSU prior to his appointment, with a significant amount of time dedicated to crop modeling.

The need for more Western Region specific crop data is apparent, particularly as it relates to crop coefficients for evapotranspiration (ET) rates. Using a protocol previously developed by Allan for modeling maize (corn), baseline data is scheduled to be collected from corn being raised in 2008 at the Fruita Research Center.

The study will compile data from soil and weather readings in combination with plant growth readings such as light area index. Should the 2008 year prove successful at collecting a meaningful sample of baseline data, the goal will be to continue data collection over a number of years so as to fully develop a western slope corn model.

## Dr. Rick Zimmerman

**2007 Research Projects**

Evaluation of trap crops to prevent the movement of beet leaf hopper into tomatoes and the subsequent transmission of Curly Top Virus (EPA, Region 8)*

European corn borer trapping survey for all commercial sweet corn grown on Western Slope (Colorado West Sweet Corn Administration)

Cooperative Agricultural Pest Survey (CAPS) program for exotic fruit insects USDA)

Management options and attractants for the European Paper Wasp

Pepper Variety Trials

**2008 Research Projects—New or Continuing**

Evaluation of trap crops to prevent the movement of beet leaf hopper into tomatoes and the subsequent transmission of Curly Top Virus (EPA, Region 8)

European corn borer trapping survey for all commercial sweet corn grown on Western Slope (Colorado West Sweet Corn Administration)

Cooperative Agricultural Pest Survey (CAPS) program for exotic fruit insects (USDA)

Earwig trap and baiting trial in organic peaches (Steve Ela)

Chemical control trial for corn earworm (DOW Chemical)

Chemical control trial for codling moth (DOW Chemical)

Determine impact of season long and late season sources of pollen for honeybee colonies using staggered planting of buckwheat and a single planting of sweet sorghum

Evaluation of three flowering plants (alyssum, sunflower, cleome) as a pollen and nectar source for natural enemies and native pollinators

Management options and attractants for the European Paper Wasp

Evaluation of entomogenous nematodes for onion thrip control

*Cooperators/collaborators/ sponsors are noted in parentheses.