Technical Report TR05-08 April 2005

# Agricultural Experiment Station

Colorado State University

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College of Agricultural Sciences

Western Colorado Research Center

Cooperative Extension

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**Insets Center: "Harvesting Alfalfa Forage Plots" – Photo by Calvin Pearson**
**clockwise from upper left corner:**

**"Grass Hay Species Evaluation at Fruita" – Photo by Calvin Pearson**
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Technical Report TR05-08

Agricultural Experiment Station | Cooperative Extension | Western Colorado Research Center: Fruita, Orchard Mesa, Rogers Mesa | April 2005

# Western Colorado Research Center 2004 Research Report

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Colorado State University
Knowledge to Go Places

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## Introduction

Economic factors are the primary driving force behind a number of issues facing agriculture on the west slope. Land values are increasing across the region, with some west slope cities and rural areas incurring the greatest increase in property values across the entire state in recent years. Land that has historically been in agricultural production is being subdivided and converted into housing with greater frequency. There are land trust organizations in the region that are successfully preserving agricultural resources by influencing the future development of many properties. Overall, the rising land values, increasing production costs, and falling or stagnant commodity prices for grain, hay, and certain horticultural crops combine to provide strong incentives for today's agricultural producer in the region to evaluate the economic feasibility of continuing their current operations.

While there has been a decrease in the number of large acreage producers on the west slope, not all the land being converted has gone away from agriculture. In fact, our clientele is shifting significantly in number to the small acreage and novice producer. Many buyers of 5-10 acre plots have been attracted to the region by the rural / agricultural setting and have a desire to raise crops or rear animals as a hobby or second source of income. Many of these "second career" farmers have no prior experience in agriculture. This presents a number of social and economic challenges for the industry.

The Western Colorado Research Center is faced with the challenge of determining how best to serve the growing small acreage and novice growers while pursuing research that has application to traditional producers within the region. As external research funds in traditional agriculture become more limited and our dependency on external sources increases, it is imperative that we look at regional issues and the potential of sourcing research funds that address those concerns. Projects currently underway at WCRC include research focused on native seed production for restoration of the Uncompaghre Plateau, drip irrigation and water use efficiency, and computer modeling of weather data to predict pest pressure. These sponsored research projects are examples of the type of research that benefits the community and region as a whole, rather than impacting only the traditional production agriculture segment. For example, the conversion of land into residential communities that surround agricultural operations will likely increase social scrutiny concerning pesticide use within the agricultural community. The eventual adoption of computer modeling of pest pressure can influence spray timing and control methods, offering the potential to reduce spray frequency to only that which is required to control pests, rather than using a calendar-based spray program that does not accurately reflect pest pressure. In such cases, there is a potential social and environmental benefit to the community in addition to the financial benefit to the producer.

With viable research projects in key areas such as water and natural resources, we endeavor to build a reputation as a vital resource for the entire community within the region. The challenge for the future will be to establish ourselves as such an asset without abandoning viable producers (small and large) who depend upon WCRC resources. Striking a balance between research programs and maintaining focus and support for traditional agriculture with few external dollars is perhaps our greatest challenge.

This document contains reports covering a breadth of projects at WCRC. Please contact the authors should you have questions concerning the information contained herein. To stay abreast of research projects and outreach activities throughout the year, please visit us on the web at http://www.colostate.edu/programs/wcrc/. Prior annual reports can be accessed from our web site via the following link: http://www.colostate.edu/programs/wcrc/researchreporthome.htm.

Frank Kelsey
Manager, Western Colorado Research Center

## 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 1/2 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 1/2 Road. It lies at an elevation of 4,750 feet with Mesa clay loam and Hinman clay loam soil types. High temperatures average 92° F in July and 37° F in January. Lows average 63° F in July and 16° 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, peaches and pears. Three acres are dedicated to wine grape variety trials and research. The balance of acreage is utilized for hybrid poplar research, grass and alfalfa production, and small demonstration plantings of tree fruits including sweet cherry, sour cherry, apricot, and plum. Additional acreage is also utilized annually 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 soil type is clay loam. 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-laboratory-conference room building, shop, residence, and greenhouse. Experimental orchards occupy approximately 8 acres, approximately half of which is managed organically. An organic table grape variety trial was planted in spring 2003, and wine grapes were planted in spring 2004. Establishment of range management and forage research plots began at Rogers Mesa in 2004. Research plots for seed production of native forages and shrubs were also established in 2004.

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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.

Current members of the WCRC Advisory Committee are listed below. Committee members serve voluntarily without compensation. WCRC Advisory Committee meetings are open to the public.

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# Using Native and Adapted Plants in Disturbed Landscapes

Calvin H. Pearson[1], Matt Rogoyski, and Frank Kelsey[2]

**Summary**

Native plants include a broad diversity of grasses, shrubs, trees, and forbs. Native plants are beneficial for their economic, ecological, environmental, genetic, and aesthetic contributions to society. These plants provide numerous environmental benefits including: add beauty to the landscape, provide food and habitat for local wildlife, protect water quality by controlling soil erosion and reducing the impact of flooding and downpours, promote water conservation, require less maintenance than many traditional horticultural species, are compatible with local fauna and flora, promote sustainable landscapes, and contribute to biodiversity. There are many people and organizations with an active interest in native plants including: conservation agencies, cattlemen and other livestock organizations, farmers and ranchers, reclamation agencies, business and industry owners, homeowners, native plant and botanical societies, environmental groups and organizations, landscapers, and others. Native plants can be used for soil erosion control; roadside reclamation; construction recovery; fire rehabilitation; forage, pasture, and range improvement; mine and pipeline reclamation; oil exploration sites; streambank stabilization; wildlife and wetland habitat enhancement; fire mitigation and prevention (defensible space); windbreaks and living privacy fences; along with various aspects and intensities of urban landscaping. In this article, we discuss basic principles and considerations for using native plants in various landscape applications. Topics included in the article are: what is a native plant, uses for native plants, planning and designing the project, site selection and evaluation, selecting species and varieties, seed mixes, container plants, purchasing seeds and plants, site preparation and planting, establishment, insects and diseases, weed control, soil moisture management, fertilizer and soil amendments, stand/plant maintenance, monitoring, and sources of information. A significant need exists for more research, information, and education on native plants.

## What is Native?

Using native plants has become increasingly popular in recent years. Native plants are beneficial for their economic, ecological, environmental, genetic, and aesthetic contributions to society. The value of native plants may be based not only on their immediate impact but also for their potential, future contributions. Native plants are promoted as being better adapted to local environments because these plants have evolved in the climatic conditions to which they are endemic.

The term "native plant" has been defined as an indigenous species in a particular region, ecosystem, and habitat that has not experienced direct or indirect human actions. Native plants have been further defined, as opposed to naturalized plants, to mean those plant species occurring in North America prior to European settlement.

While the concept of native plants has considerable public appeal, the use of the term "native plant" often creates considerable misunderstanding. The term "native plant" can be quite ambiguous. The question is often raised, "Just how native is native?" Does this mean native to the nation, native to the state, native to a region, or native to an ecosystem or habitat (Harper-Lore and Wilson, 2000)?

To what geographical region and to what climatic or geophysical condition is a particular native plant ideally adapted? When planted in what location and under what particular applications should the native plant no longer be considered a native but an introduced plant

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species? The term “native plant” generally has as much or possibly more value and understanding when used in political discussions than in scientific or technical applications.

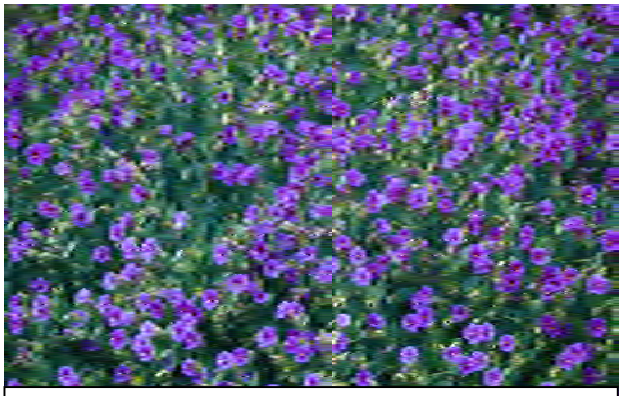
In many ways, the term “adapted” plant has more value and utility than the term “native” plant (Roger Kjelgren, personal communication, 2004). In fact, many native plants are not very well adapted except in very specific natural habitats. Thus, while some of these native plants may grow well in their niche environments they would not be useful for widespread planting in many disturbed landscapes.

Accompanied by additional information as to their particular use, adapted plants, whether native or introduced, can exhibit a high degree of superior performance when used appropriately. A common myth of native plants is that when “native” plants are used the result will be desirable. This is not always the case. For the purposes of this discussion, when we use the term native plant we are also including plants that are also well adapted for well known and understood specific applications.

There are many people and organizations with an active interest in native plants including: conservation agencies, cattlemen and other livestock organizations, farmers and ranchers, reclamation agencies, business and industry owners, homeowners, native plant and botanical societies, environmental groups and organizations, landscapers, and others.

*Sphaeralcea coccinea* (scarlet globemallow). Fruita, Colorado. Photo by Calvin Pearson.

In this article, we discuss basic principles and considerations for using native plants in various landscape applications. These basic principles apply to all projects. Unless these basic principles are actively implemented, the success of the project may be in jeopardy (Bluhm, 1992).



*Mirabilis multiflora* (Torrey) Gray (Colorado four o’clock). Grand Junction, Colorado. Photo by Calvin Pearson.

## Uses for Native Plants

The uses of native plants is largely driven by social values, public policy, and new native plant and related technology (Richards, et al., 1998). Thus, there can be many reasons and motivations for using native plants.

Proper landscaping not only enhances the value and utility of the impacted area but can have spillover affects to surrounding areas. Increased value and utility of plants in a successful project can be attributed to one or more of the following: increased aesthetics, climatic amelioration, improved wildlife habitat, visual and privacy barriers, natural disaster mitigation, site restoration, increased and varied public use, and others.

Landscapes are disturbed and changed to accommodate industrial, commercial, recreational, and residential development. These changes generally cause fragmentation of the landscape, concentrate waste, disrupt balance in the ecosystem, create instability particularly in the soil, increase the potential for soil erosion and flooding, alter water quality, may affect soil drainage and infiltration, and may promote weed and pest invasion. Changing the landscape to accommodate new development typically increases the need for specific management to deal with these altered landscapes.

Native plants have many applications and are well suited to a range of planting scale- from one plant in a container to large areas spanning thousands of acres. The applications for using native plants are very diverse. Native plants can be used for soil erosion control; roadside reclamation; construction recovery; fire rehabilitation; forage, pasture, and range improvement; mine and pipeline reclamation; oil exploration sites; streambank stabilization; wildlife and wetland habitat enhancement; fire mitigation and prevention (defensible space); windbreaks and living privacy fences; along with various aspects and intensities of urban landscaping.

Urban applications alone offer tremendous opportunities for using native plants in a diversity of situations and land areas, including uses in parks, golf courses, sports and playing fields, schools, businesses, and, of course, residential landscaping.

Including native plants in landscapes on both large and small scales is on the increase. Native plants provide numerous environmental benefits including: add beauty to the landscape, provide food and habitat for local wildlife, protect water quality by controlling soil erosion and reducing the impact of flooding and downpours, promote water conservation (Lockett et al., 2002), require less maintenance than many traditional horticultural species, are compatible with local fauna and flora, promote sustainable landscapes, and contribute to biodiversity.

Native plant species create a dynamic, interactive, complex community (Klett and Cox, 1998) that adds interest and excitement for the landowner. When carefully selected, native plants are particularly well suited for use in a variety of challenging situations such as dry sites, windy locations, wet and boggy places, and saline areas.

The use of native plants in broader applications, particularly in urban settings, has only caught on recently. More and more people are finding out about native plants and hence the demand is creating larger markets. Increased demand for native plants has resulted in increased availability of planting stock for a selection of native plant species.

Native plants are certainly not new. They have evolved and persisted for eons in our local environments. These plants include a broad diversity of grasses, shrubs, trees, forbs, and others. Farmers and ranchers, private companies, and government agencies, such as the Bureau of Land Management, the Natural Resources Conservation Service, and departments of transportation have been well acquainted with native plants for many years. These organizations are not reluctant to use native plants and well-adapted, introduced plant species in their projects.

The use of native plants, while preferred by many, may be mandatory in many projects under state and Federal control. Recent state and federal regulations may require the use of native plants in restoring disturbed sites (Smith and Whalley, 2002).

*Cercocarpus intricatus* Watson (little-leaf mountain mahogany). Goblin Valley, Utah. Photo by Calvin Pearson.

## Planning and Designing the Project

The importance of proper planning and design of a project cannot be overstated. An ample amount of time should be spent planning the project to clearly draft the objectives of the project. Planning and design work should be done well ahead of starting the project in the field. The objectives of the project are especially important when the project is well underway. When this occurs, the project objectives can be reviewed to determine if the project is on track.

At the outset, project planners will likely have an idea of what they want to accomplish. These ideas must be refined into clear objectives that have measurable milestones. These milestones can be used to check the success of the project as it progresses. It is important that a realistic

timeframe be established for the project objectives.

The project should be designed, taking into account how the area will be used and what kinds of activities are planned for the location. Particular attention during planning should focus on how the project will affect wildlife, vehicle and foot traffic, wind patterns, drainage and runoff, terrain and edaphic factors, summer and winter temperature conditions, and sunlight and lighting. With most projects there is an element of beauty that should be considered. Forms, colors, sizes, growth patterns, flowering, leaf and flower shedding, and other factors can add or detract from the beauty of the landscape and should be factored into the design of the project.

A landscape or a garden designed by a landscape architect is the best way to assure the full benefits of native and adapted plants are achieved. Money spent on professional services will pay off in many ways in the future, both in terms of long term environmental impact and monetary value. Using an experienced designer for the project will likely have a positive impact on increasing the overall value of the property.

There are landscape architects that specialize or are knowledgeable about utilizing native and adapted plants. An experienced landscape architect may be more willing to suggest using native plants than someone not trained in the principles of landscape design. This is important because of the increased difficulty and challenges encountered when designing, sourcing, and working with many native plants.

A visit to a botanical garden, various demonstration water-conserving gardens, and participation in garden tours can be helpful to visualize various ideas. Landscape designs and uses of native plants can be visualized in several distinct ways. The most popular use of native and adapted plants is one that integrates these plants into existing landscapes, as long as cultural requirements, such as irrigation, are compatible with existing plants. This is an effective way to introduce native plants into a landscape.

*Ephedra viridis* Coville (Mormon tea). Colorado National Monument. Photo by Calvin Pearson.

The second most popular design is to utilize native plants to mimic or reflect aspects of natural landscapes. Creating landscapes that blend with natural surroundings is a relatively new and trendy fashion.

The third way to design with native plants is to use them to simulate traditional garden designs such as English, Mediterranean, or cottage gardens. These gardens do not literally recreate the original design but capture the essence, look, or feel of these gardens. There are outstanding examples of this emerging and growing trend. Many people yearn for more traditional gardens even in areas where they may seem inappropriate.

By far the most innovative view of landscaping with native plants is to create completely new, original designs. Designers using this approach view nature as an inspiration but do not model it literally. These novel gardens may reflect the natural landscape in an abstract way. This design is the most difficult and challenging to create and implement. Because there is a growing interest and need for water conservation, this type of innovative landscape creates opportunities for talented landscape architects to develop novel designs.

Even the best possible design and plan is less effective if it is not followed. If, for example, a plant with high water requirements is placed among drought tolerant plants and everything is watered according to this plant's requirements the obvious result is major over-watering of other plants. Not only is the water conservation potential of drought tolerant plants not achieved, but most plants in the landscape become greatly stressed and could be potentially killed because of over-watering. When additional plants are added in the future it is very important to group them according to their cultural requirements.

Costs associated with a proposed project need to be considered in the overall design. The rule of thumb for costs associated with landscaping for a new residence is 10 percent of the value of the property. The cost for landscaping businesses, and restoration and reclamation of various sites varies dramatically based on many factors. Landscaping projects may need to be designed in phases over a period of years to accommodate the needs of a budget.

The design of a project may be restricted by various laws and regulations. Depending on the project, it may fall under the regulatory oversight of one or more regulatory agencies. One should thoroughly check to see which entities have regulatory requirements that apply to the project. There could be Federal and state regulations, city and county ordinances, homeowner association restrictions, and land deed ownership requirements.

### Site Selection and Evaluation

It is important to understand the site and what effect the site will have on plants. Numerous factors should be considered and thoroughly evaluated to adequately understand what effect the conditions at the site will have on plant performance in the project (Aldrich, 2002). Conditions that should be evaluated are soils, topography, hydrology, existing ecological communities of plants and animals, disturbances, climate including microclimate, and others.

It is particularly important that the soils be thoroughly understood. Seeds and plants will spend their entire existence in the soil and will depend on it for survival. Soil factors that must be known are soil fertility, soil salinity, soil texture, pH, possible specific ion toxicities, soil depth, organic matter, soil contaminants, and other relevant factors.

### Selecting Species and Varieties

When selecting native plants, the major environmental characteristics that affect how well they grow are: temperature, precipitation, soil type, soil pH, wind conditions, air humidity, and surrounding vegetation, which includes weeds. Other factors that should be considered when selecting species and varieties include: competitiveness, salt tolerance, water use, drought tolerance, rooting depth, mature plant height, ease and rate of establishment, growth habit, maintenance requirements, pest resistance, and small and large animal impacts.

Not only do the plant species and varieties need to be determined but the plant product must also be selected. Plant product types are balled-in-burlap (B&B) nursery stock, bare root, containers, cuttings or whips, liners, plugs or tubelings, salvage plants, and, of course, seeds.

Selecting the right species for the project does not guarantee that they are available in the marketplace. In some cases, there is a glut of one species and a scarcity of another. Most production and availability is based on past orders and sales (Shank, 1994). It is wise to do some checking with various vendors to determine if the plant species and varieties selected for the project are available for purchase.

Well-trained professionals, nursery owners, sales attendants, and landscape architects may not be that familiar with native plants. Customers should be willing to ask questions. Such inquiries and requests will encourage vendors to become better acquainted with native plants.

*Amorpha canescens* (leadplant). Grand Junction, Colorado. Photo by Calvin Pearson.

### Seed Mixes

Seed mixtures of native plants offer a multitude of combinations and possibilities. Wildflowers and grasses can be included together or alone and range from a few to many kinds and species. Seed mixtures can be formulated and packaged to meet specific conditions. Adapted annual, biennial, and

perennial seeds of wildflowers, mixed with some grass species, can be planted together. Aggressive species should be avoided to prevent the loss of plant diversity in the disturbed landscape (Klett, 1998).

The specific characteristics of the project will dictate the best seed mix required to obtain the best result. One particular seed mix for use in all projects is not a wise and realistic approach (Berlin, 1999).

### Container Plants

Native plants produced in containers need to be grown with a different objective than container plants produced for the traditional nursery market. The appearance of above-ground growth of plants in containers for the typical nursery market is of paramount importance. For native plants grown in containers, the condition of the roots should be of greater importance than the above-ground growth (Roger Kjelgren, personal communication, 2004). Native plants are likely to be used in many applications in which they are subjected to severe stress conditions and some of these native plant species can be difficult to establish even under what many people would consider to be ideal conditions. Under these stress conditions the health of the root is more important for plant survival than the appearance of the foliage.

### Purchasing Seeds and Plants

Buying native plants can be challenging. Availability is likely to be a hurdle in some areas, although this is becoming less of a problem as native plants gain in popularity. Native plants, especially, are not likely to be available from large merchandisers. Many garden centers, nurseries, and greenhouses carry natives or they can be ordered. In some locations, there are nurseries that specialize in native plants.

The key is to find an outlet with knowledgeable staff who are able to provide sound advice on selecting and using native plants. Some nurseries may also have small demonstration plantings or they may know of gardens where people can see native plants growing in the landscape.

*Forestiera neomexicana* Nuttall (New Mexican privet). Grand Junction, Colorado. Photo by Calvin Pearson.

Wherever buying plants, one needs to be aware that many customers buy plants that are attractive at time of sale. For example, plants that are in bloom are more attractive to a buyer than a non-blooming plant. The issue here for natives is that a blooming plant may not be compatible with the design plan and may have very different cultural requirements than surrounding plants. As much as this type of impulse buying is an integral part of marketing and selling plants, one needs to see the bigger picture and, at least initially, follow the layout provided by the project designer.

When it comes time to purchase plant material it is important to obtain high value from the purchase. It is also important to make sure the plant materials are appropriate for the objectives of the project and are readily available in the marketplace (Issacson, 1995).

There are several other aspects of making purchases that should be considered. For projects that require large purchases it is advisable to obtain prices and quotes from several reputable suppliers. Orders should be clear and, in many cases, it would be wise to submit order requests in writing to minimize possible miscommunications about the plant species, varieties, and quantities desired.

Determining where to purchase seeds and plants should be given forethought. Before selecting the business or organization from which to make purchases the following should be considered. Determining service reliability, reputation, product range and lines, specialized

products, willingness and ability to handle special orders, and onsite expertise will help ensure that the purchase goes smoothly and that the products purchased are high quality.

If shipping is required, pertinent information related to when plants will be shipped, expected delivery date, and who pays for shipping should be clearly understood by both the buyer and the seller.

The terms for payment should also be clearly understood. Guarantees associated with the purchase should be provided in detail to the buyer in the event seeds and plants do not perform to the satisfaction of the buyer or as guaranteed by the seller.

### Site Preparation and Planting

Soil preparation is a critical step. This involves evaluation of soil physical and chemical properties. Determination of soil salinity (electrical conductivity) is very important because some native and adapted plants do not tolerate elevated levels of soil salinity. Soil drainage is also important. Many drought tolerant native and adapted plants do not tolerate growing in soils with high water tables or prolonged saturated conditions. Poor soil drainage contributes to soil salinity.

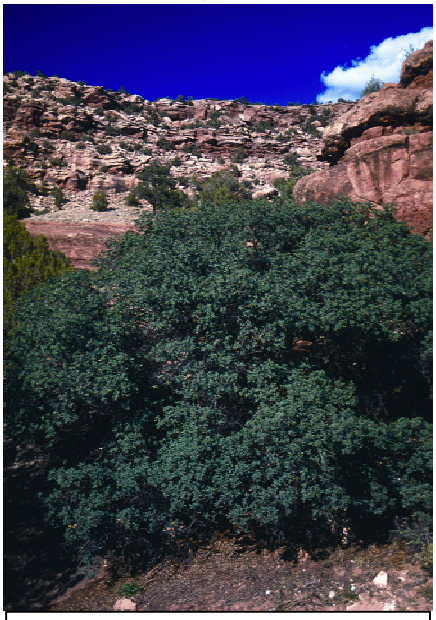
Similar to other plants, proper site preparation is critical to the successful establishment of native plants (Aldrich, 2002). Successful environment restoration of disturbed sites requires that all environmental factors that are capable of inhibiting or restricting plant establishment be identified and appropriately modified (Elmarsdottir, et al., 2003). Planting at a location where the site has not been properly prepared is likely to doom the project and waste considerable time and money. Possible options to use for site preparation, depending on the scale and objectives of the project, include fumigation, soil solarization, grazing, mowing, herbicides, burning, various tillage operations, mulches, soil amendments, and others.

When to plant is as important as how to plant. Selecting the proper planting time for the project is crucial, particularly if soil moisture will be a limiting factor for germination of seeds and plant establishment. For many annuals spring planting is preferred, while for many perennials fall or spring planting can both work equally well. In some cases, winter planting is recommended. For example, a highly successful planting time for winterfat is during the winter months when snow is on the ground. Under these conditions, winterfat can be broadcast seeded directly on top of the snow (Harrison et al., 2000).

If the project is to be irrigated, the date selected for planting will be more flexible. Whenever planting occurs, seeds must germinate and emerge as quickly as possible, and transplants must grow as quickly as possible to reduce weed competition.

All projects require some sort of equipment for preparing the site and planting. In many situations, specialized equipment may be required. Larson (1980) and Stevens and Monsen (2004) provided a comprehensive presentation on equipment used in revegetation projects. This equipment could be used in many other projects as well. The availability of equipment and its working condition should be determined well ahead of when it will be needed. Needed maintenance and repairs should be performed to make sure the equipment is in good working condition.

Additionally, at times, a novel method or approach may be valuable to use during planting (Dumroese et al., 2002).



*Quercus turbinella* (Greene) (holly oak). Dolores River. Photo by Calvin Pearson.

## Establishment

Establishment of plants in a landscape is a challenging task. Native plants, in some cases, may be more difficult to establish than traditional plants. Native plants are often tougher plants when compared to traditional garden plants, but this is only the case once plants are well established. This generally takes at least one growing season. During the establishment phase, depending on the plant species, natives often require as much care as traditional garden plants, including frequent irrigation.

An important aspect to successful establishment of native plants is patience. Many native plants require more time to establish than introduced plant species. Many introduced species have experienced considerable breeding and selection and are highly domesticated. Such extensive plant development work has resulted in plants that establish more quickly than many native plants. Native plant seeds often need to experience specific climatic conditions such as the proper temperature, rainfall, or light conditions to overcome seed dormancy factors before they will germinate or accelerate growth. This is part of the niche growth requirements that typically make natives so compatible to their native environment. Many species of natives often grow slower than many introduced species. Native plants may need considerable time to establish and grow well, maybe a year or two or more. For example, Jefferson et al. (2002) noted that warm-season grass cultivars may require more than 2 years to become established.

## Insects and Diseases

Insects can feed on foliage, roots, flowers, and seed, which may reduce plant growth and health, visual appeal, and under severe conditions can cause plant death. Diseases can appear on plant foliage and roots and be caused by fungi, bacteria, viruses, and other organisms. Severe outbreaks of insect infestations and diseases can create havoc in a landscape.

As with conventional or traditional crops and plant species, insects and diseases can adversely affect native plants. However, an adequate knowledge base for understanding and controlling economically important insects and diseases of some native plants may be very limited. When native plants are planted in a monoculture the potential for a widespread insect infestation or disease outbreak is increased. Native plant fields and landscapes should be inspected regularly, even during the winter months, for potential insect and disease problems.

*Penstemon strictus* (Rocky mountain or porch penstemon). Western Colorado Research Center. Photo by Calvin Pearson.

Insects are likely to be observed, to one degree or another, on native plants; however, damage levels or insect populations must reach an economic threshold level before control measures are required. For many field crops, the economic injury level or economic insect population level has been established and is well understood. For many native plant species, little is known about economic injury levels.

When insect populations or plant injury levels are suspected to be reaching an economic and aesthetic threshold an experienced entomologist or plant pathologist should be consulted. The selection of appropriate pesticides, applications according to the pesticide label, and the impact of the pesticide on the environment and other organisms, particularly pollinators, should be carefully considered (Stevens et al., 1996).

## Weed Control

Rapidly growing weeds are particularly competitive with slow-growing native plants. A comprehensive weed control program needs to be implemented for all projects. The optimal weed control plan should start a year or two prior to planting.

If not controlled, weeds are likely to be a problem at some point during the course of the project. Weed competition can have a major negative impact on the establishment of native plants (Vogel, 2002). Without adequate attention to weed control before, during, and after planting the project is likely to be in jeopardy. There are numerous weed control strategies that when deployed appropriately can be effective in combating weeds (Fig. 1).

| Methods of Weed Control | |
|---|---|
| ▪ A dense, vigorous stand | ▪ Planting time and methods |
| ▪ Proper irrigation | ▪ Companion crops |
| ▪ Adequate soil fertility | ▪ Weed-free seed |
| ▪ Crop rotation | ▪ Weed control before planting |
| ▪ Adapted varieties | ▪ Mowing |
| ▪ Good soil drainage | ▪ Mob grazing |
| ▪ Pest control | ▪ Burning/flaming |
| ▪ Site selection | ▪ Herbicides |
| ▪ Cultivation | ▪ Biological |
| ▪ Flooding | ▪ Smother crops |
| ▪ Residue management | ▪ Herbicide-resistant varieties |

Fig. 1. Possible weed control methods for use in landscaping projects.

Before any work begins in preparing the site, it should be inventoried for weed species and their abundance (Dunne, 2002). Difficult to control weeds may require control efforts months or even a year or two in advance of the scheduled planting date (Bluhm, 1992). Otherwise, difficult to control weeds will persist. Aggressive perennial weeds and annual weeds that produce large of amounts of seed can create a large seed reserve in the soil that may require several years of control in order to reduce the seed reservoir to a manageable level.

### Soil Moisture Management

In the arid West, water is often the limiting factor for plant establishment and growth. How plants obtain sufficient water to meet plant growth needs should be considered during the planning phase of the project. If supplemental irrigation is needed for establishment and/or plant maintenance, a suitable irrigation system must be designed and included in the total cost of the project.

Numerous factors should be considered if an irrigation system will be needed for the project. Factors directly related to purchasing an irrigation system include: irrigation water source, water quality, type of irrigation system to be used, access to energy (electrical, gasoline/diesel engine), capacity of the irrigation system, maintenance costs, and others.

There are numerous possible irrigation methods for use in native plant projects, including flood and basin, furrow, sprinkler, drip, and subsurface irrigation. Factors that will impact the irrigation system and which irrigation system may perform best for the project include: plant water needs, water source and quantity, weather, site topography, edaphic conditions, and associated purchase and maintenance costs.

The amount of water that needs to be applied will depend on plant species, age of plants, soils, and the environment in which they are growing. Plants should be irrigated to meet plant water requirements and evaporative demand. Irrigating more than is needed is wasteful; creates unnecessary, added expense; and may adversely alter the environment and have adverse effects on the native plant species and other associated plant species. In some cases, excess irrigation water, above plant requirements, is needed to reduce or at least maintain soil salinity levels.

If the site will not be irrigated obtaining sufficient soil moisture to promote high plant survival rate must be achieved. Suitable plant species to include in the project will be greatly influenced by the amount and distribution of annual precipitation available for plants. Other factors that should be considered in a non-irrigated site are: seeding rate and plant density, soil water holding capacity and other soil factors, slope, shading, associated plant species, possible water harvesting techniques, and effects created on and by wildlife.

### Fertilizer and Soil Amendments

Whether they come from seeds or containers, plants must grow and be as productive as possible in the environment in which they are

exposed. The soil has a profound effect on the performance of plants. Adequate soil fertility is essential to promote optimum growth of plants. A soil test of the project area should be performed to determine if the natural fertility is adequate or if fertilizer should be applied.

A soil test report will not only reveal what nutrients are lacking, but will provide recommendations for needed fertilizer applications. However, many native plants do not respond to fertilizer applications as readily as plants that have been subjected to long-term breeding and selection efforts. Thus, soil fertility, needed fertilizers, and fertilizer application rates should be tailored to meet the needs of a particular plant species. Applying more fertilizer than is needed to meet the needs of the desired plant species may promote increased weed competition (Aldrich, 2002)

### Stand/Plant Maintenance

Adequate care must be given to the site to properly maintain the plant stand. Consideration should be given to irrigation requirements, erosion control, weed control, insect and disease control, fertilization, protection of the site from adverse impacts from large and small animals, particularly rodents, and protection of the site from vandals and trespassers.

*Mahonia fremontii* (Torrey) Fedde (yellowwood). Orchard Mesa Research Center. Photo by Calvin Pearson.

Wildlife damage management is often an overlooked component of environmental restoration projects as wildlife grazing can devastate a newly restored site. Wildlife exclusion methods are most commonly used when it is practical to prevent damage to native plants. Fencing an entire area or using protective tubes for individual plants are highly effective methods. Wildlife population reduction methods are also effective in preventing wildlife damage to native plants but such approach may not be acceptable to the public.

Another, sometimes overlooked, consideration is the maintenance of plant diversity in newly restored landscapes. We observed that following plant establishment one of the replanted species may crowd out other introduced plants. Thinning out of some plants may be required to reestablish and maintain desired biological and functional plant diversity.

### Monitoring

The objectives of the project will often dictate how much and what type of monitoring will be required for the project. Monitoring may be as simple as a periodic visual inspection to assess progress, or it may as complex as regular detailed samplings and data collection on various plant, soil, and environmental variables. Possible aspects of the project that may require collecting quantitative data include plant populations, plant diversity, percent cover, biomass, soil moisture, insect populations, disease incidence, changes in soil fertility and various other soil factors, changes in animal populations and movements, etc.

### Sources of Information

In a survey of 33 companies in Colorado, Potts et al. (2002) concluded that a significant need exists for more research, information, and education on native plants. Some reliable information on native plants is available to the public. There is a reasonably good selection of excellent books on native plants and one is likely available to meet the specific needs of most people. Many of the large chain bookstores carry books on native plants, although their selection may be limited. A few examples of informative books and other publications on native plants for the Intermountain West are by

Busco and Morin (2003), Mee et al. (2003), Monsen et al. (2004), and Klett et al. (2002a, 2002b).

There are publishing companies in the U.S. that specialize in plants, gardening, and landscaping and these companies have fairly extensive listings for native plants.

Various websites are available and contain useful information. A particularly useful website that contains information that follows the theme of this article is located at: www.nps.gov/plants/restore/pubs/intronatplant/index.htm. This website was useful in the preparation of this article and is gratefully acknowledged.

Another source of information on native plants is Cooperative Extension. Keep in mind extension offices in different locations typically don't carry the same publications, so it is wise to check with Cooperative Extension in surrounding states and areas to see what they have in their particular office.

Other sources of native plant information are Federal agencies including the Natural Resources Conservation Service, forest service agencies, and plant material centers located around the country. Native plant societies can also be a reliable source of information on native plants.

Seed companies and nurseries that sell native and adapted plants can also be an excellent source of information. Larger companies often have catalogs that are full of very useful information about native/adapted plants. These larger companies are generally not the local feed and seed store, but are the ones that supply seed and plants to local retail stores.

## Conclusion

Using native and adapted plants can be a rewarding experience on many levels. Proper planning, site preparation, and establishment of native plant material can result in a stable landscape that can be useful and enjoyed for a long period of time. Detailed planning and an understanding of the long term goal of the project is necessary to ensure that objectives such as beautification, creation of habitat or wildlife forage, soil erosion control, or other targets will ultimately be met. Successful use of native and adapted plants in the landscape requires a greater understanding of growth requirements and tolerances than typical cultivated plant material that has been selected to facilitate commercial success. As the demand for native plant material increases, the supporting knowledge base, diversity, and availability of native plants should grow, making the native plant approach an even more viable option for landscaping in the future.

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# Effects of Organic Alternatives for Weed Control and Ground Cover Management on Apple Tree Growth, Fruit Size and Productivity

Ron Godin[1], Steve Ela[2],Shane Max[3], Kim Schultz[4], and Jim Rohde[4]

**Summary**

Organic fruit production in the U.S. is expanding to meet market and consumer demand. Producing high quality fruit is a must for organic growers. Most organic tree fruit are grown on established orchards that have been transitioned to organic production and hence are comprised mostly of mature trees. Much research has been conducted on the negative effects of weeds on young orchards, however, little research has been conducted on mature orchards. The objective of this study was to determine the effect of several mulch and weed control treatments on weed control and the subsequent effect on apple yield and fruit size in an older orchard setting. Results show that mulching treatments did suppress weeds and improved yield, however, three years of drought during the study may have skewed results towards treatments that benefited soil moisture retention along with weed suppression, namely the mulching treatments, rather than as a direct effect of weed suppression alone.

## Introduction and Objectives

Organic fruit production in the US, especially the western regions, is expanding. The increase is occurring for both economic and ecological reasons. Current market conditions dictate that organic apple growers produce large, flavorful, high quality fruit in order to receive price premiums and market acceptance. To grow large fruit, trees must be unstressed and provided with adequate water and nutrition. Weeds can compete with fruit trees for both water and nutrients. Research has demonstrated that weed competition in young fruit trees reduces tree growth and efficiency, and therefore decreases fruit production and fruit size (Merwin and Stiles, 1994). Reduced tree growth reduces tree volume and potential production. Thus, it is a standard orchard practice to control weeds during the establishment and early growth of an orchard. However, the effect of weed competition on production and fruit size of mature fruit trees has not been studied. Most experiments are conducted on young trees so that blocks can be established solely for the purpose of the experiment. Most commercial fruit, both peaches and apples, are produced on mature trees. Thus it is important to understand the effects or lack of effects that weeds may have on a mature tree. This information could have significant impact on how orchards are managed. Currently, organic growers spend considerable time and money controlling or removing weeds from their orchards based primarily on the research trials in young orchards. If weeds have only a minor effect on fruit size in mature trees, this time and money could be redirected to other parts of the operation. If weeds do have an effect, then the growers need to know if one means of weed control is more effective than another. This study investigated the effects of several different weed control methods on fruit yield and size in mature apple trees. The information generated will give organic growers better knowledge on how to manage weeds while producing large, marketable fruit. This research was conducted at the Silver Spruce Orchard (SSO), a commercial orchard in the North Fork Valley of the Gunnison River in western Colorado.

## Materials and Methods

The SSO site is a commercial, certified organic block of nine-year old Gala apples on EMLA 26 rootstock, on an Aqua Fria clay loam

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soil. The block used for this study has eight rows, of which the middle six rows were used for the data collection. The experimental design is a randomized complete block with seven treatments and eight replications. Plots consisted of five consecutive trees where treatments were applied. Within each plot, the 3 center trees were used for data collection with the 2 outside trees in each plot serving as guard trees. The seven different treatments were applied in the tree row. The tree row consisted of a six-foot wide strip, three feet on either side of the tree trunk. The seven different weed control treatments were: 1) a mowed control (M), 2) flamer (F), 3) landscape fabric (LF), 4) shredded paper mulch (P), 5) mowing with material thrown into the tree row (M&T), 6) shredded bark mulch (B) and 7) farmer's favorite (FF), where no weed treatments were imposed and weeds were allowed to grow throughout the season. The experimental plots were established during the summer of 2000 with data collected from 2001 through 2003. A permanent weather station is located at RM approximately one mile away from SSO and data is downloaded to a computer daily. A summary of average in-season climatic data can be found in Table 1, and monthly weather summaries are located in Appendix A. For evaluation purposes of weather data, the growing season was defined as April 1st to August 31st. All three years of the study were considered drought years due to well below average in-season precipitation (Table 1) and below average annual precipitation (Appendix A). However, of the three drought years 2002 was considered a severe drought year not only because of the very low precipitation amounts but also because of the extreme dryness and extreme heat (Table 1). Average in-season precipitation at RM over the last 20 years is 4.85 inches and average maximum high temperature is approximately 80˚F (Table 1). In-season precipitation for both 2002 and 2003 was ½ inch or less and average maximum temperatures were above 85˚F and 83˚F, respectively.

Organic fertilizer was applied each spring at the rate of 160 lbs of nitrogen (N) per acre. What remained of the mulches in the second and third spring was raked aside prior to fertilizer application. Following spring fertilizer application the old mulch was then raked back into the tree row over the organic fertilizer and new mulches applied. Mulches were renewed or replenished each spring in the tree row to a depth of approximately eight inches. The P mulch consisted of shredded recycled paper. The B mulch consisted of coarse bark from a local lumber mill. For the landscape fabric treatment, the fabric was removed, fertilizer applied, and the fabric replaced. The flamer and both mowing treatments were applied approximately every two weeks to one month as needed during the growing season.

Trees were pruned each winter. Approximately two weeks after bloom, fruit were thinned to an equivalent number of fruit per tree to establish a consistent crop load across all treatments. The orchard was irrigated with micro-sprinklers approximately every five to ten days as needed during the growing season.

Data was collected for weed density, fruit yield and mean fruit size, tree growth and soil inorganic N and organic matter (OM) levels. Weed density, or the percentage of the tree row covered by weeds, was estimated on all plots approximately once a month during the growing season prior to flame and mowing treatments. The weed density was then averaged over the growing season for each treatment. Fruit yield and fruit number was determined by counting and weighing fruit from each of the three data trees within each plot at harvest and averaged for each treatment. Average fruit weight was calculated from total fruit weight and fruit number. Tree growth was determined by measuring tree circumference at six inches above ground level of each of the three data trees in each plot and calculating the total trunk cross-sectional area (TCA). Tree growth measurements were taken prior to the initiation of the study and following the onset of dormancy each fall. Tree growth was evaluated as a percentage increase in tree TCA between the initial measurement and final measurement following the 2003 harvest. Soil samples were taken prior to bud break and following the first fall frost each year. The soil was analyzed for nitrate-nitrogen ($NO_3$-N), ammonium-nitrogen ($NH_4$-N) and percent organic matter (OM). Data was analyzed using the general linear model with a least significant difference level of 0.05 (SAS Institute, 2001).

Table 1. Average in-season climatic data 2001-2003.

| Year | Max. Temp. (˚F) | Min. Temp. (˚F) | Precipitation (in) | GDD | Reference ET (in) |
|---|---|---|---|---|---|
| 2001 | 82.7 | 49.7 | 1.1 | 1180 | 38.4 |
| 2002 | 85.4 | 49.6 | 0.4 | 1270 | 40.6 |
| 2003 | 83.4 | 49.6 | 0.5 | 1148 | 37.4 |
| 20 yr avg | 79.8 | 48.2 | 4.85 | | 28.0 |

## Results and Discussion

*Weed Density*

Weed density data show a significant treatment by year interaction. The M, FF and M&T treatments had a significantly higher weed density than the other treatments with the LF having significantly lower weed density than the other treatments, as expected (Fig. 1). In 2002, the M and FF were significantly higher and the LF significantly lower in weed density that the other treatments (Fig. 1). In 2003, the FF treatment was significantly higher than all other treatments and the LF had significantly lower weed density. In all treatments except FF, weed density was less each subsequent year, probably due to the cumulative effect of the treatments over the three years of the study, mentioned above. The weed density in the FF treatment was much less in 2002 than in the other two years, presumably due to the severe drought. Although irrigation was done on a regular basis, the extremely low relative humidity and very high daytime temperatures may have contributed to the reduced weed density (Table 1 and Appendix A). Overall the LF, P and B treatments appear to have shown the best weed suppression.

*Fruit Yield*

Fruit yields varied significantly by year probably due to the climatic factors mentioned above. Yields varied widely by year and treatment (Fig. 2). In 2001, the P treatment yielded more than all other treatments but not significantly higher than the M, F or B treatments. This is probably due to the study being in its first year so the treatment effects have not had sufficient time to take full effect and show significant treatment differences. This may be especially true in organic, perennial tree crops systems versus the typically quicker response of annual crops and/or conventional cropping systems where conventional fertilizers are readily available for plant uptake. In 2002, there were no significant yield differences in any of the treatments applied (Fig. 3). This is probably due to the severe dryness, drought and heat stress. The relative humidity (RH) was very low and temperatures were very high during the growing season in 2002 (Table 1), and probably had major effect on yield. In 2003, the P treatment did yield significantly higher than all other treatments (Fig. 2). This is likely due to better soil moisture retention in this treatment. The yield results indicate that some form of ground cover or mulching for weed control does significantly increase fruit yields in mature orchard blocks although the results are not as unambiguous as we would like. This result may only hold in drought years and mulching the trees may not have as significant an impact in a year with “normal” climate.

*Fruit Weight*

There was no significant treatment effect on fruit weight in any year, nor was there a treatment by year interaction. Therefore, data for each year were pooled to calculate the average fruit weight by year (Table 2). Fruit weight was significantly different each year. The highest fruit weight was in 2001 and the least in the severe drought year of 2002. Crop load was similar in 2001 and 2002, and only slightly higher in 2003. Hence, the climate and growing conditions in each particular year had a more significant effect on fruit weight than any of the treatments imposed.

Table 2. Fruit weight, 2001 – 2003.

| Year | Average Fruit Weight (g) |
|---|---|
| 2001 | 154 a* |
| 2002 | 117 c |
| 2003 | 126 b |

* Different letter indicates significant differences between means ($P < 0.05$).

*Tree Growth*

Tree growth showed no significant treatment differences over the three years of the study. This may be due to the fact that the study was done on a mature orchard (data not presented).

*Soil Organic Matter*

The soil OM showed a significant increase based on the percent change over the three years of the study (Table 3). The largest increase occurred in the B treatment and was significantly higher than all other treatments except the M&T treatment. The results indicate that any of these treatments will increase OM levels in the short-term, likely due to yearly additions of organic fertilizer plus additions due to treatments. These results are somewhat as expected, in that the LF and FF treatments have the lowest increase, probably due to lack of weeds and not mowing, respectively.

Table 3. Soil organic matter increase 2001 – 2003.

| Treatment | OM increase (%) |
|---|---|
| Mow | 77.8 bc* |
| Flamer | 61.1 cd |
| Landscape Fabric | 28.8 d |
| Paper | 47.5 cd |
| Farmer's Favorite | 25.2 d |
| Mow & Throw | 94.1 ab |
| Bark | 119.3 a |

* Different letter indicates significant differences between means ($P < 0.05$).

*Soil Inorganic Nitrogen*

Soils were sampled for NO3-N and NH4-N prior to the start of the study and in the fall each year. However, the source of organic fertilizer was changed between the first and second year due to fertilizer availability. Blood meal (13-2-1) was used in 2001 and a commercial organic fertilizer (12-2-0) was used in 2002 and 2003. There were no significant effects on soil $NO_3$-N due to treatments over the three years of the study, therefore the soil NO3-N was averaged over treatments (Figure 3). There were, however, significant year-to-year differences of soil $NO_3$-N over the three years of the study. The soil $NO_3$-N remained relatively steady for 2001 and 2002, however, soil $NO_3$-N did increase significantly in the fall of 2003 (Fig. 3). This is possibly due to an adequate N application rate and the trees not needing to 'draw down' the soil N for tree growth and maintenance in 2003.

The soil $NH_4$-N levels did have significant year-to-year differences, however, the actual difference are small, between two and six lbs $NH_4$-N per acre (data not shown). Typically, soil $NH_4$-N levels do not show large fluctuations, as can be the case for soil $NO_3$-N levels. This is due in part to large microbial populations under organic systems that either quickly immobilize the $NH_4$-N as it is mineralized from decomposing soil organic matter or convert it quickly from $NH_4$-N to $NO_3$-N.

## Conclusions

The results from this study are not conclusive, suggesting that a three-year study may be of too short in duration to obtain definitive results in an organic perennial system. Considering that the three years of the study were during drought years, the outcome may also be skewed due to climatic stresses on the trees. The data do show that mulching reduces weed density and hence, weed pressure on the orchard, which along with the soil moisture effect likely led to the higher yields. Two of the mulch treatments, the P and B treatments did show a trend towards producing higher yields. In the third year of the study, the P treatment produced significantly higher yields than all other treatments, but this is by no means conclusive. Fruit weight appears to have been influenced more by stresses due to climate than by treatments. Tree growth was not significantly affected by any of the treatments imposed. Soil organic matter levels were significantly increased over the three years of the study in most treatments, the benefits of which will probably be a higher soil quality in the years to come but does not appear to have an immediate, short-term impact on fruit yield or weight as may be expected in organic systems. It appears that soil inorganic N was positively influenced during the study, however, this may be much more heavily influenced by increases in OM levels than by imposed treatments. We can conclude that organic perennial agricultural systems are highly buffered and very resistant to changes and change appears to be small and incremental over the short term. This buffered

system may be the strength of an organic system compared to conventional systems where there can be large year to year changes in both production and fertility.

**Acknowledgments**

A special thanks to Bryan Braddy and George Osborn for assistance with this project.

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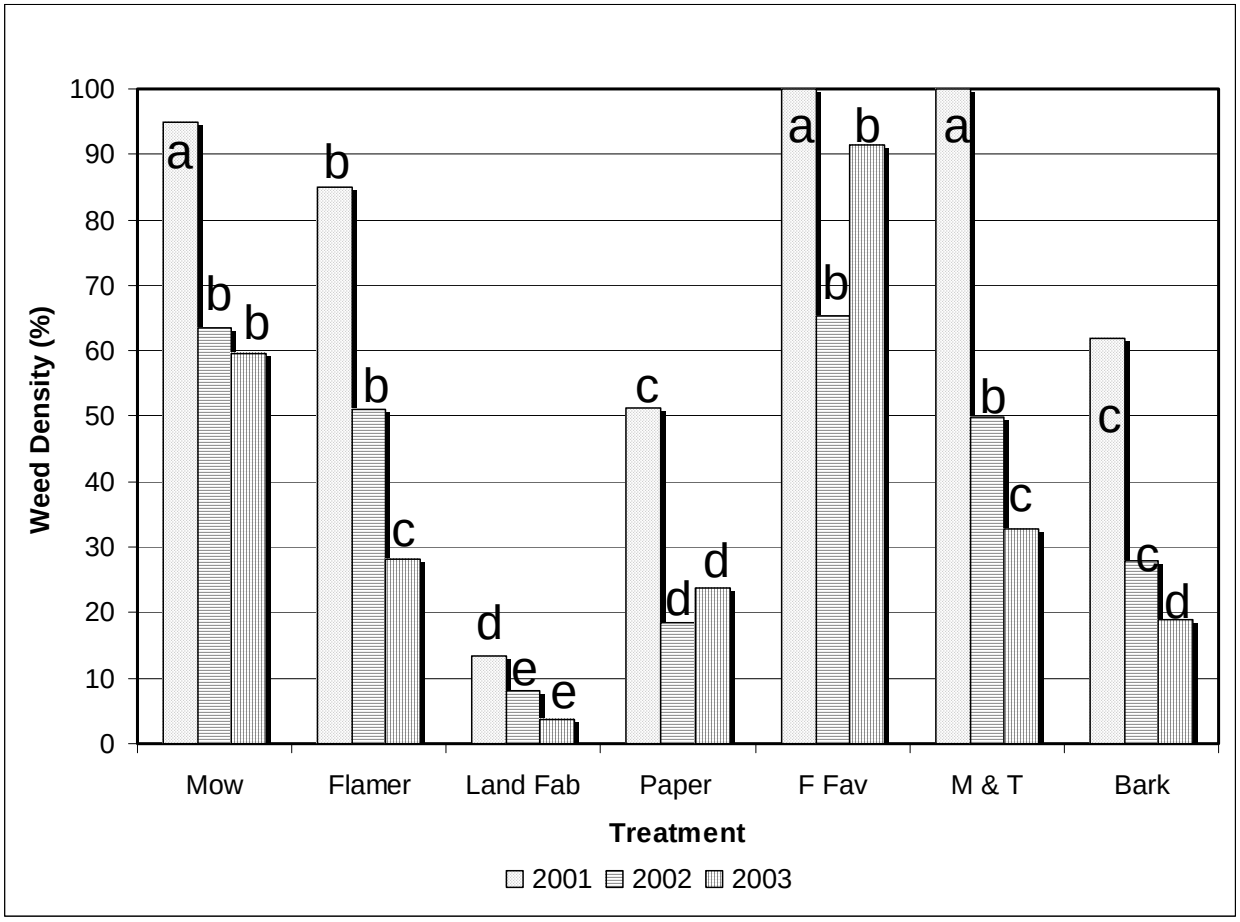


Fig. 1. Effect of weed control methods in a mature 'Gala' apple orchard on weed density, 2001 – 2003. Different letters indicate significant differences between means ($P < 0.05$).

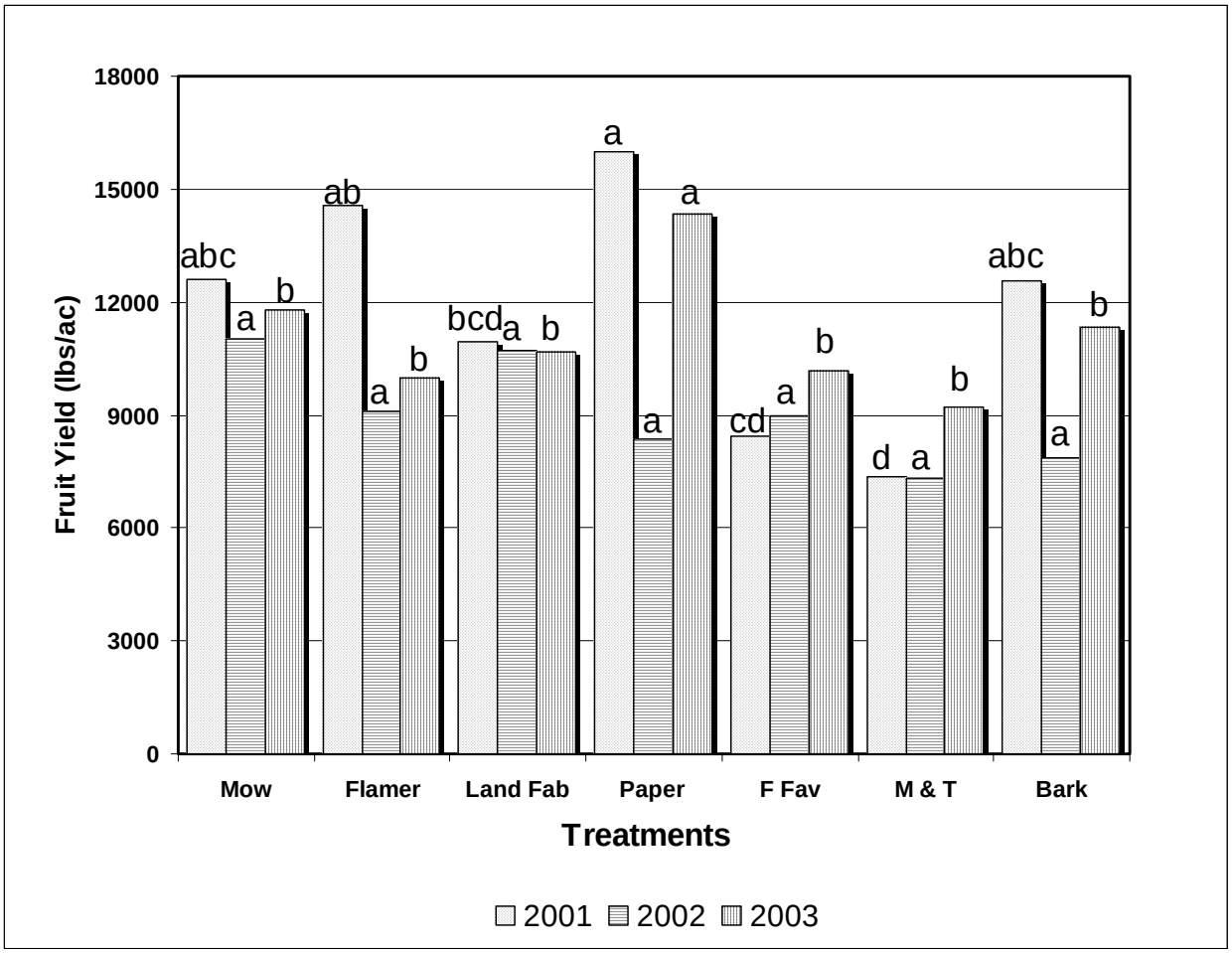


Fig. 2. Effect of weed control methods on fruit yield of mature 'Gala' apple trees, 2001 – 2003. Different letters within the same year indicate significant differences between means ($P < 0.05$).

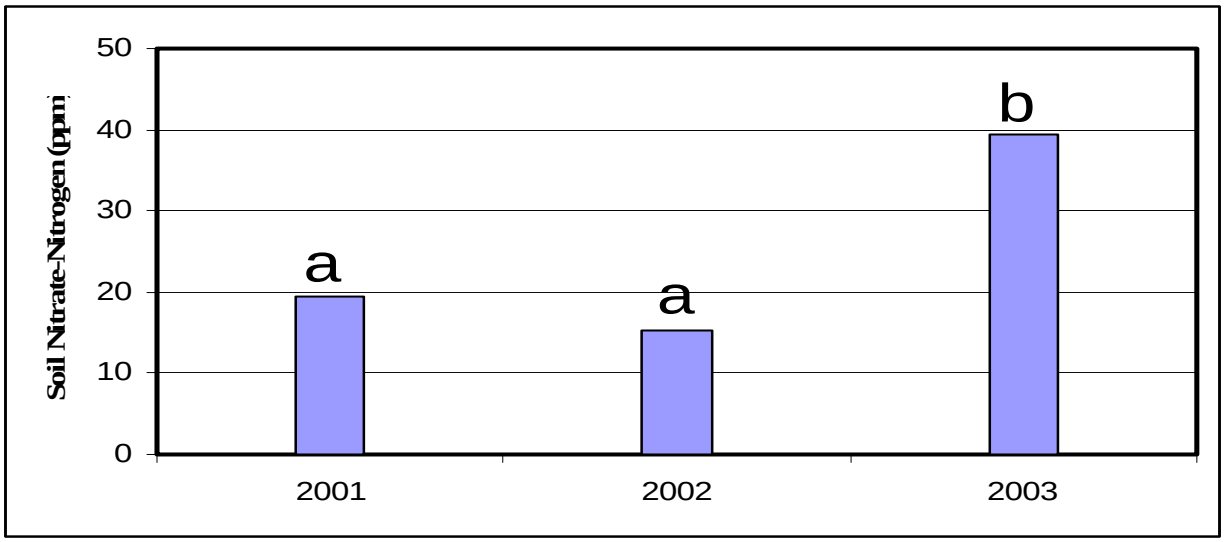


Fig. 3. 'Gala' apple orchard soil $NO_3$-N, fall 2001 – fall 2003. Different letters indicate significant differences between means ($P < 0.05$).

Appendix A. Monthly mean maximum and minimum temperatures, and monthly totals of precipitation, growing degree days, and reference evapotranspiration for Rogers Mesa, 2001 – 2003.

| | Max. Temp. (ºF) | Min. Temp. (ºF) | Precipitation (in) | Growing Degree Days (base 50 ºF) | Reference ET (in) |
|---|---|---|---|---|---|
| Jan-01 | 40.6 | 16.1 | 0.45 | | 1.20 |
| Feb-01 | 47.6 | 24.4 | 0.72 | | 1.63 |
| Mar-01 | 56.2 | 31.2 | 1.41 | 46 | 3.20 |
| Apr-01 | 66.1 | 37.9 | 0.63 | 215 | 5.47 |
| May-01 | 78.0 | 44.5 | 1.48 | 555 | 7.81 |
| Jun-01 | 89.0 | 51.2 | 0.38 | 1064 | 9.26 |
| Jul-01 | 91.8 | 58.8 | 1.37 | 1701 | 8.35 |
| Aug-01 | 88.8 | 56.2 | 1.62 | 2369 | 7.49 |
| Sep-01 | 85.5 | 48.7 | 0.19 | 2934 | 6.36 |
| Oct-01 | 69.9 | 38.0 | 0.73 | 3206 | 3.67 |
| Nov-01 | 56.6 | 30.8 | 0.86 | | 1.84 |
| Dec-01 | 40.4 | 19.6 | 0.55 | | 0.82 |
| **2001** | **67.5** | **38.1** | **10.39** | **3206** | **57.1** |
| | | | | | |
| Jan-02 | 40.1 | 17.5 | 0.20 | | 1.06 |
| Feb-02 | 43.5 | 16.9 | 0.07 | | 1.54 |
| Mar-02 | 54.0 | 24.1 | 0.52 | 41 | 3.46 |
| Apr-02 | 70.6 | 38.5 | 0.63 | 282 | 6.03 |
| May-02 | 78.1 | 42.2 | 0.05 | 628 | 8.16 |
| Jun-02 | 92.0 | 53.3 | 0.03 | 1149 | 9.66 |
| Jul-02 | 95.9 | 59.4 | 0.34 | 1814 | 8.72 |
| Aug-02 | 90.2 | 54.7 | 0.69 | 2477 | 8.06 |
| Sep-02 | 77.6 | 48.8 | 3.26 | 3012 | 4.84 |
| Oct-02 | 63.8 | 35.5 | 2.11 | 3208 | 3.08 |
| Nov-02 | 50.2 | 24.9 | 0.46 | | 1.36 |
| Dec-02 | 43.4 | 20.5 | 0.27 | | 0.90 |
| **2002** | **66.6** | **36.4** | **8.63** | **3208** | **56.9** |
| | | | | | |
| Jan-03 | 48.4 | 23.1 | 0.17 | | 1.16 |
| Feb-03 | 44.6 | 23.0 | 0.90 | | 1.27 |
| Mar-03 | 55.9 | 29.6 | 0.57 | 56 | 3.10 |
| Apr-03 | 65.4 | 36.1 | 0.27 | 224 | 5.28 |
| May-03 | 76.6 | 44.5 | 1.33 | 511 | 7.04 |
| Jun-03 | 85.6 | 50.2 | 0.23 | 1027 | 9.36 |
| Jul-03 | 98.1 | 59.1 | 0.31 | 1635 | 8.67 |
| Aug-03 | 91.3 | 58.3 | 0.18 | 2344 | 7.09 |
| Sep-03 | 80.0 | 45.4 | 1.42 | 2906 | 5.25 |
| Oct-03 | 73.2 | 40.4 | 0.42 | 3144 | 3.91 |
| Nov-03 | 48.5 | 27.6 | 0.85 | | 1.27 |
| Dec-03 | 41.7 | 20.3 | 0.40 | | 0.68 |
| **2003** | **67.4** | **38.1** | **7.05** | **3144** | **54.1** |

# Application of Crop Modeling for Sustainable Grape Production

Harold J. Larsen[1] and Horst W. Caspari[2]

**Summary**

In 2004, the third year of this study, no grape powdery mildew was detected until late June / early July in four out of five participating vineyards. At all sites, the incidence and severity of leaf infection were higher in the integrated disease management program than in the grower standard program. However, overall both the incidence of leaf infection and the severity on infected leaves were low, and there was no fruit infection in either program. Spray applications in response to initial observations of powdery mildew infections reduced incidence and severity to levels similar to that of a season-long control program while reducing the number of applications. Control costs were lower as a consequence for three vineyards, but higher on two vineyards compared to the grower standard program.

Overall, the project has demonstrated that the integrated disease management program has the potential to substantially reduce both the number of spray applications and application costs compared to a calendar-based spray program. Under favorable weather conditions, i.e. dry spring and early summer, it is feasible to control powdery mildew with as little as 1-2 spray applications compared to 7-8 applications in a calendar-based program. Survey data from 2004 suggest that many grape growers are adopting the reduced spray program.

## Introduction and Objectives

Grape powdery mildew is one of the most serious and ubiquitous diseases of grape throughout the world. It is the primary disease of *Vitis vinifera* grapes in Colorado historically, and control has required multiple (two to eight) mildewcide sprays through the season with a seasonal cost of $40 - 115 per acre for a four spray seasonal program typically used by grape producers.

The typical grape powdery mildew control program in western Colorado vineyards has been preventative in nature, with the use of prophylactic sprays applied beginning with early shoot growth and continuing through veraison at intervals determined by the spray longevity of the materials used. This has historically resulted in four to as many as eight sprays applied each season. Often, however, such a prophylactic approach may not be needed in the more arid climate of western Colorado. There are many years in which grape powdery mildew infection periods (defined as 12 hour time periods in which temperatures range between 50 and 85 ºF with high humidity and leaf wetness periods of 12 hours or more) do not occur until mid-summer. Prophylactic sprays applied prior to such infection periods are likely unneeded for disease control and an unnecessary expense for producers.

The present study investigates the use of electronic weather data to monitor and forecast the risk of powdery mildew infection based on such weather data. Predicted mildew infection risk is verified by on-site monitoring of actual powdery mildew incidence and severity through the season. Finally, comparisons are made of mildew control and costs for adjacent plots that use a "grower's standard control program" with that of plots that use an "integrated mildew control program" which limits sprays to times associated with actual infection risk.

## Materials and Methods

Five cooperator vineyards were identified with a minimum 2 acres of a single grape variety (four Chardonnay, vineyards A, B, C & E, and one Sauvignon blanc, vineyard D). Grower

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cooperators were to use their choice of control programs (grower's standard control program) for grape powdery mildew control on one half of the block (minimum of 1 acre) and to use the control program designated by the researchers for the other half of the block (minimum of 1 acre, which included the site of a remote weather station described below). The spray programs varied from one spray per season to seven sprays per season (Tables 1 - 5).

Table 1. Powdery mildew spray program used at cooperator vineyard A during the 2004 season.

| **Grower's Standard Mildew Program** | | | **Integrated Disease Management Program** | | |
|---|---|---|---|---|---|
| Date | Materials & rates used | Cost[z] | Date | Materials & rates used | Cost[z] |
| 4/26 | Sulfur 6L @ 0.5 gal/a | $2.50 | 4/26 | Sulfur 6L @ 0.5 gal/a | $2.50 |
| 5/10 | Sulfur 6L @ 0.5 gal/a | $2.50 | | | |
| 5/28 | *Stylet-Oil @ 1.0%*[y] | *$7.25*[y] | 5/28 | *Stylet-Oil @ 1.0%*[y] | *$7.25*[y] |
| 6/11 | Rubigan 1E @ 4 oz./a | $9.43 | | | |
| 6/24 | Stylet-Oil @ 1.5% | $10.88 | | | |
| | | | 7/2 | Rubigan 1E @ 4 oz./a + Sulfur 6L @ 2 qt/a | $11.93 |
| 7/6 | Rubigan 1E @ 4 oz./a + Sulfur 6L @ 2 qt/a | $11.93 | | | |
| 7/22 | Sovran 50W @ 4 oz./a + Stylet-Oil @ 1.0% | $33.00 | | | |
| 8/6 | Bayleton 50DF @ 4 oz./a | $15.75 | 8/6 | Bayleton 50DF @ 4 oz./a | $15.75 |
| Total Spray Program Cost | | **$93.24**[y] | Total Spray Program Cost | | **$37.43**[y] |

[z] Costs per acre for spray material only.
[y] Although Stylet-Oil was applied at 1% to control leafhoppers it is likely to have had some fungicidal activity. The costs for this spray are excluded from the total.

Table 2. Powdery mildew spray program used at cooperator vineyard B during the 2004 season.

| **Grower's Standard Mildew Program** | | | **Integrated Disease Management Program** | | |
|---|---|---|---|---|---|
| Date | Materials & rates used | Cost[z] | Date | Materials & rates used | Cost[z] |
| 4/20 | Thiolux 80DF @ 5 lbs/a | $4.25 | 4/20 | Thiolux 80DF @ 5 lbs/a | $4.25 |
| 5/18 | Nova 40W @ 3.3 oz./a | $14.19 | | | |
| 6/10 | Flint 50WDG @ 2 oz./a | $30.00 | | | |
| 6/15 | Nova 40W @ 5 oz./a | $21.50 | 6/15 | Nova 40W @ 5 oz./a | 21.50 |
| 7/6 | Stylet-Oil @ 1.5% | $19.50 | | | |
| 7/12 | Flint 50WDG @ 2 oz./a | $30.00 | 7/12 | Flint 50WDG @ 2 oz./a | $30.00 |
| | | | 7/30 | Thiolux 80 DF @ 3 lbs/a | $2.55 |
| 8/9 | Nova 40W @ 3 oz./a + Thiolux 80DF @ 3 lbs/a | $15.45 | | | |
| Total Spray Program Cost | | **$134.89** | Total Spray Program Cost | | **$58.30** |

[z] Costs per acre for spray material only.

Automated Adcon weather stations were installed at two vineyards in 2002, two additional vineyards in 2003, and one additional vineyard in 2004. The stations each were equipped with sensors to measure air temperature, humidity, leaf wetness, precipitation, wind speed and direction, and solar radiation. Data was relayed back to a base station via radio telemetry on 15-minute intervals. The base station database was then accessed using the Thomas-Gubler powdery

mildew disease model to assess mildew infection risk.

Field scouts assessed powdery mildew infection incidence and severity on variable intervals, typically once a week. Incidence and severity of powdery mildew infections on shoots and leaves were recorded from late May to mid August 2004 (about two weeks after veraison). Our sampling protocol was changed from the previous season to include both basal (near the fruit zone) and more apical leaves at each sampling time. Also, 25 vines were tagged in each block at the beginning of the season and were monitored throughout the season, with an additional 25 vines selected at random at each sampling date.

Table 3. Powdery mildew spray program used at cooperator vineyard C during the 2004 season.

| **Grower's Standard Mildew Program** | | | **Integrated Disease Management Program** | | |
|---|---|---|---|---|---|
| Date | Materials & rates used | Cost[z] | Date | Materials & rates used | Cost[z] |
| 6/25 | Sulfur 6L @ 4 qts/a + Nova 40W @ 5 oz./a | $26.50 | | | |
| | | | 7/8 | Sulfur 6L @ 0.6 gal/a | $3.00 |
| 7/30 | Thiolux 80DF @ 3 lb/a | $2.55 | 7/30 | Thiolux 80DF @ 3 lb/a | $2.55 |
| Total Spray Program Cost | | **$29.05** | Total Spray Program Cost | | **$5.55** |

[z] Costs per acre for spray material only.

Table 4. Powdery mildew spray program used at cooperator vineyard D during the 2004 season.

| **Grower's Standard Mildew Program** | | | **Integrated Disease Management Program** | | |
|---|---|---|---|---|---|
| Date | Materials & rates used | Cost[z] | Date | Materials & rates used | Cost[z] |
| 5/26 | Sulfur 6L @ 7 pts/a | $4.38 | 5/26 | Sulfur 6L @ 7 pts/a | $4.38 |
| 6/11 | Sulfur 6L @ 7 pts/a | $4.38 | | | |
| 7/14 | Thiolux 80DF @ 6 lbs/a | $5.10 | | | |
| 7/29 | Thiolux 80DF @ 6 lbs/a | $5.10 | | | |
| | | | 8/2 | Thiolux 80DF @ 3 lbs/a + Flint 50WDG @ 2 oz/a | $32.55 |
| Total Spray Program Cost | | **$18.96** | Total Spray Program Cost | | **$36.93** |

[z] Costs per acre for spray material only.

Table 5. Powdery mildew spray program used at cooperator vineyard E during the 2004 season

| **Grower's Standard Mildew Program** | | | **Integrated Disease Management Program** | | |
|---|---|---|---|---|---|
| Date | Materials & rates used | Cost[z] | Date | Materials & rates used | Cost[z] |
| 7/9 | Sulfur 6L @ 2.4 qts/a | $3.00 | | | |
| | | | 7/20 | Sulfur 6L @ 1.6 lbs/a + Nova 40WP @ 2.63 oz./a | $12.60 |
| Total Spray Program Cost | | **$3.00** | Total Spray Program Cost | | **$12.60** |

[z] Costs per acre for spray material only.

## Results

Weather conditions in the spring of 2004 differed markedly from those of 2003. April 2004 was the wettest April on record in the Grand Valley with 11 days of measurable precipitation for a total of 3.3 inches at the Orchard Mesa Research Center. There were seven days with precipitation exceeding 0.1 inch compared to only 1 day in 2003. In contrast, there was only one day with significant rainfall in May 2004 compared to three days in 2003. Despite the wet April as well as the rainfall

event in mid May no powdery mildew was found in any of the monitored vineyards until mid June (vineyard C) or July (all other sites; Fig. 1a,b). This lack of early-season infection is likely due to the low temperatures during rain events in April, and a short duration of leaf wetness in May. It is unclear why powdery mildew was found at vineyard C in mid June, as there was no significant rainfall until late June. At vineyard C, many vines had to be retrained from the ground following winter damage and it is possible that wetting of basal leaves via drip irrigation may have created artificial wetness periods sufficient to cause primary infections. This hypothesis is supported by the occurrence of an extended leaf wetness period on June 11/12 that was not detected at any other site. The first powdery mildew was observed five days later.

While the wetness period at vineyard C might explain the earlier onset of powdery mildew at that site, powdery mildew was also found, albeit at later dates, at all other monitored vineyards without extended wetness periods that are deemed required to cause a primary infection. At this point we can only speculate about the mechanism(s). It is possible that a primary infection occurred during the rainfall events in spring (April, May) but powdery mildew didn't develop much further until later in the season. This is unlikely as the weather conditions throughout May and June were very conducive to secondary infections. The most probable cause is that powdery mildew spores were blown in from other infected vineyards where artificial wetness periods caused a powdery mildew infection. Once powdery mildew is established conidial spores can be dispersed over longer distances by wind and, under favorable weather conditions, can start new infections. Temperatures and humidity in June and early July were indeed were favorable for secondary mildew infections. The establishment of powdery mildew without an apparent primary infection on site also illustrates the importance of vineyard monitoring.

With the exception of vineyard A, where no powdery mildew was found at all in the grower program, all vineyards had low levels of incidence and severity, irrespective of spray program (Fig. 1a,b). There was a tendency for higher levels early in the season in the integrated disease program, however disease incidence and severity were similar to the grower program once treatments were initiated. The model program led to a reduction in spray applications on four vineyards, while there was only one application in both programs in vineyard E.

Spray costs (materials only) were reduced by up to $76 per acre (Table 6). Vineyards C and E had the same number of application in both programs, and costs were either higher (vineyard C) or lower (vineyard E) in the integrated program, depending on the spray material used. Likewise, costs for spray material were higher in the integrated program for vineyard D as the grower used a sulfur-only program with four applications versus only two applications - one sulfur, and one Flint and sulfur - in the integrated program. The higher costs in the integrated program were due to the higher cost for Flint.

Table 6. Multi-year comparison of number of sprays applied and costs per acre for five cooperator vineyards in western Colorado that used the grower's standard program and the integrated (model-driven) program to control grape powdery mildew (2002-2004).

| Vineyard | YIP[z] | Grower | | | | | | IDM | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2002 | | 2003 | | 2004 | | 2002 | | 2003 | | 2004 | |
| | | # | Cost[y] | # | Cost[y] | # | Cost[y] | # | Cost[y] | # | Cost[y] | # | Cost[y] |
| A | 3 | 4 | $32.06 | 8 | $154.20 | 7 | $93.24 | 4 | $32.06 | 6 | $149.45 | 3 | $37.43 |
| B | 3 | 7 | $118.55 | 5 | $110.40 | 7 | $134.89 | 2 | $19.05 | 4 | $115.49 | 4 | $58.30 |
| C | 2 | | | 6 | $83.36 | 2 | $29.50 | | | 2 | $40.26 | 2 | $5.55 |
| D | 2 | | | 1 | $2.55 | 4 | $18.96 | | | 1 | $2.55 | 2 | $36.93 |
| E | 1 | | | | | 1 | $3.00 | | | | | 1 | $12.60 |

[z] Years participating in the program.
[y] Costs per acre for spray material only.

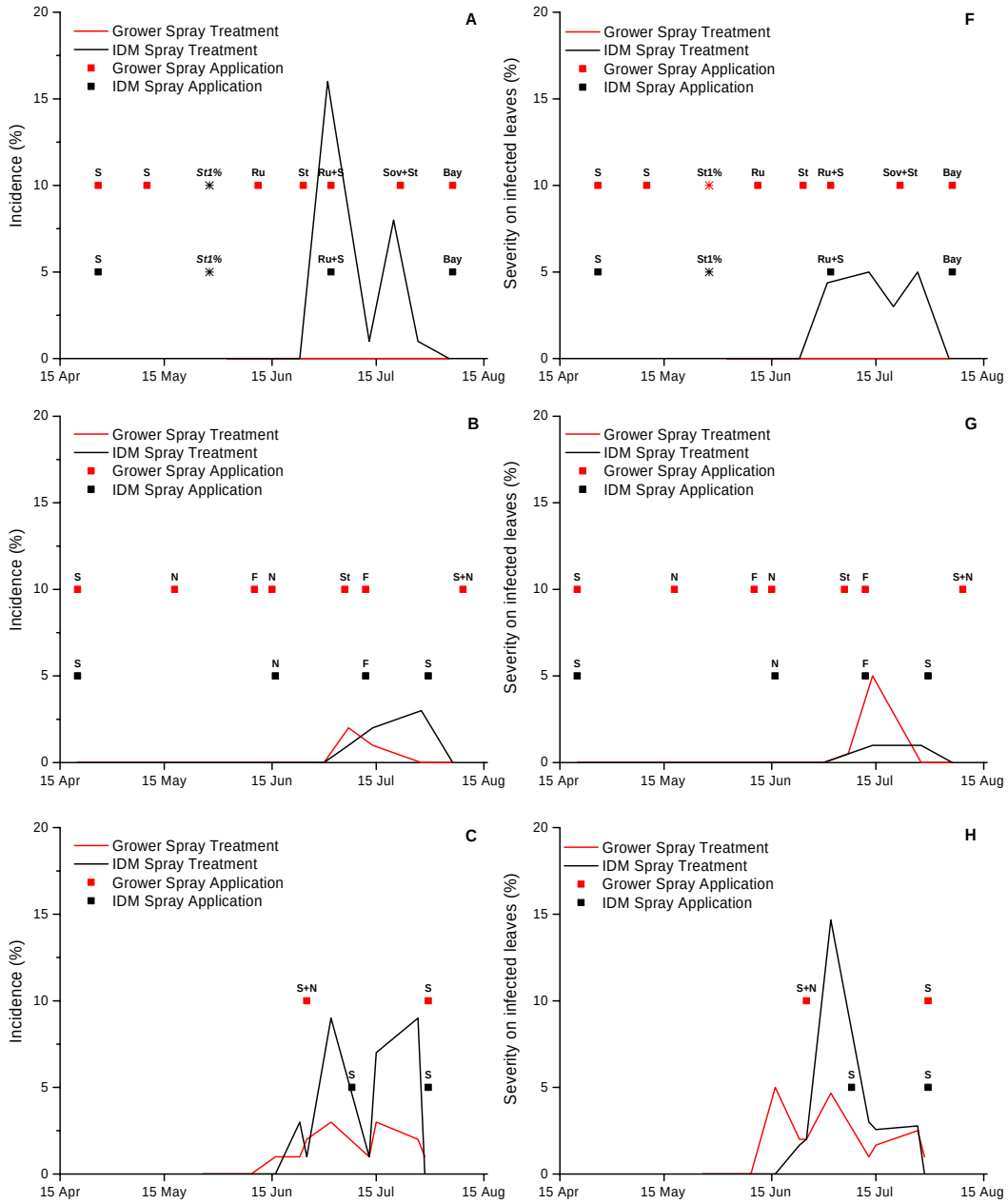


Fig. 1a. Incidence (A-C) and severity (F-H) of grape powdery mildew on Chardonnay leaves at three Colorado vineyards in 2004. Note that the severity is for infected leaves only. At each site, the grower's standard spray program was compared to a reduced (IDM) spray program. Spray applications are indicated by "■" (grower program) and "■" (IDM program). Abbreviations: Bay - Bayleton, F - Flint, N - Nova, Ru - Rubigan, S - sulfur, Sov - Sovran, St - Stylet Oil.

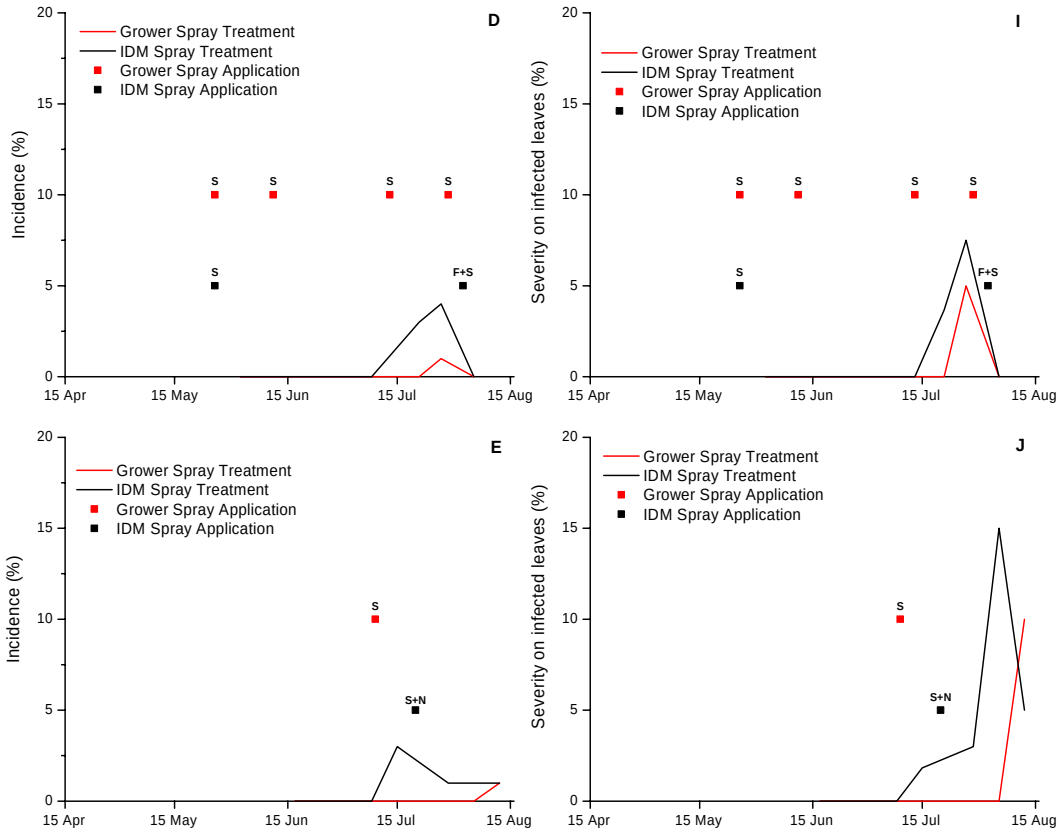


Fig. 1b. Incidence (D-E) and severity (I-J) of grape powdery mildew on Chardonnay (E, J) and Sauvignon blanc (D, I) leaves at two Colorado vineyards in 2004. Note that the severity is for infected leaves only. At each site, the grower's standard spray program was compared to a reduced (IDM) spray program. Spray applications are indicated by "■" (grower program) and "■" (IDM program). Abbreviations: Bay - Bayleton, F - Flint, N - Nova, Ru - Rubigan, S - sulfur, Sov - Sovran, St - Stylet Oil.

This project has shown that grape powdery mildew can be effectively controlled with a spray program that is reactive rather than preventative in nature. Using such a program can lead to significant reductions in both spray applications and the costs for spray materials. However, early detection of powdery mildew infection is critical for the success of any control strategy, including the integrated program. When initial infections are missed, such as in 2003, costs to control the disease might equal those of a calendar-based program due to the requirement to use more expensive material to control an infection. It should also be noted that powdery mildew developed rather late in the three years of this project, and there may be no cost savings in years when a powdery mildew infection happens in early spring. Nevertheless, in years when climatic conditions are less favorable for powdery mildew, significant cost savings can be achieved.

In the "2004 Colorado Wine Grower Survey" we asked growers how many powdery mildew sprays they had applied in the 2004 season. Eightysix out of 99 survey respondents provided information on their spray program. More than 25 % of the growers did not apply a powdery mildew spray in 2004, and more than half the growers used two or less sprays (Fig. 2). In contrast, less than 10 % applied five or more sprays to control powdery mildew. When only the producing vineyard area is considered the percentages change slightly, however the overall trend remains the same. These data suggest that many growers have adopted a spray program that is in response to powdery mildew infection rather than a calendar-based preventative program.

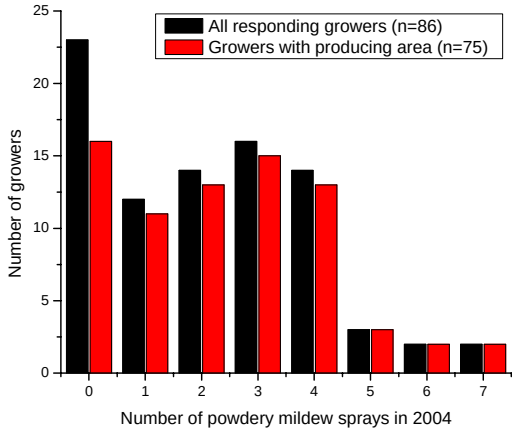


Fig. 2. Number of powdery mildew sprays applied in 2004 by Colorado grape growers.

**Acknowledgments**

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# Integrating Control Strategies for Powdery Mildew

Andrew P. Norton[1], Harold J. Larsen[2], Horst W. Caspari[3]

**Summary**

Grape powdery mildew is one of the most serious pests of grapes worldwide. Although fungicides are often an effective management strategy, concern over resistance development and the expense of multiple applications of fungicides warrant the investigation into alternative methods for managing this pest. We report the results of three years research on the impact of two different programs (a DMI / Strobilurin rotation or Stylet-Oil) and the fungal feeding mite, *Homeopronematus anconai* on powdery mildew incidence and severity. Both fungicide programs provided similar levels of control and were able to substantially reduce mildew severity in the vineyard. Releases of *H. anconai* did not have a significant impact on mildew levels, most likely because the mite populations remained at low levels throughout the experiment. Laboratory tests of the impact of commonly used pesticides on mite survivorship indicate that pesticide use in the vineyard was not likely a contributing factor to low mite densities. Rather, environmental conditions (hot, dry summers) are a more likely reason for poor mite population growth.

## Introduction and Objectives

Powdery mildew is the most destructive pest of grapes worldwide (Pearson and Goheen, 1988). The causal agent of grape powdery mildew, *Uncinula necator*, is North American in origin but has spread to every grape growing region of the world. Without the use of fungicides grape powdery mildew results in reduced vine health, grape quality and yield. This pest consistently has been rated as a top pest and a research priority by California grape producers (AVF, 1999). Current management practices for this pest rely upon the regular application of fungicides throughout the growing season (Gubler and Hirschfelt, 1992; Weigle and Kovach, 1995). Use of fungicides for powdery mildew control has been an effective means of managing this pest, but there is continued concern that the rapid ability of the pathogen to develop resistance to these compounds has left researchers and growers only one step ahead of the pathogen. Although there has been considerable interest in finding effective biological controls for this pest, successes have been limited due to the environmental requirements of fungal parasites of the pathogen (Verhaar et al. 1999a, 1999b) and the sensitivity of these organisms to the same fungicides used to control outbreaks of the pest. Here we propose the development of a biological control entirely novel to the western region: mycophagous mites.

In Colorado, powdery mildew is the primary disease problem faced by grape growers. The crop susceptible period typically runs around 16 weeks per season in western Colorado, with possible additional protection needed for foliage and canes after veraison (the initiation of fruit coloration). This means that as many as eight sprays of sulfur plus an additional one or two sprays with short pre-harvest intervals after veraison may be applied. Sulfur currently is the least expensive control and runs around $10 per acre per spray. Other control options include DMI and strobilurin fungicides, which are recommended to be used in programs that rotate chemistries throughout the season to avoid development of chemical resistance within the pathogen population. Such rotational programs may stretch spray intervals to 3 weeks between sprays and reduce number of spray applications to five or six prior to veraison, costs to $60 - 70

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per acre per season, although some rotational programs can range up to as high as $115 per acre per season.

Recent work has demonstrated that a new class of biological control organisms for fungal epiphytes may prove to be extremely useful for powdery mildew control. Mites in the family Tydeidae feed upon fungal epiphytes and other microorganisms on the leaf surface. Research in New York (English-Loeb et al. 1999, Norton et al. 2000) has demonstrated that at least two species of tydeid mite are potent consumers of grape powdery mildew on 2 different species of grapes (the native *V. riparia* and the wine and table grape, *V. vinifera*). One of these mites, *Orthotydeus lambi*, is able to persist and thrive in experimental plantings of grapes in spite of regular applications of fungicides and insecticides. Research in 2001 in Colorado (Norton, unpublished) demonstrated that another species of mite, *Homeopronematus anconai* thrives on cultivated grapes and reduces mildew as well (Fig. 1). Surveys for these mites indicate that *O. lambi* is more common in northeastern and in western coastal North America and *H. anconai* is common on wild grapes in the drier Colorado climate. Research by Knop and Hoy (1983) demonstrated that this species has been a common inhabitant of commercial vineyards in California as well.

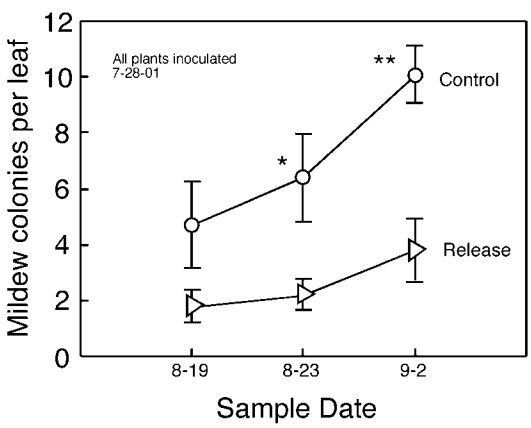


Fig. 1. Reduction in powdery mildew incidence in response to releases of the mite *Homeopronematus anconai*. Vines were inoculated on 7/28/2001 with powdery mildew spores. Mites were released onto the vines on 8/5 and averaged 11 mites per leaf. * $P < 0.05$, ** $P < 0.01$

This document reports the results of three years research on powdery mildew management in Western Colorado. This research emphasized 1) determination of the efficacy of two proposed fungicide programs: a DMI / strobilurin rotation and a Stylet-Oil program, 2) measurement of the impacts of these programs on the tydeid mite *H. anconai*, and 3) measurement of the impact of *H. anconai* on mildew severity. Further, we used laboratory bioassays to determine the impact of several commonly used fungicides, insecticides and acaricides on *H. anconai* survivorship.

## Materials and Methods

Mites (*H. anconai*) were collected from wild grape vines near Fort Collins, CO and transferred to vines in the experimental vineyard at the Western Colorado Research Center – Orchard Mesa in Grand Junction, CO in 2002. Mite populations were monitored during 2002, 2003, and 2004 growing seasons. Vines intended to be mite-free were treated with pyridaben at 370 g a.i./ha early on June 12, 2003 at early shoot growth. The 2002 growing season was hotter and drier than usual, and powdery mildew infestations did not develop until later in the season. In this year only two applications of fungicides were applied (Table 1). Three powdery mildew sprays were applied during 2003 and 2004 (Table 1). In 2003, a grape leafhopper spray of imidacloprid was applied at the rate of 52.54 g a.i./ha on July 30. The three powdery mildew spray programs were as follows: 1) non-sprayed control; 2) a rotational program that rotated myclobutanil (applied at the rate of 140 g a.i./ha) with kresoxim-methyl (applied at the rate of 175 g a.i./ha); and 3) Stylet-Oil (paraffinic oil) applied at the rate of 1% vol./vol. Powdery mildew infection was evaluated on six leaves (using the last fully expanded leaf on shoots) for incidence and severity on four dates in 2003: 6/24, 7/9, 7/28, and 8/29.

Counts of tydeid mites were made from a 15-leaf sample from each vine. In 2002 we counted mites on 7/15, 8/02, 8/16, and 10/1. In 2003, mite assessments were made on 6/24, 7/8, 7/29, 8/14, and 9/24. A single count was made in 2004 on 7/07. Leaves were collected from the field, shipped overnight to Fort Collins and counted under a dissecting microscope.

*Impact of pesticides on H. anconai survivorship.*

In 2004, we determined the impact of several commonly used pesticides on *H. anconai* survivorship. We applied field rates of the pesticides to the leaves of potted grapevines kept outside in Fort Collins, CO, on 7/20 and 8/03. For compounds tested and rates applied, see Table 4. Residues were allowed to dry for 24 hours. The impact of these residues on tydeid survivorship was determined by transferring 10 adult mites to each of three 20 mm diameter leaf disks. Leaf disks were held on moistened cotton to keep the disk from drying out and to restrict mites to the leaf disks. Mite survivorship and fecundity were determined at 24, 48 and 72 hours. This experiment was repeated twice.

## Results

*Homeopronematus anconai densities*

Mite releases resulted in higher densities of *H. anconai*. Vines where we released the mites had 0.23 mites per leaf compared to only 0.11 on control vines. Mite releases did result in an increase in the density of this beneficial. However, in the winter of 2002 - 2003, severe cold weather killed the above ground portion of a large number of vines, and mite densities on the vines in 2003 were very low in the early part of the season. Late season mite counts found slightly more mites in 2003 (0.38 mites per leaf) than in 2002, but densities never reached levels approaching those seen on wild *V. riparia* grapes. In the single census of mites in 2004, we found 0 mites on all leaves sampled.

In 2003, there was a significant effect of fungicide program on field densities of mites. There were significantly greater numbers of mites on the Stylet-Oil treated vines than on control vines (0.4 mites per leaf on Stylet-Oil, 0.2 mite per leaf in the control, $P < 0.05$). The DMI / Strobilurin program also had more mites than control vines, averaging 0.36 mites per leaf, but this was not significantly different from either control or Stylet-Oil treatments. These results indicate that neither of these fungicide programs resulted in mite reductions.

These densities of *H. anconai* are lower than we anticipated finding in the vineyard, and were dramatically lower than those found in surveys of wild grape vines. For example, *H. anconai* densities averaged 1.95 and 4.41 mites per leaf in surveys taken in July of 2002 and 2003, respectively. It may be that mite densities will continue to increase in this vineyard, or alternatively, the low humidity conditions in western Colorado and the absence of significant alternative food sources will limit *H. anconai* densities in this part of the world.

*Mildew levels*

In 2002, late season assessment of mildew incidence and severity indicated that the DMI / Strobilurin rotation significantly reduced both incidence and severity of powdery mildew (Fig. 2). In this year there was no significant effect of Stylet-Oil on mildew levels. In 2002, spray applications were made in 50 gallons of water per acre, lower than the 200 gallons per acre used in subsequent years. In addition, because of hot dry weather powdery mildew did not develop in the vineyard until later than usual, and the first spray application was not made until July 13th. In 2003 and 2004, both the rotational program and Stylet-Oil significantly reduced mildew severity. In both of these years, our experiment found no significant difference between these two treatments. Not surprisingly, the low densities of mites in this experiment did not significantly reduce mildew severity on our vines. Across all treatments severity averaged 31 % on mite release vines and 34% in control vines.

*Impact of pesticides on H. anconai survivorship*

Laboratory bioassays of the effects of 24 hour old residues of field rates of common pesticides on *H. anconai* survival indicated that the fungicides Quadris (azoxystrobin) and Sovran (kresoxim-methyl) and the insecticide Provado (imidacloprid) did not significantly reduce mite survivorship relative to the control. The fungicides Flint (trifloxystrobin) and Dithane (mancozeb) and the insecticide Sevin (carbaryl) exhibited intermediate effects, resulting in 24-hour survivorship of 77%, 68%, and 43%, respectively. The acaricides Pyramite (pyridaben) and Kelthane (dicofol) and the fungicide sulfur were the most toxic, killing greater than 97% of beneficial mites exposed to residues of these compounds (Fig. 3).

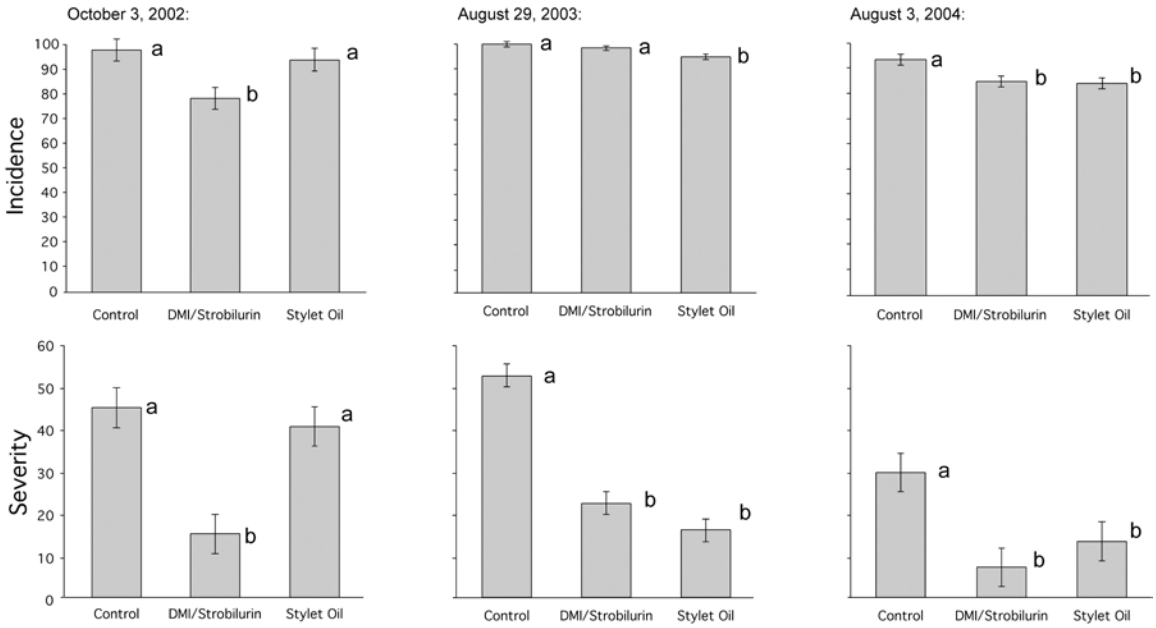


Fig. 2. Grape powdery mildew incidence (top) and severity (bottom) in response to fungicide applications for the three years of the experiment.

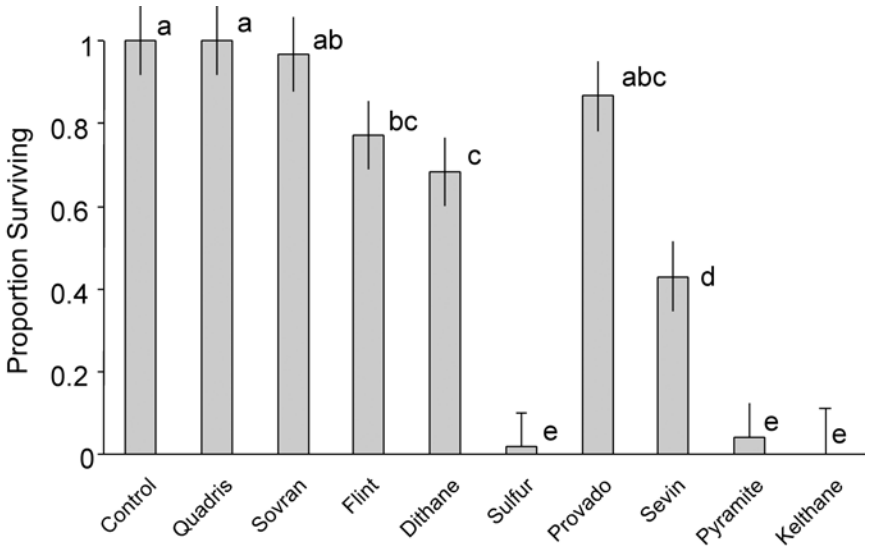


Fig. 3. *H. anconai* survivorship in response to pesticide residues. Bars not followed by the same letter are significantly different ($P < 0.05$).

## Conclusions

Both Stylet-Oil and the Nova / Sovran fungicide programs provided similar levels of powdery mildew control. At 2004 prices ($26.00 per acre per application for Stylet-Oil, $25.65 per acre per application for Sovran, and $17.20 per application per acre for Nova) the DMI / Strobilurin rotation is less expensive than Stylet-Oil for powdery mildew management. However, as there may be additional advantages of Stylet-Oil applications (i.e. low potential for resistance development and Stylet-Oil may contribute to reduced spider mite and leafhopper densities), a powdery mildew management program that includes Stylet-Oil applications may be warranted.

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## Acknowledgments

Funding for this study was provided by a grant from the Western Regional Integrated Pest Management Program.


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Table 1. Fungicide application dates, materials and rates used in vineyard plots at W. Colorado Research Center – Orchard Mesa, Grand Junction, CO during the 2002, 2003, and 2004 growing season. Spray volumes were 50 gallons per acre in 2002, and 200 gallons per acre in 2003 and 2004.

| Treatment Program Type | Spray Dates | Materials & rates used |
|---|---|---|
| 2002 | | |
| Control | Non-treated control | None |
| Rotation Program | a. 7/13/2002<br>b. 8/5/2002 | a. Nova (myclobutanil) 40W @ 5 oz. / acre<br>b. Sovran (kresoxim-methyl) 50WG @ 2 oz. / acre |
| Stylet-Oil | a. 7/13/2002<br>b. 8/5/2002 | a. Stylet-Oil (paraffinic oil) @ 1% vol./vol.<br>b. Stylet-Oil (paraffinic oil) @ 1% vol./vol. |
| 2003 | | |
| Control | Non-treated control | None |
| Rotation Program | a. 6/25-26/2003<br>b. 7/11/2003<br>c. 7/30/2003 | a. Nova (myclobutanil) 40W @ 4 oz. / acre<br>b. Sovran (kresoxim-methyl) 50WG @ 4 oz. / acre<br>c. Nova (myclobutanil) 40W @ 4 oz. / acre |
| Stylet-Oil | a. 6/26/2003<br>b. 7/11/2003<br>c. 7/30/2003 | a. Stylet-Oil (paraffinic oil) @ 1% vol./vol.<br>b. Stylet-Oil (paraffinic oil) @ 1% vol./vol.<br>c. Stylet-Oil (paraffinic oil) @ 1% vol./vol. |
| 2004 | | |
| Control | Non-treated control | None |
| Rotation Program | a. 6/18/2004<br>b. 7/7/2004<br>c. 7/30/2004 | a. Sovran (kresoxim-methyl) 50WG @ 4 oz. / acre<br>b. Nova (myclobutanil) 40W @ 4 oz. / acre<br>c. Sovran (kresoxim-methyl) 50WG @ 4 oz. / acre |
| Stylet-Oil | a. 6/18/2004<br>b. 7/7/2004<br>c. 7/30/2004 | a. Stylet-Oil (paraffinic oil) @ 1% vol./vol.<br>b. Stylet-Oil (paraffinic oil) @ 1% vol./vol.<br>c. Stylet-Oil (paraffinic oil) @ 1% vol./vol. |

Table 2. Pesticides and rates used for *H. anconai* bioassays. In all cases concentrations used assumed a total spray volume of 200 gallons per acre for the amount of product listed. Pesticides were then applied to run off using a small hand sprayer.

| Pesticide | Active ingredient | Rate of product per acre |
|---|---|---|
| Fungicides | | |
| Dithane DF | Mancozeb | 2.5 lb |
| Quadris | Azoxystrobim | 15.4 fl oz |
| Flint 50WG | Trifloxystrobin | 3.0 oz |
| Rubigan EC | Fenarimol | 6 fl oz |
| Sulfur 6L | Sulfur | 2 qt |
| Sovran | Kresoxim-methyl | 6.4 fl oz |
| Insecticides or acaricides | | |
| Pyramite | Pyridaben | 13.2 oz |
| Kelthane 50W | Dicofol | 2.5 lb |
| Sevin XLR | Carbaryl | 2 qt |
| Provado 1.6F | Imidacloprid | 1 oz |

# Evaluation of Two Methods of Thermal Weed Control In Fruit Tree Orchards

Rick J. Zimmerman[1]

**Summary**

There are not many options for non-chemical weed control. One option is the use of intense, directed heat on weeds. There are two methods for utilizing direct heat for weed control: direct flame and infra-red. This study compares the efficacy of both methods for controlling weeds in an apple orchard. After two years, the study found that the direct flame was significantly better at reducing weed canopy cover than infra-red heat. However, the infra-red heat did reduce vigor and growth of weeds, while providing a safer operating environment for both the operator and tree.

## Introduction and Objectives

Weed control without the use of synthetic herbicides is an expensive and time-consuming task in perennial organic/sustainable agricultural systems. Orchardists have few non-synthetic options available for weed control. A few naturally derived herbicides are commercially available, but have biological and economic disadvantages for commercial growers. Currently, orchardists are employing two types of physical weed control; permeable landscape cloth and mechanical cultivation using devices such as weed badgers, Clement's hoe or flamers. The landscape cloth significantly reduces weed growth and competition. However, there are significant material and installation costs. Weed mat also harbours overwintering rodent populations, which feed on the trees, and it is difficult to incorporate fertilizers or organic matter into the soil. The use of mechanical cultivation is also effective in controlling weed growth, however, during the cultivation process, tree roots near the surface of the soil are destroyed and adverse effects to soil organic matter and soil structure are likely to occur.

In the last decade researchers and growers have intensified research and adaptation of thermal methods for weed control. There are two basic designs of thermal weeders: direct flame and infrared radiant heat. Both methods rely on propane combustion to generate heat. Direct flamers utilize shielded burners that direct an intense flame on the plant surface. Direct flamers can generate temperatures in excess of 1900 °C. Infrared heat involves heating ceramic or metal surfaces to red brightness with a temperature of approximately 900 °C. This heat radiates onto the plants. Equipment costs for direct flamers are less than infrared flamers, however infrared flamers are considered to be more economical to operate.

The principle of thermal weed control is to target the plant for less than 1 second with intense temperatures. The intense heat destroys plant cellular material, coagulating plant proteins, which disables plant respiration and normal plant functioning. There are several advantages to the use of thermal energy for weed control. Thermal weed control has been found to be equal to or nearly as good as that obtained by the use of glyphosphate. In 2001, a direct flamer was observed to perform as well as herbicides in test plots located in an apple block in western Colorado. These plots included field bindweed, *Convolvulus arvensis* L., purple mustard, *Chorispora tenella* (Pall.) DC., Canada thistle, *Cirsium arvensae* (L.) Scop., wild lettuce, *Lactuca serriola* L., and common mallow, *Malva neglecta* Wallr. Herbicide tolerant plants such as field bindweed was not killed, but growth and biomass was significantly reduced.

The use of thermal energy in orchard weed control has many advantages for orchardists,

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including: minimal ground disturbance, reduced labour costs and the elimination and/or reduction in herbicides.

This study had two objectives:

Compare the efficacy of two different types of thermal flamers: a direct flamer (Red Dragon Inc., LaCrosse, Kansas) and a prototype infrared weed flamer (Sunburst, Inc., Eugene, Oregon) in controlling weed populations in an apple orchard.

Determine optimum tractor speeds and treatment intervals that would provide optimum weed control with the most economical use of propane. Flamer heights will remain constant from ground level.

## Material and Methods

There were a total of twelve treatments. Each treatment was replicated six times. Each treatment plot consisted of 25 feet of tree row. Weed species and total weed cover was assessed at the beginning and end of the growing season. The weed cover was estimated in each plot using a 3-foot by 3-foot grid. The grid was placed against the tree trunk and extended towards the alleyway between the tree rows. In the second year of the trial the sample grid was changed to a 3 foot by 2-foot grid.

The following treatments were applied:

1) Flamer 2-week interval: speed 1.0mph
2) Flamer 2-week interval: speed 1.5mph
3) Flamer 2-week interval: speed 2.0mph
4) Flamer 3-week interval: speed 1.0mph
5) Flamer 3-week interval: speed 1.5mph
6) Flamer 3-week interval: speed 2.0mph
7) Infra-red 2-week interval: speed 1.0mph
8) Infra-red 2-week interval: speed 1.5mph
9) Infra-red 2-week interval: speed 2.0mph
10) Infra-red 3-week interval: speed 1.0mph
11) Infra-red 3-week interval: speed 1.5mph
12) Infra-red 3-week interval: speed 2.0mph
13) Control

## Results

*Year 1 (2003)*

Weed control was mixed for both types of thermal weed control devices. Plant canopy was significantly reduced in those plots that were treated with the direct flamer in comparison with those plots treated with the infra-red weeder (Fig. 1). The only exception was when the direct flamer was moving at its lowest rate of speed (1.0 mph) and treated at a three-week interval. Treatment intervals (2 and 3 weeks) also did not have a significant impact on weed control from either thermal treatment. Speed also did not affect the amount of weed control. All infra-red treatments did not have significantly less plant cover than the control. The amount of weed cover in the infra-red treatments may have been higher due to a larger percent of plant cover on the far edge of the sample grid. This edge overlapped onto the alley between the tree rows. The width of the strip covered by the infra-red weeder is approximately 8 inches less than the direct flamer. In conventional orchards a weed free strip encompasses approximately a 3-foot strip on each side of the tree. However, a 2-foot strip would be adequate. Reducing weed growth close to the tree decreases competition between the tree and weed species for water and nutrients. Another factor that may have affected weed control was the treatments were not started until late May due to engineering problems with the infra-red weeder and all treatments were ceased in early August due to hazardous fire conditions due to the drought.

*Year 2 (2004)*

In the second year there was a clear separation in plant canopy density between the infra-red and direct flame treated plots (Fig. 2 and 3). Plant canopy densities were significantly higher in the infra-red treated plots. The sampling area was reduced for the second year of the project. The sample plot was reduced from a 3ft x 3ft grid to a 3ft x 2ft grid. The sample area was reduced because the infra-red weeder was not reaching the outer 6-8 inches of the sampling area. Increasing or decreasing the speed of the tractor did not affect the percent of weed control. Also changing the timing of the treatments from 2 to 3 weeks also did not affect the percent of weed control.

## Discussion

After two years of study, direct flame heat was significantly better at reducing weed cover than the infra-red heat. If the goal is a weed free strip, the direct flame treatment would eventually achieve this goal, based on observations where direct flame heat has been used for more than

three years. However, in the plots treated with infra-red heat plant height and vigour were observed to be greatly reduced in comparison with the untreated control plots. The plants in the infra-red treated plots tended to be stunted and pale green in nature. The effect of the infra-red heat on the plants may be sufficient that there is reduced competition with the fruit tree for nutrients and water. If the goal is to sufficiently eliminate weed-tree competition for water and nutrients, while maintaining safety and minimizing tree damage then infra-red heat may have a greater advantage.

The infra-red weeder has several advantages over the direct flame machine. The infra-red weeder is safer for the operator to use because the propane heat source and the ceramic heating element are shielded from the operator. There is also minimal potential for injury to the tree because the heat is directed straight down onto the weeds and ground. Due to its design, the infra-red weeder allows for greater precision in weed control. The operator has to be careful when operating the direct flame weeder. If the angle of the flame is too high, the bark of the tree and the leaves may be scorched.

Also, this study found that there were no significant increases in weed canopy cover when going from a two to three week interval. Just a one week change in treatment intervals can result in significant economics savings in propane, labour and other associated costs. Future studies could focus on increasing treatment intervals during the growing season.

The infra-red machine has great promise for controlling weeds in an orchard setting. Design changes in the machine may increase weed control. For example, the ceramic plate could be elongated to increase the time plants are exposed to heat and also decreasing the distance between the ground and the ceramic plate.

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**Acknowledgments**

Assisting in field evaluations were Glenn Suppes and Christa Hawk. Treatments were applied by George Osborn and Jim Rhode, Western Colorado Research Center (Rogers Mesa Site). Equipment design and fabrication by Sunburst Technologies, Inc., Eugene, Oregon. Funding provided by the Environmental Protection Agency Region 8 (X988708-01)

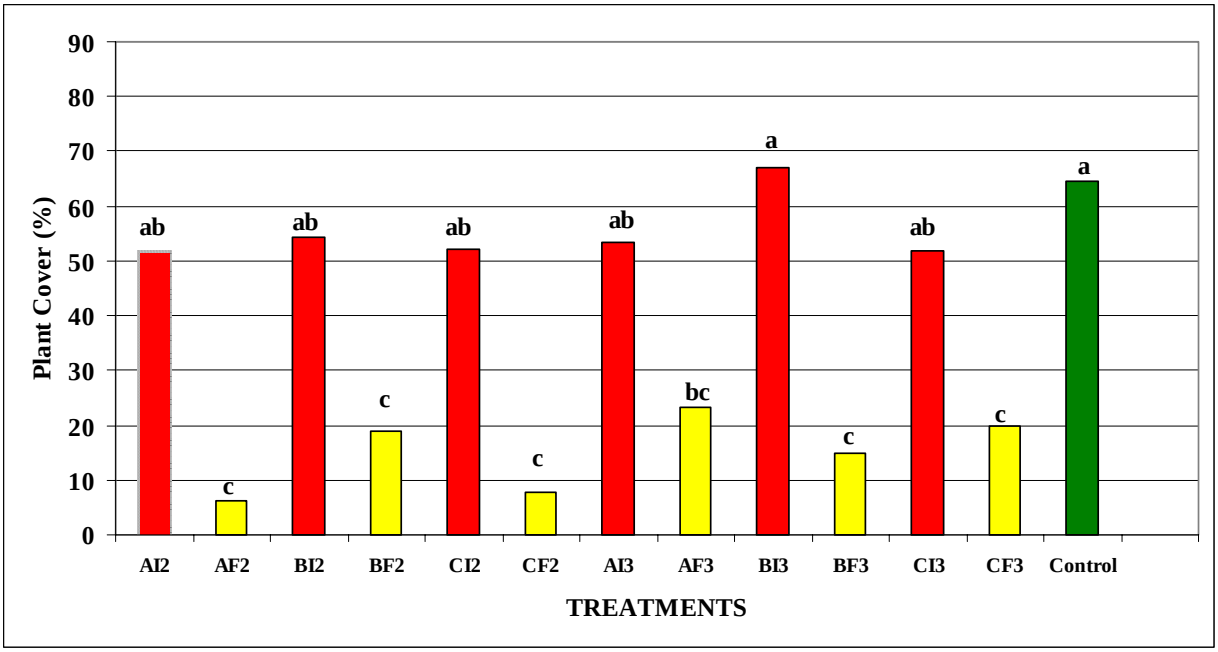


Fig. 1. Impact of two different types of thermal weed control equipment - direct flame and infra-red - on reducing weed canopy cover. The amount of weed cover was measured in a 3 foot X 3 foot grid extending from the base of the tree trunk into the alleyway between the tree rows. Key to treatments: A = 1.0 mph, B = 1.5 mph, C = 2.0 mph, I = infra- red, F = direct flame, 2 = two week treatment interval and 3 = three week treatment interval. Treatments with the same letter are not significantly different at $p < 0.001$ (Student-Newman-Keuls procedure).

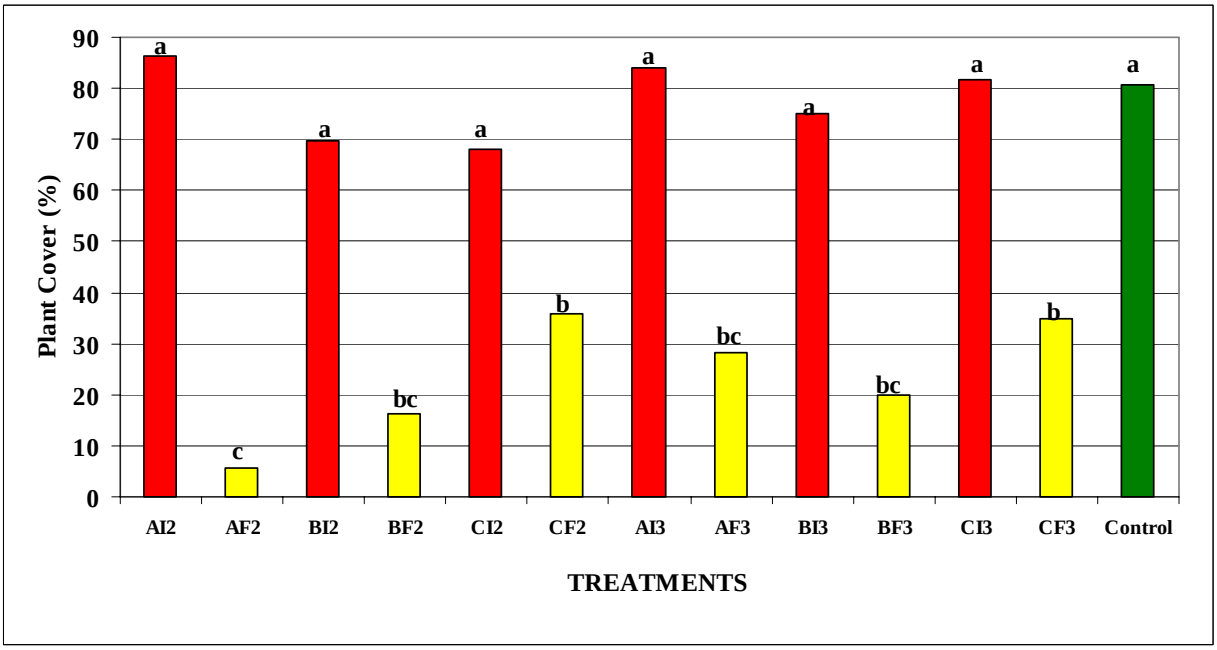


Fig. 2. Impact of two different types of thermal weed control equipment - direct flame and infra-red - on weed canopy cover. The amount of weed cover was measured in a 3 foot X 2 foot grid extending from the base of the tree trunk into the alleyway between the tree rows. Sample date June 15, 2004. For treatment information see Fig. 1. Treatments with the same letter are not significantly different at $p < 0.001$ (Student-Newman-Keuls procedure).

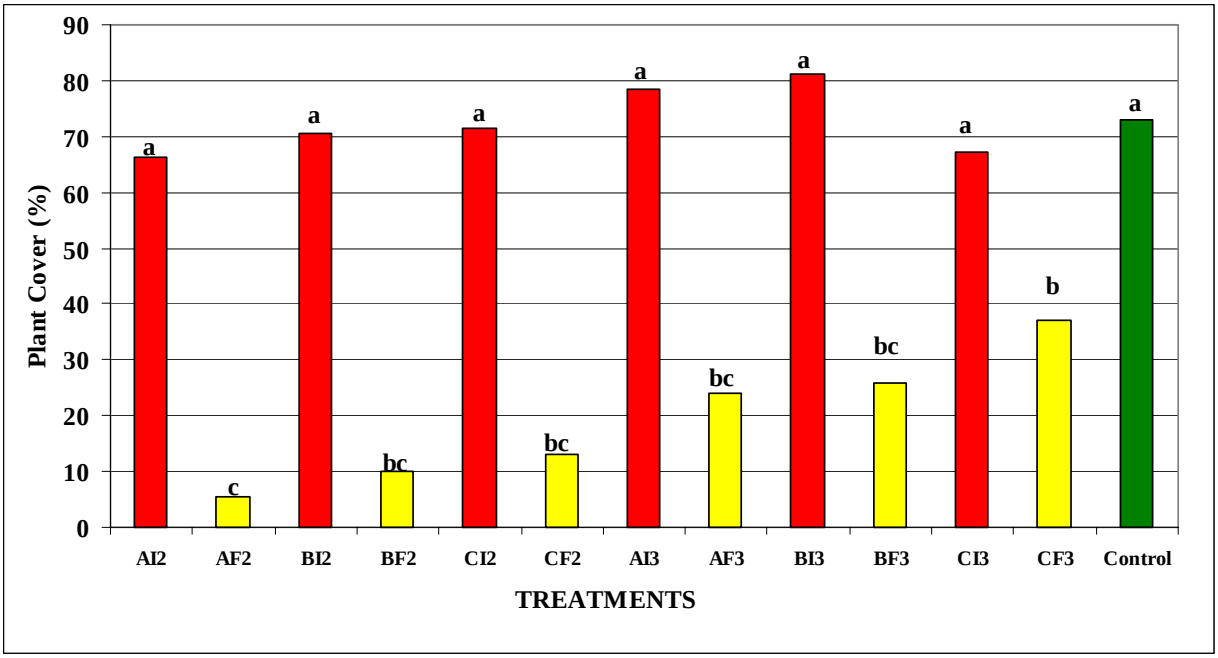


Fig. 3. Impact of two different types of thermal weed control equipment - direct flame and infra-red - on weed canopy cover. The amount of weed cover was measured in a 3 foot X 2 foot grid extending from the base of the tree trunk into the alleyway between the tree rows. Sample date August 29, 2004. For treatment information see Fig. 1. Treatments with the same letter are not significantly different at $p < 0.001$ (Student-Newman-Keuls procedure).

# Agronomic Performance of Roundup-Ready Soybean Cultivars at Fruita, Colorado 2004

Calvin H. Pearson[1]

**Summary**

In the 1980s, soybeans were grown commercially in the Grand Valley of western Colorado. Primarily because of yield variations, marketing problems, and low crop prices, commercial production of soybean in the Grand Valley dwindled. In the intervening years, numerous new soybean cultivars have been developed. Of particular interest are the recent Roundup-Ready® cultivars. The objective of this research was to evaluate Roundup-Ready soybean cultivars for seed yield and related agronomic performance and determine how these cultivars might perform when produced commercially in western Colorado. Weed control in the plot area was excellent. Weeds in the field and plot area were easily controlled with two Roundup applications. Maturity ratings for the twenty-three cultivars ranged from Late Group 1 to 3.6. Average seed yield for the twenty-three soybean cultivars was 3091 lbs/acre (51.5 bu/acre). Seed yields ranged from a high of 3879 lbs/acre (64.6 bu/acre) for H-3135 RR to a low of 2432 lbs/acre (40.5 bu/acre) for 92B38. Roundup-Ready soybean cultivars performed similar to the conventional cultivars evaluated in 1986-1989. Roundup-Ready soybean cultivars provide producers with a convenient, cost-effective, and highly effective weed control management tool that results in weed-free fields and promotes high soybean productivity.

## Introduction

In the 1980s, several studies were conducted on soybeans in western Colorado by Colorado State University researchers (Pearson et al., 1987; Pearson and Golus, 1988; Pearson et al., 1989; Pearson et al., 1990). The objective of this research was to determine the potential of soybean as an alternative crop in western Colorado. Seed yield of several cultivars were found to produce 60 bu/acre and, in some cases, even higher.

Commercial acreages of soybean were grown in the Grand Valley of western Colorado in the 1980s. Farmers who produced soybeans found that soybean yields varied more than most of the other crops they grew on their farms. Soybean yield variations were primarily due to varying soil types and production management practices including weed control and planting and harvesting methods. Timing of harvest was particularly important in an attempt to keep seed shattering losses to a minimum. While production practices for this alternative crop were challenging to farmers, another significant constraint to the successful soybean production in western Colorado was identifying reliable markets for their crop. Eventually, because of yield variations, marketing problems, and low crop prices for soybean, commercial production of this alternative crop in the Grand Valley dwindled, and currently only one or two farmers in the area continue to grow soybeans.

In the intervening years since soybean production research was conducted in western Colorado, numerous new soybean cultivars have been developed. Of particular note, Roundup-Ready® soybean cultivars have been developed and are now readily available and widely used in commercial agriculture throughout the USA.

Application timing of Roundup herbicide can be quite flexible. Furthermore, applying Roundup can be accomplished more quickly and often with fewer concerns for weed control than when cultivating operations are used.

Weed control can be a major challenge and can contribute significantly to seed yield variations. Commercial production of soybean

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using Roundup-Ready cultivars offers producers with considerable crop management flexibility. Roundup-Ready soybean cultivars can be planted on a more timely basis than traditional cultivars. By comparison, traditional soybean cultivars require the use of herbicides that have to be applied preplant followed by precise soil incorporation. Commercial production using Roundup-Ready cultivars allows considerable timing application flexibility and ease for controlling weeds during the growing season.

The objective of this research was to evaluate Roundup-Ready soybean cultivars for seed yield and related agronomic performance and determine how these cultivars might perform when produced commercially in western Colorado.

## Materials and Methods

A Roundup-Ready® soybean cultivar performance test was conducted at the Western Colorado Research Center at Fruita, Colorado during 2004. The experiment was a randomized complete block with four replications. Twenty-three cultivars were included in the trial. Plot size was 5-feet wide by 25-feet long (2, 30-inch rows). The previous crop was sunflower.

Planting occurred on 18 May 2004 with an air planter modified for planting plots. Seeding rate was approximately 185,000 seeds/acre.

Bradyrhizobium inoculum was applied in-furrow with the seed at planting. Granular soil implant inoculum was applied at a rate of 6 oz. per 1000 feet of row. The inoculum was applied using a Gandy box with drop tubes that were positioned between the double disc openers. This procedure allowed the seed and the inoculum to be applied simultaneously; thus, the inoculum came in direct contact with the seed. This planting method was designed to promote rapid bacterial infection and rapid production of nitrogen-fixing nodules on soybean roots.

Glyphomax herbicide at 1 qt/acre plus 1 qt/acre of Activator 90 plus 1 qt. of urea ammonium nitrate fertilizer in 100 gals of water was applied at 25 psi in 20 gpa on 23 June 2004. Another application of Glyphomax herbicide at 1.5 qt/acre plus 1 pt/acre of Activator 90 plus 1 gal. of urea ammonium nitrate fertilizer per 100 gal. of water was applied at 25 psi using 22 gpa on 7 July 2004.

The experiment was furrow-irrigated using gated pipe. The plot area was irrigated ten times during the season with irrigations averaging 17.0 hours per set. Plots were harvested on 26 Oct. 2004 using a Hege small plot combine.

Data were collected for plant population, seed yield, seed moisture, number of days to first flowering, plant height, height to first pod, test weight, seeds/lb, plant lodging, and seed shattering. Seed moisture and test weight were obtained using a Seedburo GMA-128 seed analyzer. Seeds/lb were determined by counting 200 seeds using a Seedburo 801-10/B COUNT-A-PAK seed counter.

## Results and Discussion

Weed control across the entire plot area was excellent (Fig. 1). The primary weed species in the plot area was flower-of-an-hour (*Hibiscus trionum* L.). Application of Roundup was convenient and provided considerable flexibility in determining when to apply the herbicide. Weeds in the field and plot area were easily controlled with two Roundup applications.

The cost to apply Roundup for commercial production of Roundup-Ready soybeans in western Colorado, based on rates, applicator costs, and adjuvants used in our study, would likely range from $20 to $25 per acre per application.

The 2004 cropping season in western Colorado was mild and longer compared to 2003. Adequate irrigation water was available

Fig. 1. Calvin Pearson standing in a soybean cultivar performance test being conducted at the Western Colorado Research Center at Fruita. 24 August 2004. Photo by Jim Weibel.

during the growing season and, thus, was not a limiting factor for crop production.

Maturity ratings for the twenty-three cultivars ranged from Late Group 1 to 3.6 (Table 1). Two cultivars were in Group 1, thirteen were in Group 2, and eight were in Group 3 maturity ratings.

Average plant population in the soybean cultivar performance study was 143,618 plants/acre (Table 1). AG2703 RR soybean cultivar had the highest plant population at 157,232 plants/acre and 31M25 had the lowest plant population at 80,794 plants/acre. Seed quality of the soybean cultivars may have been a factor that contributed to the wide range in plant population among the cultivars. Based on previous research in western Colorado, grain yields increased as plant populations increased up to 170,000 plants/acre (Pearson et al., 1989).

Average seed moisture content was 10.0% (Table 1). There were no significant differences among soybean cultivars for seed moisture. Seed moisture contents at harvest in the Grand Valley can be lower. In 1987, average seed moisture content of the 15 varieties evaluated in a cultivar performance test was 6.4% (Pearson and Golus, 1988).

Average seed yield for the twenty-three soybean cultivars in 2004 was 3091 lbs/acre (51.5 bu/acre) (Table 1). Seed yields ranged from a high of 3879 lbs/acre (64.6 bu/acre) for H-3135 RR to a low of 2432 lbs/acre (40.5 bu/acre) for 92B38. High yielding soybean cultivars in this study were H-3135 RR, 35D33, AG 2703 RR, and AG 3005 RR.

Yields obtained in the 2004 study are comparable to those obtained from previous research conducted in western Colorado in the 1980s. Highest seed yields obtained in previous research conducted in the Grand Valley were 73.6 bushels/acre in 1986 (Pearson et al., 1987), 67.8 bushels/acre in 1987 (Pearson and Golus, 1988), 61.9 bushels/acre in 1988 (Pearson, et al., 1989), and 55.7 bushels/acre in 1989 (Pearson et al., 1990).

Determining when soybean cultivars begin to flower provides information about how cultivars may differ in growth allocated for vegetative and reproductive stages of development. The average number of days to first flowering in 2004 was 56.6 (Table 1). Cultivar 35D33 required 60.5 days to reach first flower while soybean cultivar 91B91 required only 50.0 days to reach first flowering. Sixteen of the twenty-three soybean cultivars required 55 days or longer to reach first flowering. In 1986, the average number of days to first flower of 19 soybean entries was 48 days. The range in number of days to first flower in 1986 was from 45 to 51 days (Pearson et al., 1987). In 1987, the average number of days to first flower of 15 soybean cultivars was 57 days. The range in number of days to first flower in 1987 was from 49 to 70 days (Pearson and Golus, 1988). In 1988, the average number of days to first flower of 21 soybean cultivars was 71 days. The range in number of days to first flower in 1988 was from 64 to 78 days (Pearson et al., 1989).

Plant height averaged 47.0 inches and the tallest cultivars were 35D33 (54.7 inches), AG 3302 RR/STS (53.3 inches) and 38K28 (53.2 inches) (Table 2). The shortest cultivars were 91B91 (40.1 inches), H-2162 RR (39.6 inches), and DKB 22-52 RR (37.6 inches). In 1987, the average plant height of 15 soybean cultivars was 37.7 inches. The range in plant height in 1987 was from 29.4 to 49.0 inches (Pearson and Golus, 1988). In 1988, average plant height of 21 soybean cultivars was 37.0 inches. The range in plant height in 1988 was from 24.1 to 46.1 inches (Pearson et al., 1989).

Height to first pod is an important harvest factor. Pods that are produced close to the soil surface may be missed during harvesting and thus, reduce yields. Harvest efficiency is increased when combining cultivars that set the first pod higher up the plant.

Average height from the soil surface to the first pod in 2004 was 9.1 inches (Table 2). Cultivars with the greatest height to the first pod were AG 3302 RR/STS at 11.8 inches, 36J29 at 11.4 inches, 3362NRR at 10.8 inches and AG 3005 RR at 10.4 inches. Cultivars with the lowest height to the first pod were H-1961 RR and 31T31 at 7.9 inches, 91B91 at 7.2 inches and AG2403 RR at 6.8 inches.

In 1987, the average height to the first pod of 15 soybean cultivars was 5.7 inches. The range in height to first pod was from 2.9 to 7.4 inches (Pearson and Golus, 1988). In 1988, average height to the first pod of 21 soybean cultivars was 3.9 inches. The range in height to the first

pod was from 2.6 to 5.3 inches (Pearson et al., 1989).

In most cases, the height to the first pod should be at least 6 inches so the combine head will be able to cut low enough without leaving pods still attached to the stem. Thus, all of the cultivars evaluated in 2004 had a high harvest efficiency with the possible exception of cultivars with heights to the first pod that were only slightly higher than 6 inches.

Test weight averaged 56.6 lbs/bu and ranged from a high of 57. 9 lbs/bu for 35D33 and 93B01 to a low of 54.6 lbs/bu for DKB22-52 RR (Table 2). There were significant differences among the twenty-three soybean cultivars for test weights. Ten varieties had high test weights (35D33, 93B01, 31T31, 38K28, 36J29, AG 3302 RR/STS, H-2811 RR, 34Z27, 3362NRR, and AG 3005 RR).

Test weight in 2004 averaged slightly less than those obtained in most other years. In 1986, test weights averaged 58.3 lbs/bu (Pearson et al., 1987), 57.8 lbs/bu in 1987 (Pearson and Golus, 1988), 57.2 lbs/bu in 1988 (Pearson et al., 1989), and 56.3 lbs/bu in 1989 (Pearson et al., 1990).

Average seed size for the twenty-three soybean cultivars was 2683 seeds/lb (Table 2). Cultivar 34F35 had the largest seed size at 2340 seeds/lb and the soybean cultivar with the smallest seed size was 91B91 at 3030 seeds/lb. There were significant differences among the twenty-three soybean cultivars for seed size. Four cultivars had small seed sizes. They were 91B91, 31M25, 93B01, and H-1961 RR. In 1986, seeds/lb averaged 2560 (Pearson et al., 1987), 2550 in 1987 (Pearson and Golus, 1988), 3059 in 1988 (Pearson et al., 1989), and 2366 in 1989 (Pearson et al., 1990). Seed size in 2004 was comparable to that obtained in other years.

Plant lodging for most cultivars in 2004 was low (Fig. 2) and averaged 2.1 for the twenty-three cultivars (Table 2). Soybean cultivar 34F35 had the lowest amount of lodging (1.2) while 38K28 had the highest amount of lodging at 2.8. In 1987, lodging averaged 2.0 (Pearson and Golus, 1988), and 2.1 in 1988 and in 1989 (Pearson et al., 1989; Pearson et al., 1990). Lodging in 2004 was similar to that experienced in previous soybean research conducted in the Grand Valley.

Fig. 2. Soybean cultivar performance test at the Western Colorado Research Center at Fruita. October 2004. Photo by Calvin Pearson.

Seed shattering for the twenty-three cultivars in 2004 averaged 1.2 (Table 2). Seven soybean cultivars exhibited no seed shattering. Soybean cultivar 92B38 had the highest amount of seed shattering at 2.1. In 1987, seed shattering averaged 0.5 (Pearson and Golus, 1988), 0.7 in 1988 (Pearson et al., 1989), and 0.3 in 1989 (Pearson et al., 1990). Seed shattering in 2004 was higher than in the other years that soybeans were evaluated in the Grand Valley. Numerous rain events occurred in fall 2004 which delayed harvest. This harvest delay could have contributed to the higher seed shattering in 2004.

In summary, Roundup-Ready soybean cultivars performed similar to the conventional cultivars evaluated in 1986-1989. Roundup-Ready soybean cultivars provide producers with a convenient, cost-effective, and highly effective weed control management tool that results in weed-free fields and promotes high soybean productivity.

**Acknowledgments**

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Pearson, C.H., Golus, H.M., and Judson, F.M. 1990. Cultivar performance tests, inoculation, and plant population of soybeans in western Colorado, 1989. Agricultural Experiment Station. Department of Agronomy. Fruita Research Center. Colorado State University Technical Report TR90-5.


Table 1. Agronomic characteristics of twenty-three Roundup-Ready® soybean cultivars grown at Fruita, CO in 2004.

| Cultivar | Maturity group | Plant population (no./A) | Moisture (%) | Seed yield | | Days to Flower |
|---|---|---|---|---|---|---|
| | | | | (lbs/A) | (bu/A) | |
| H-3135 RR | 3.1 | 149557 | 10.8 | 3879 | 64.6 | 57.8 |
| 35D33 | 3.3 | 145823 | 9.8 | 3828 | 63.8 | 60.5 |
| AG 2703 RR | 2.7 | 157232 | 9.9 | 3561 | 59.3 | 56.2 |
| AG 3005 RR | 3.0 | 152150 | 10.8 | 3535 | 58.9 | 59.8 |
| 3362NRR | 3.6 | 128192 | 10.4 | 3442 | 57.4 | 59.8 |
| H-1961 RR | 1.9 | 150490 | 9.6 | 3402 | 56.7 | 50.2 |
| H-2453 RR | 2.4 | 149246 | 10.2 | 3319 | 55.3 | 55.0 |
| 34Z27 | 2.7 | 150387 | 10.2 | 3184 | 53.0 | 59.0 |
| 37B28 | 2.8 | 142401 | 11.0 | 3170 | 52.8 | 54.5 |
| DKB 22-52 RR | 2.2 | 148105 | 11.0 | 3120 | 52.0 | 53.8 |
| 34F35 | 3.5 | 136489 | 10.8 | 3116 | 52.0 | 59.8 |
| 31T31 | 3.1 | 152772 | 10.4 | 3078 | 51.3 | 58.8 |
| 93B01 | Early 3 | 141986 | 9.4 | 2968 | 49.4 | 58.2 |
| AG 2403 RR | 2.4 | 148209 | 9.6 | 2938 | 49.0 | 55.5 |
| 39V26 | 2.6 | 150283 | 9.8 | 2902 | 48.4 | 54.2 |
| 31M25 | 2.5 | 80794 | 10.0 | 2824 | 47.1 | 56.0 |
| 38K28 | 2.8 | 140742 | 9.1 | 2786 | 46.4 | 59.8 |
| 36J29 | 2.9 | 135763 | 10.1 | 2762 | 46.0 | 57.2 |
| H-2162 RR | 2.1 | 151218 | 9.7 | 2756 | 45.9 | 50.8 |
| AG 3302 RR/STS | 3.3 | 150283 | 9.6 | 2723 | 45.4 | 60.2 |
| H-2811 RR | 2.8 | 133585 | 8.8 | 2710 | 45.2 | 57.5 |
| 91B91 | Late 1 | 156713 | 9.8 | 2662 | 44.4 | 50.0 |
| 92B38 | Mid 2 | 150802 | 9.8 | 2432 | 40.5 | 56.5 |
| Column Mean | | 143618 | 10.0 | 3091 | 51.5 | 56.6 |
| LSD (0.05) | | 11990 | NS | 369 | 6.2 | |
| CV (%) | | 5.9 | 9.8 | 8.5 | 8.5 | 4.2 |

Table 2. Plant height, height from the soil surface to the first pod, test weight, seeds/lb, lodging score, and seed shattering of twenty-three Roundup-Ready® soybean cultivars grown at Fruita, CO during 2004.

| Cultivar | Plant height (in.) | Height to first pod (in.) | Test weight (lbs/bu) | Seeds/lb | Lodging score[1] | Seed shattering[2] |
|---|---|---|---|---|---|---|
| 31M25 | 41.6 | 8.4 | 56.4 | 3028 | 2.2 | 1.5 |
| 39V26 | 46.5 | 8.9 | 56.0 | 2595 | 2.1 | 1.0 |
| 34Z27 | 48.9 | 8.5 | 57.0 | 2553 | 2.4 | 1.1 |
| 37B28 | 49.3 | 8.7 | 56.0 | 2592 | 2.4 | 1.4 |
| 38K28 | 53.2 | 9.8 | 57.2 | 2801 | 2.8 | 1.2 |
| 36J29 | 50.5 | 11.4 | 57.1 | 2661 | 1.9 | 1.0 |
| 31T31 | 49.1 | 7.9 | 57.7 | 2454 | 2.4 | 1.0 |
| 35D33 | 54.7 | 10.0 | 57.9 | 2674 | 2.6 | 1.1 |
| 34F35 | 44.7 | 10.1 | 56.5 | 2340 | 1.2 | 1.1 |
| 3362NRR | 48.3 | 10.8 | 57.0 | 2552 | 2.1 | 1.0 |
| 93B01 | 44.8 | 8.9 | 57.9 | 3002 | 1.6 | 1.1 |
| 92B38 | 48.1 | 8.8 | 56.0 | 2503 | 1.5 | 2.1 |
| 91B91 | 40.1 | 7.2 | 56.8 | 3030 | 1.9 | 1.9 |
| AG 2403 RR | 41.1 | 6.8 | 55.5 | 2436 | 1.6 | 1.0 |
| AG 2703 RR | 50.7 | 8.4 | 56.2 | 2593 | 2.5 | 1.1 |
| AG 3005 RR | 51.6 | 10.4 | 57.0 | 2549 | 2.8 | 1.0 |
| AG 3302 RR/STS | 53.3 | 11.8 | 57.1 | 2742 | 2.6 | 1.0 |
| DKB 22-52 RR | 37.6 | 8.9 | 54.6 | 2802 | 1.5 | 1.2 |
| H-1961 RR | 44.7 | 7.9 | 55.4 | 2922 | 2.0 | 1.2 |
| H-2162 RR | 39.6 | 8.6 | 55.5 | 2636 | 1.8 | 1.6 |
| H-2453 RR | 44.5 | 8.8 | 56.7 | 2703 | 2.1 | 1.2 |
| H-2811 RR | 51.1 | 10.0 | 57.1 | 2837 | 2.2 | 1.4 |
| H-3135 RR | 47.4 | 9.0 | 56.6 | 2700 | 2.4 | 1.0 |
| Column Mean | 47.0 | 9.1 | 56.6 | 2683 | 2.1 | 1.2 |
| LSD (0.05) | 2.7 | 1.5 | 0.9 | 111 | | |
| CV (%) | 4.0 | 11.7 | 1.2 | 2.9 | | |

[1]Lodging scale (1 = no lodging, 5 = totally lodged).
[2]Shattering scale (1 = no shattering, 5 = totally shattered).

## Dr. Horst W. Caspari

### 2004 Research Projects

Viticulture and enology programs for the colorado wine industry (Colorado Wine Industry Development Board; H. Larsen, R. Zimmerman)*

Short- and long-term effects of Partial Rootzone Drying on tree physiology, fruit quality and yield of apples (Washington Tree Fruit Research Commision; M. Whiting, Washington State University)

Methods to delay bud break in grape (Viticulture Consortium East; H. Larsen & C. Stushnoff, CSU, and I. Dami & D. Ferree, Ohio State University)

Application of crop modeling for sustainable grape production (Environmental Protection Agency; H. Larsen)

Integrating control strategies for grape powdery mildew (USDA-CSREES, WR-IPM; A. Norton, H. Larsen)

*Sponsors/Cooperators are noted in parentheses.

### 2004 Publications

#### Refereed Publications:

Lombardini, L., Caspari, H.W., Elfving, D.C., Auvil, T.D., and McFerson, J.R. 2004. Gas exchange and water relations in 'Fuji' apple trees grown under deficit irrigation. Acta Horticulturae 636:43-50.

Caspari, H.W., Neal, S., and Alspach, P. 2004. Partial rootzone drying – a new deficit irrigation strategy for apple? Acta Horticulturae 646:93-100.

Caspari, H.W., Einhorn, T.C., Leib, B.G., Redulla, C.A., Andrews, P.K., Lombardini, L., Auvil, T., and McFerson, J.R. 2004. Progress in the development of partial rootzone drying of apple trees. Acta Horticulturae 664:125-132.

Einhorn, T. and Caspari, H.W. 2004. Partial rootzone drying and deficit irrigation of 'Gala' apples in a semi-arid climate. Acta Horticulturae 664:197-204.

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Caspari, H. 2004. Winter/drought injury in 2001/2002, and recovery in 2003. Southwest Regional Vine & Wine Conference, 27 – 28 February 2004, Albuquerque, NM, USA, pp. 122-151.

Caspari, H. 2004. Leaf analysis as a guide to vine nutrition. Southwest Regional Vine & Wine Conference, 27 – 28 February 2004, Albuquerque, NM, USA, pp. 152-166.

Leib, B.G., Caspari, H.W., Andrews, P.K., Redulla, C.A. Jabro, J.D., and Strausz, D.A. 2004. Deficit irrigation and partial rootzone drying compared in Fuji apples: Fruit yield, fruit quality and soil moisture trends. Proc. ASAE/CSAE Annual International Meeting, August 1 - 4, 2004, Ottawa, Ontario, Canada.

#### Client Reports

Caspari, H. and Whiting, M. 2004. Short- and long-term effects of Partial Rootzone Drying on tree physiology, fruit quality and yield of apples. Annual Report, Washington Tree Fruit Research Commission, 6 pp.

#### Outreach/Extension Reports

Caspari, H.W. and Larsen, H.J. 2004. Evaluating grape bud damage prior to pruning, 7 pp. (on the web at: http://www.colostate.edu/programs/wcrc/Viticulture/EvaluatingBudDamage.pdf).

Caspari, H.W., Larsen, H.J., and Sharp, R. 2004. Specialty Crops Annual Report, 2003: Application of crop modeling for sustainable grape production, 5 pp. (on the web at: http://www.colostate.edu/programs/wcrc/Viticulture/pm2003annreport.pdf).

## Dr. Ronald Godin

### 2004 Research Projects

The use of on-farm cover crops for fertility in organic fruit production (S. Ela; Specialty Crops Program)
Native seed production for crop diversification (USDA Western Region SARE, Uncompahgre Plateau Project, USFS, BLM, Public Lands Partnership, C&C Roberts Farm, and Herz Farm)
Organic seedless table grape variety trial.
Organic green bean seed production trial.
Soil and irrigation water acidification effects on sweet corn production (Del Mesa Farms, Olathe Sweet Corn, NRCS; W. Cooley)
Organic weed control for vegetable production (US-EPA)
Organic brewing hops variety trial.

*Sponsors/Cooperators are noted in parentheses.

### 2004 Publications

**Refereed Publications:**

Reighard, G., Anderson, R., Anderson, J., Autio, W., Beckman, T., Baker, T., Belding, R., Brown, G., Byers, P., Cowgill, W., Deyton, D., Durner, E., Erb, A., Ferree, D., Gaus, A., Godin, R., Hayden, R., Hirst, P., Kadir, S., Kaps, M., Larsen, H., Lindstrom, T., Miles, N., Morrison, F., Meyers, S., Ouellette, D., Rom, C., Shane, W., Taylor, K., Walsh, C., and Warmund, M. 2004. Eight-year performance of 19 peach rootstocks at 20 locations in North America. J. Am. Pomological Soc. 58(4):174-202.

**Dr. Harold J. Larsen**

**2004 Research Projects:**

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

Methods to delay bud break in grape (Viticulture Consortium East; H. Caspari & C. Stushnoff, CSU, and I. Dami & D. Ferree, Ohio State University)

Application of crop modeling for sustainable grape production (Environmental Protection Agency; H. Caspari)

Integrating control strategies for grape powdery mildew (USDA-CSREES, WR-IPM; A. Norton, H. Caspari)

Remediation of stone fruit replant problems in Colorado orchards (Arvesta Corp., Eden Research)

*Sponsors/Cooperators are noted in parentheses.

**2004 Publications**

**Refereed Publications:**

Reighard, G., Anderson, R., Anderson, J., Autio, W., Beckman, T., Baker, T., Belding, R., Brown, G., Byers, P., Cowgill, W., Deyton, D., Durner, E., Erb, A., Ferree, D., Gaus, A., Godin, R., Hayden, R., Hirst, P., Kadir, S., Kaps, M., Larsen, H., Lindstrom, T., Miles, N., Morrison, F., Meyers, S., Ouellette, D., Rom, C., Shane, W., Taylor, K., Walsh, C., and Warmund, M. 2004. Eight-year performance of 19 peach rootstocks at 20 locations in North America. J. Am. Pomological Soc. 58(4):174-202.

**Technical Reports / Other Publications / Written Works:**

Caspari, H.W. and Larsen, H.J. 2004. Evaluating grape bud damage prior to pruning, 7 pp. (on the web at: http://www.colostate.edu/programs/wcrc/Viticulture/EvaluatingBudDamage.pdf).

Caspari, H.W., Larsen, H.J., and Sharp, R. 2004. Specialty Crops Annual Report, 2003: Application of crop modeling for sustainable grape production, 5 pp. (on the web at: http://www.colostate.edu/programs/wcrc/Viticulture/pm2003annreport.pdf).

Larsen, H.J. 2004. Possible tree fruit cultivars for cold locations in Colorado, 1 p. (on the web at: http://www.colostate.edu/programs/wcrc/infopages/treefruitcoldclimate.pdf).

Larsen, H.J. 2004. Suggested fruit tree varieties for Colorado, 1 p. (on the web at: http://www.colostate.edu/programs/wcrc/infopages/Treefruitsuggest.pdf).

Larsen, H.J. 2004. Additional fruit growing references, 1 p. (on the web at: http://www.colostate.edu/programs/wcrc/infopages/treeFruitgrowingref.pdf).

Larsen, H.J. 2004. Computer models for fruit crop and pest development, 2 pp. In: Western Phytoworks (WCRC Newsletter), Fall, 2004.
(on the web at: (http://www.colostate.edu/programs/wcrc/infopages/Fall04.pdf)

Larsen, H.J. 2004. Use of the multi-pest degree day calculator, 5 pp. (on the web at: http://www.colostate.edu/programs/wcrc/omrcweather/weatherdata/instructionspestcalculator.pdf).

Larsen, H.J. 2004. Multi-pest degree day calculator (a MS Excel spreadshee program created by researchers at Washington St. Univ. and adapted for use in Colorado. (on the web at: http://www.colostate.edu/programs/wcrc/omrcweather/weatherdata/degreedayscalculator.htm).

Larsen, H.J. 2004. Bloom dates at WCRC – Orchard Mesa, 1 p. (on the web at: (http://www.colostate.edu/programs/wcrc/infopages/ombloomdates.pdf).

Larsen, H.J. 2004. Fruit industry outlook. In: Weitzel, D. (Ed.) 2004 Colorado Agricultural Outlook Forum. (on the web at: http://www.colostate.edu/programs/wcrc/infopages/fruitindustryoutlook04.pdf)

Larsen, H.J. 2004. Leaf analysis standards, 4 pp. (Updated 10/2004). (on the web at: http://www.colostate.edu/programs/wcrc/Viticulture/LeafAnalysisnutrientlevels04.pdf).

Larsen, H.J. 2004. Effective use of pest monitoring & degree day calculations for optimum pest control. Colorado Apple Administrative Committee Newsletter, Fall 2004, pp. 2-3. Colorado Apple Administrative Committee, Delta, CO.

## Dr. Matthew Rogoyski

### 2004 Research Projects

An irrigation trial for container-grown plants (F. Stonaker and others)*

Multi-site evaluation of PlantSelect® plant material (Colorado Nursery Association; R. McDonald, J. Klett)

Evaluation of the Pot-In-Pot system for production of native plant material. (USDA Western Region SARE; R. Kjelgren, Utah State University)

Evaluation of effectiveness and phytotoxicity of preemergence herbicide for container-grown crops (USDA, IR-4; J. Klett, D. Staats)

Production of maples trees in the Pot-In-Pot system. (J. Klett)

Hybrid poplar performance tests - Fruita, Orchard Mesa, and Hotchkiss (C. Pearson, R. Godin, F. Kelsey, and staff)

*Sponsors/Cooperators are noted in parentheses.

### 2004 Publications

Rogoyski, M.K. 2004. Production of container-grown cliffrose plants in three environments using several irrigation systems, 1p. Western Phytoworks Spring 2004 (on the web at: http://www.colostate.edu/programs/wcrc/infopages/Spring%2004-web.pdf)

Klett, J., Staats, D., and Rogoyski, M. 2004. Preemergence weed control in container-grown herbaceous perennials. HortScience 39(4):745-746 (Abstract).

## Dr. Calvin H. Pearson

### 2004 Research Projects

Winter wheat cultivar performance test - Hayden (M. and D. Williams, S. Haley, C.J. Mucklow)
Spring wheat cultivar performance test - Hayden (M. and D. Williams, S. Haley, C.J. Mucklow)
Using polyacrylamide to increase yield in spring wheat - Hayden (M. and D. Williams, C.J. Mucklow)
Long season corn grain hybrid performance test - Fruita (J. Johnson; seed companies)
Short season corn grain hybrid performance tests - Fruita, Delta (W. Brew, J. Johnson; seed companies)
Corn forage hybrid performance tests - Fruita, Olathe (E. Seymour, J. Johnson; seed companies)
Evaluation of Golden Harvest corn hybrids for BES - Fruita (W. Fithian of J.C. Robinson Company)
Alfalfa variety performance test (2002-2004) - Fruita (J. Johnson; seed companies, breeding companies, private industry)
Alfalfa germplasm evaluations, 2002-2004 - Fruita (P. Reisen of Forage Genetics)
Evaluation of Roundup-Ready alfalfa, 2003-2005 (2006-2008) Forage Genetics and Monsanto
Pinto bean cultivar performance test - Montrose (CDBAC; J. Johnson)
Hybrid poplar performance tests - Fruita, Orchard Mesa, and Hotchkiss (M. Rogoyski, R. Godin, F. Kelsey, and staff)
Soybean cultivar performance test – Fruita
Performance of three plant species grown in three potting mixes – Grand Junction
Water-use efficiency of cool-season turf grass species in western Colorado - Fruita
Development of sunflower as an industrial, natural rubber-producing crop (K. Cornish and Colleen McMahan, USDA-ARS, Albany, CA; J. Keasling, U.C. Berkeley; D. Ray, University of Arizona; J. Vederas, University of Edmonton; USDA-CSREES)

*Cooperators/collaborators/sponsors are noted in parentheses.

### 2004 Publications

Pearson, C.H. 2004. Letter from the Editor. Agron. J. 96:319-320.
Pearson, C.H. 2004. Western Colorado alfalfa performance test at Fruita 2002-2003, p. 21-22. In: Brummer, J.E. and Pearson, C.H. (eds.). Colorado forage research 2003: Alfalfa, irrigated pastures, and mountain meadows. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Bulletin TB04-01. Fort Collins, CO.
Pearson, C.H. 2004. Western Colorado alfalfa performance test at Fruita 1999-2001, p. 23-28. In: Brummer, J.E. and Pearson, C.H. (eds.). Colorado forage research 2003: Alfalfa, irrigated pastures, and mountain meadows. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Bulletin TB04-01. Fort Collins, CO.
Pearson, C.H. 2004. Making hay the right way, p. 29-40. In: Brummer, J.E. and Pearson, C.H. (eds.). Colorado forage research 2003: Alfalfa, irrigated pastures, and mountain meadows. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Bulletin TB04-01. Fort Collins, CO.
Pearson, C.H., and Brummer, J.E. 2004. Potential for selecting alfalfa varieties based on forage quality, p. 41-47. In: Brummer, J.E. and Pearson, C.H. (eds.). Colorado forage research 2003: Alfalfa, irrigated pastures, and mountain meadows. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Bulletin TB04-01. Fort Collins, CO.
Pearson, C.H. 2004. Pasture grass species evaluation at Fruita 1995-2001, p. 65-70. In: Brummer, J.E. and Pearson, C.H. (eds.). Colorado forage research 2003: Alfalfa, irrigated pastures, and mountain meadows. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Bulletin TB04-01. Fort Collins, CO.

Pearson, C.H. 2004. Pasture grass, forage legume, and mixed species evaluation at Meeker 1997-2001, p. 71-79. In: Brummer, J.E. and Pearson, C.H. (eds.). Colorado forage research 2003: Alfalfa, irrigated pastures, and mountain meadows. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Bulletin TB04-01. Fort Collins, CO.

Pearson, C.H. 2004. Pasture grass, forage legume, and mixed species evaluation at Hotchkiss 1998-2001, p. 81-89. In: Brummer, J.E. and Pearson, C.H. (eds.). Colorado forage research 2003: Alfalfa, irrigated pastures, and mountain meadows. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Bulletin TB04-01. Fort Collins, CO.

Smith, J.A., and Pearson, C.H. 2004. Tillage Practices. In: Schwartz, H.F., Brick, M.A., Harveson, R.M., and Franc, G.D. (eds.). Dry bean production & Integrated Pest Management. Bulletin 562A, 2nd ed. Regional publication produced by: Colorado State University, University of Nebraska, and University of Wyoming.

Brick, M.A., Pearson, C.H., and Smith, J.A. 2004. Post-Harvest. In: Schwartz, H.F., Brick, M.A., Harveson, R.M., and Franc, G.D. (eds.). Dry bean production & Integrated Pest Management. Bulletin 562A, 2nd ed. Regional publication produced by: Colorado State University, University of Nebraska, and University of Wyoming.

Pearson, C.H., Haley, S., Johnson, J., and Johnson, C. 2004. Winter wheat variety performance test at Hayden, Colorado 2003, p. 28-29. In: Making better decisions: 2003 Colorado winter wheat variety performance trials. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Report TR04-03. Fort Collins, CO.

## Dr. Rick Zimmerman

### 2004 Research Projects

Evaluation of two methods of thermal weed control in fruit tree orchards (Sunburst Technologies, Eugene, Oregon; U. S. Environmental Protection Agency)*

The use of on-farm cover crops for fertility in organic fruit production (S. Ela, R. Godin; Colorado Organic Crop Management Association)

Effects of organic alternatives for weed control and ground cover management on tree fruit growth development and productivity (S. Ela, R. Godin; Organic Farming Research Foundation)

Evaluation of narrow spectrum and biological insecticides for control of lepidoptera pests in broccoli (Valent Biosciences Corporation)

Trapping survey for the european corn borer, ostrinia nubialis, in western colorado sweet corn (Western Colorado Sweet Corn Administrative Committee)

Survey results: exotic lepidopteran and coleopteran pests of fruit and ornamental plantings (Cooperative Agricultural Pest Survey, NAPIS, USDA-APHIS).

*Cooperators/Sponsors are noted in parentheses.

### 2004 Publications

Zimmerman, R. 2004. Survey results: exotic lepidopteran and coleopteran pests of fruit and ornamental plantings. Delta County, Colorado. Cooperative Agricultural Pest Survey, NAPIS, USDA/APHIS.

Zimmerman, R. 2004. Survey results: European corn borer in commercial Western Colorado sweet corn fields. Western CO Sweet Corn Admin. Comm. and the CO State Dept. of Agriculture.