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Cooperative Extension
Western Colorado Research Center:
Fruita
Orchard Mesa
Rogers Mesa
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Western Colorado Research Center 2003 Research Report

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Colorado State University
Knowledge to Go Places

Introduction

2003 was a year of significant change at the Western Colorado Research Center. A new manager joined the staff in February, and soon thereafter came a series of statewide budget cuts that impacted all facets of higher education. As a direct result of the budget crisis, two permanent positions were eliminated at WCRC, and a significant portion of operating expenses were transferred to cash resources derived from crop sales. Budget constraints lead to the closing of the Mountain Meadow Research Center in Gunnison, and as a result, we welcomed Dr. Joe Brummer and his forage research program into the WCRC mission. In 2004, Joe will be establishing forage research plots at WCRC-Rogers Mesa and bringing new expertise to benefit growers in the Western Colorado Region.

While interviewing for the vacant manager position in late 2002, I was impressed with the breadth of programs at the Western Colorado Research Center. The multi-disciplined, project oriented approach is rather unique in a University setting, resembling more of a private industry concept of team oriented projects rather than the traditional single scientific discipline focus. Given the resource constraints and financial pressures facing the Agricultural Experiment Station, the challenge at WCRC is to remain focused on the quality of our research and outreach activities across such a diversity of disciplines and project areas. The scientists at WCRC are rising to this challenge, striving to resolve problems associated with traditional crops grown in Western Colorado, and searching for new and alternative crops that may offer growers viable economic alternatives to traditional crops within the region. The four primary research program areas at WCRC (Viticulture, New and Alternative Crops and Cropping Systems, Establish Crops and Natural Resource Systems, and Organic Crop Management Systems) reflect this focus and commitment.

One of the primary strengths of the Western Colorado Research Center is the expertise and dedication of the administrative and research support staff. Their interest, dedication and ownership in the research programs played a significant role in my decision to join WCRC. This group continually rose to each new challenge in 2003, as we found more efficient ways to control costs and share resources across the three WCRC sites. I relied heavily on the considerable expertise of this group during my first year. The information contained within this report is only a small representation of the significant contributions they make to the research and overall operations at WCRC.

Scientists at the Western Colorado Research Center spend considerable time competing for external grant funds. This is because research at the University level is now almost exclusively dependent upon federal or private industry grants. While the scientists typically acknowledge project contributors or sponsors in their reports, I wish to recognize the following individuals and organizations for their generous donations to WCRC in 2003: Chann Fogg, Clark Family Orchards, Robert Cunningham, Curtis Talley, Morton's Orchards, Frank Moore, Harvestime Enterprises, Melvin Rettig, Michael Turner, Mick Shaw, Talbott Farms, Inc., and Walt Morrison.

Please contact the authors should you have questions concerning the information contained within this report. To stay abreast of research projects and outreach activities throughout the year, please visit the Western Colorado Research Center on the web at http://www.colostate.edu/programs/wcrc/.

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Western Colorado Research Center Station Descriptions

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

The Fruita site 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, and a dry bean conditioning facility/storage building. A comprehensive range of agronomic equipment is based at the site.

Orchard Mesa Location: 3168 B 1/2 Road
Grand Junction, CO 81503
(970) 434-3264
(970) 434-1035 *fax*

The Orchard Mesa site is located seven miles east and south of Grand Junction on B 1/2 Road and south of Clifton. 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 between 63/ F in July and 16/ F in January. Readings of 100/ F or higher are infrequent, and about one-third of the winters have no readings below 0/ F. Relative humidity is very low during the summer. 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 and propane orchard heaters. Irrigation is by mini-sprinkler and gated pipe systems supplied by ditch water from the Colorado River. Facilities at the Orchard Mesa Center include the regional office, conference room and several labs. Other buildings include a workshop and greenhouse. Approximately 20 of the center's 80 acres are devoted to experimental orchards, principally apples, peaches and grapes. Smaller plantings of pears and cherries are also grown.

Rogers Mesa Location: 3060 Highway 92
Hotchkiss, CO 81419
(970) 872-3387
(970) 872-3397 *fax*

Rogers Mesa Research Center 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 and propane orchard heaters. Irrigation methods used include drip, mini-sprinklers, gated pipe and open ditch, all supplied from the Fire Mountain canal water. Facilities at the Rogers Mesa Research Center include offices, several laboratories and a conference room. Other buildings include workshop, machine shed, barn, and greenhouse. Approximately 20 of the 80 acres are planted with experimental orchards. Apples and peaches are the main crops. A small acreage is also devoted to sweet cherries and vegetable production. An arboretum was planted in 2001.

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ADVISORY COMMITTEE

We would like to sincerely thank all the members of our 2003 Advisory Committee for their time and input into our planning processes. Maylon Peters, the committee chairman, in particular put a lot of time and commitment into ensuring the group had an active voice in our programmatic decisions.

The committee's role is to suggest, provide input, promote, and influence research planning that is conducted at WCRC centers. The outreach role is to work in conjunction with other committee members, research scientists and Experiment Station administrators to promote the interest of agriculture and the Agricultural Experiment Station within the region and to inform politicians, service groups, and the general public of current research being conducted at WCRC centers.

Members of the 2003 Advisory Committee are listed below. The Advisory Committee has been restructured in late 2003 and will have new membership in 2004. For a listing of the current Advisory Committee members, see the WCRC website: www.colostate.edu/programs/wcrc.

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A Production System For High Value Crops – Retractable Roof Greenhouses in Western Colorado

Matthew Rogoyski[1], Calvin H. Pearson, Frank Kelsey, and John Wilhelm[2]

Summary

Three new retractable roof greenhouses were constructed at the Western Colorado Research Center (WCRC) during spring 2002. The two flat roof and one peak roof greenhouses have a growing area of 7500 ft^2. Retractable roof greenhouse technology is enabled by two innovations: the development of flexible and durable greenhouse covering material and automated digital control systems. The Cravo retractable-roof greenhouses are equipped with an Argus automated environmental control system. This system has the capability of measuring wind velocity, humidity, air and soil temperature, and can also detect precipitation. The Argus control system can be programmed to automatically respond to external or internal environmental conditions. For example, the system is programmed to close the side walls and roof of both greenhouses when winds become gusty. As we approach our third growing season, we have encountered very few maintenance issues with the Cravo greenhouse and Argus control system. The main drawbacks of retractable roof greenhouse technology at this time probably are the cost of the structures and the relatively small amount of science-based information available for this technology. After growing plants in the retractable greenhouses for two seasons, we have observed first hand how this technology moderates temperature, humidity, solar radiation load, and impact of high velocity winds. The advantages of retractable greenhouses are reported to be numerous and research will continue to be conducted at WCRC to document how this technology performs in western Colorado.

Introduction

A unique production system for high value crops is being investigated at the WCRC at Orchard Mesa in Grand Junction (Fig. 1). Retractable roof greenhouse technology is being adopted by the nursery industry in the United States (Davis, 2004) and two major universities, Ohio State University and Arizona State University, constructed retractable greenhouse facilities recently (Pollock, 2002; McGinley, 2004). A few years ago, several researchers and staff from WCRC visited two nurseries in Oregon that use these type of structures. Owners and operators of the retractable roof greenhouses we toured were pleased with their performance, and we were stimulated to evaluate this technology in western Colorado. Construction of three retractable roof greenhouses was completed at the WCRC Orchard Mesa site in summer 2002. Production systems for container-grown ornamental nursery crops are currently being investigated in these two types of structures.

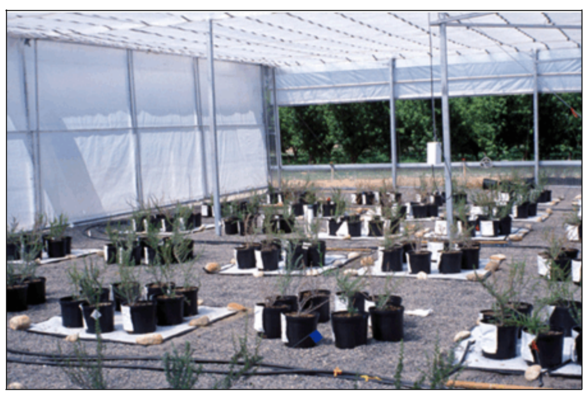

Fig. 1. The retractable greenhouses were the site of the irrigation experiments utilizing container-grown cliffrose plants and several irrigation methods including capillary mat technology during the 2003 growing season. (Photo by Matt Rogoyski)

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Western Colorado is known for its excellent climate for plant production. Our high light intensity, warm days, cool nights, low disease pressure, long growing season, and relatively mild winters make western Colorado a unique production area. These climatic advantages for plant production are not fully realized because of large daily temperature fluctuations, low humidity, and excessive solar radiation that occur in the area. Retractable roof greenhouses are capable of moderating these climatic extremes and accomplishing this task with minimal consumption of energy when compared to conventional greenhouses.

Clearly, plants, unlike animals, cannot move to avoid unfavorable environments. The protected growing environments in general, and retractable roof greenhouses in particular, are designed to provide an improved environment for plant growth and development. Flexible, movable covering materials on both the roof and sidewalls, combined with other features of the system, allow for manipulation of the environmental conditions within the greenhouse.

Overview of Retractable Roof Greenhouse Technology

The potential advantages of the retractable roof greenhouse technology are numerous. This technology integrates aspects of open field and protected greenhouse environments. Retractable roof greenhouses have many advantages of both of these systems but without most of the drawbacks of either system. Retractable roof greenhouse technology is enabled by two innovations: the development of flexible and durable greenhouse covering material and automated digital control systems.

Because both the roof and sides of these structures can almost be completely retracted, there is no need for expensive and energy-consuming cooling and venting systems, such as wet pads, misting, or fogging systems used in conventional greenhouses. As the roof covering can be completely retracted during rain events rain water than can fall directly onto pots as supplemental irrigation (Fig. 2). Plants can be grown and over-wintered at the same site, thus eliminating the need for expensive labor to move containers. Most of our experience with

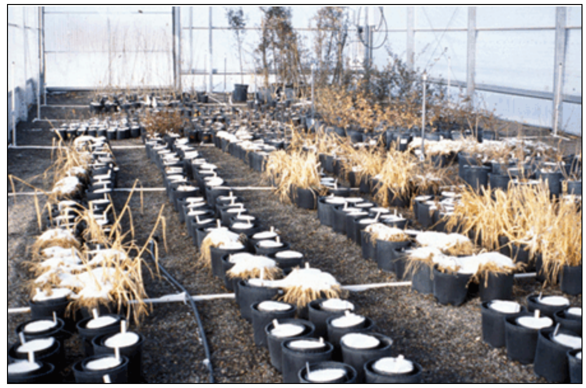

Fig. 2. The roof of our greenhouses can be completely retracted and snow or rain water can be harvested to supplement irrigation. (Photo by Matt Rogoyski)

retractable greenhouses to date is based on producing plants during the growing season rather than over-wintering them.

Sides of these greenhouses can retract, minimizing the adverse effects of high winds that are prevalent in the spring in our area. “wind-roll” or “tipping” of containers can be greatly reduced or eliminated in retractable roof greenhouses. Wind roll can be a serious problem that contributes to plant loss and creates large labor inputs needed to rearrange containers. The protection from wind in these houses is also responsible for lower water use by plants and therefore promotes water conservation.

Another important advantage of these houses is the light environment they create (Morgan, 1999). The covering used on these structures diffuses sunlight and provides some degree of shade depending on the roof material used. As compared to direct sunlight, the diffused light in these greenhouses is less stressful to plants. The uniform light distribution throughout the plant canopy often results in higher quality plants. Depending on the covering used by the manufacturer, a portion of the incoming infrared radiation is reflected, resulting in reduced heat load.

Retractable roof greenhouses are also used to manipulate the rate of plant growth and development. This provides the capability to manipulate the timing when plants are ready for the market. This is accomplished by continuously adjusting the thermal environment inside the greenhouse by venting the greenhouse. These procedures are referred to as "cold or heat trapping." For example, the cold trapping is accomplished by opening the sides and roof of the greenhouse early in the morning before sunrise to cool the greenhouse environment, growing medium, and plants, then closing the sides and roof after sunrise until the temperature in the greenhouse starts rising above that of ambient temperature. This procedure allows a grower to, for example, delay bud break and thereby manipulate the time to market. Similar procedures can also be used to extend a growing season beyond those possible for plants grown in the field.

The main drawbacks of retractable roof greenhouse technology at this time probably are the cost of the structures and the relatively small amount of science-based information available for this technology. Our research efforts at WCRC, in a targeted way, will attempt to address the limitation of science-based information.

Overview of Retractable Roof Greenhouse Facility at Western Colorado Research Center

Construction of the Cravo greenhouses at WCRC (Cravo Equipment Ltd.), equipped with Argus controls (Argus Control Systems Ltd.), began on April 9, 2002. Over the course of the next 5 weeks, a crew of six to ten people worked to complete the new structures. When completed, 7500 ft^2 of new greenhouse space had been added to our facilities. This new space included one peak roof greenhouse and two contiguous, separately controlled flat roof greenhouses. The obstacles encountered and overcome during the construction of the greenhouse are described in this section of this report.

Construction

The greenhouse arrived by a truck as a completely unassembled kit. The most critical stage of construction was the initial step of measuring, marking, and determining the precise location for all 50 support posts. This was done with the assistance of a technician from Cravo who utilized laser-equipped surveying equipment for this task. The shallow, rocky soils at the Research Center presented a significant challenge in drilling the holes for the support posts and 24

Fig. 3. Structures of the two greenhouses: the flat roof greenhouse has load bearing cables as a key structural component; trusses are the key structural component for the peak roof greenhouse. (Photo by Harold Larsen)

primary anchors for the flat roof houses. The flat roof house design is based on weight-bearing support cables (Fig. 3). In total, approximately 28 cubic yards of concrete were required to fill the holes for all support posts and anchors.

Once the primary structural components were in place, construction of the remainder of the greenhouses proceeded without significant difficulty (Figs. 4 - 6). Successful completion of the project would have been more difficult without the significant contribution of several dedicated volunteer workers and a professional electrician who wired the electrical motors and control system.

The greenhouse floor was prepared by grading the area, cutting drainage trenches in the center of the greenhouse floor area, installing a drainage pipe for each greenhouse and tying the drain pipes into existing drain lines. Also, the entire floor area was covered with weed mat and a 2" layer of gravel was spread on top of the mat.

Operation

The Cravo greenhouses are equipped with an Argus automated environmental control system. This system has the capability of measuring wind velocity, humidity, air and soil temperature, and can also detect precipitation. Our version of the Argus software for the control system allows anyone who has access to Argus software to monitor greenhouse environmental conditions using a dial-up modem. A password is required in order to change any of the control settings. The system is user friendly, requiring only basic computer skills for operation and programming. The Cravo structure contains a control panel with manual electrical switches that can be used to operate various greenhouse electrical motors. The manual controls can override the automated Argus system. We mostly use them to demonstrate the operation of the retractable roof to visitors.

Fig. 4. A progression of construction of two retractable roof greenhouses at Western Colorado Research Center – Orchard Mesa during spring 2002. (photos by Harold Larsen)

The Argus control system can be programmed to make greenhouses responsive to external or internal environmental conditions. For example, the system is programmed to close the side walls and roof of both greenhouses when winds become gusty. The operator selects the wind velocity at which the structure should close, causing an automatic response when high winds develop. This quick response time can be useful in preventing damage to containerized plant material. The greenhouses can also be programmed to respond to other climatic conditions, such as temperature, humidity, and precipitation. To prevent a snow load from building up on the roof, we have programmed the greenhouse roofs to open when precipitation is detected. The sensor we use has an internal heater that can melt snow and allow us to detect a winter precipitation event. A sensor is available for the Argus system that is specifically designed for snowfall, but our sensor has worked well so far. Our unit does not always detect very light or blowing snow, but in these instances we would not expect to encounter a significant snow load on the roof.

The Argus system is a general-purpose greenhouse control system and has many features including the capability of controlling heating and cooling systems. Our Cravo greenhouses do not have auxiliary climate control equipment but are equipped with irrigation solenoids that are also controlled by the Argus system. We are using this automation feature.

Temperature inside the structures is managed by the settings programmed into the Argus system that gradually open or close side panels and the roof to moderate the internal environment. The heavy grade woven plastic covering material that comprises the sides and roof material of the greenhouse is designed to last 10 years, and to date the material has not torn or shown other signs of significant wear and tear. We will continue to evaluate the performance of this material under our high UV conditions.

As we approach our third growing season, we have encountered very few maintenance issues with the Cravo greenhouse and Argus control system. We have replaced several electrical fuses and encountered a few electrical glitches, but none were serious or difficult to repair. The structure is inspected periodically to ensure that all mechanical and electrical equipment opens and closes side walls and that the roof is operating properly. The operating parameters of the Argus system are reviewed daily to ensure that the automated functions are being performed as designed.

Fig. 5. A view of partially constructed greenhouses. (photo by Harold Larsen)

Fig. 6. A view of partially constructed and completed greenhouses – the side walls are open, the roof covering is closed. (Photo by Matt Rogoyski).

Growing Plants in Retractable Roof Greenhouses

Our retractable roof greenhouses have performed faultlessly during their first and second seasons. During the 2003 growing season the peak roof greenhouse and one flat roof greenhouse was used to conduct an experiment with container-grown cliffrose plants and the second flat roof greenhouse was used for other projects. The goal of the experiment with cliffrose plants was to evaluate how five irrigation methods perform in three growing environments (two retractable roof greenhouses and the environment of an open container yard). The beneficial effects were observed on the irrigation requirements, a growing medium temperature, and plant growth. The specific data will be reported in another report.

The roof coverings on the greenhouses reduced solar radiation load enough that working in these greenhouses was noticeably more comfortable for workers than working outside in the container yard. On the other hand, the work environment in the greenhouses was noisy on windy days, especially when both sides and roof were closed, but this concern can be readily overcome with personal noise protection devices.

There is one design feature that some of us wish we did not specify for our retractable roof greenhouses. The manufacturer of our greenhouses (Cravo) offers designs with and without a 2 foot high polycarbonate skirt all-around the structures and standard sliding greenhouse doors. Advantages of the skirt and sliding door architecture include: animal access control, pot wind-roll control, wind-blown debris ingress control, and greenhouse aesthetics. Based on these considerations and manufacturer recommendations, both the flat roof and the peaked roof houses are equipped with this skirt and standard sliding greenhouse doors. However, we have found that this design feature impacts the labor utilization efficiency in the retractable roof greenhouses. Without this skirt, a significant labor savings could be achieved. This would have a two fold-effect: it would eliminate the need for the rather expensive greenhouse rolling doors and, more importantly, plants could be accessed from several directions by both people and equipment. In the peak roof greenhouse the plants could be accessible from all the sides of the structure. In the flat roof houses the load bearing support wires obstruct the East and West vehicular access to plants, but people can easily move plants in and out of the greenhouse on these sides. The North and South side of our flat roof greenhouse could be fully accessible both for equipment and people if there was no skirt. This superficially minor issue has a major impact on labor utilization efficiency, the area of where the retractable greenhouses have a significant advantage over the conventional growing structures.

Conclusion

After growing plants in the retractable greenhouses for two seasons, we have observed first hand how this technology moderates

Inducing Shoot Production in Sunflower Using TDZ in Tissue Culture

Donna Rath[1] and Calvin H. Pearson[2]

Summary

Sunflower (*Helianthus annuus*, L.) is a recalcitrant species when organogenic regeneration is attempted in tissue culture. A reliable tissue culture regeneration system is needed for sunflower. The objective of our research was to determine the effects of phenylurea cytokinin, N-phenyl-*N´*-1,2,3-thiadiazol-5-ylurea (thidiazuron, TDZ) on organogenic regeneration of sunflower cotyledons in tissue culture. We conducted three experiments with TDZ. Shoot induction in sunflower cotyledons in tissue culture was achieved by using Murashige and Skoog's medium supplemented with TDZ. The explants in all three experiments developed large amounts of callus. Although shoot production was very low, the findings of these studies showed that sunflower shoots can be produced when TDZ is used in the tissue culture media.

Abbreviations: TDZ, thidiazuron; ETOH, ethanol; NAA, α-naphthaleneacetic acid solution; PAA, phenylacetic acid; KNO_3, potassium nitrate; GA_3, gibberellic acid; BA, 6-benzylaminopurine solution; $AGNO_3$, silver nitrate; SG, seed germination media; SI, shoot induction media; SD, shoot development media; SdH_20, sterile distilled water

Introduction

Sunflower (*Helianthus annuus* L.) is an important annual oilseed crop in the U.S. Introducing new genes into this species, as it is with other important agronomic crops, is necessary to improve various plant traits, be it disease and insect resistance, increased seed yield, or improving plant compounds that could be used for industrial applications.

Developing reliable and rapid organogenic regeneration techniques in sunflower would be useful for screening new genetic material and in propagating desired breeding lines. However, sunflower is a recalcitrant species when organogenic regeneration is attempted. Furthermore, successful regeneration in tissue culture is genotypic dependent. A reliable tissue culture regeneration system is needed for sunflower.

Cytokinins are a class of plant hormones required for cell division and are required in the *in vitro* growing medium used in tissue culture. These hormones are needed to induce shoot production in regenerating plant tissue and to provide assistance with auxin transport.

Thidiazuron, N-phenyl-*N´*-1,2,3-thiadiazol-5-ylurea (TDZ) is a phenylurea compound. TDZ was first used as a cotton defoliant in 1976. Mok et al. (1982) demonstrated cytokinin-dependent tissue growth in tissue culture of *Phaseolus lunatus* L. using TDZ. This demonstrated TDZ's ability to behave as a cytokinin (Fellman et al., 1987).

In low concentrations, TDZ induces shoot production in common bean (*Phaseolus vulgaris* L.), and raspberry (*Rubus* sp. L.), both of which are also considered to be recalcitrant. TDZ has been demonstrated to be a highly active cytokinin at lower concentrations than amino purine cytokinins (Mok et al., 1987; Huetteman & Preece, 1993).

The objective of our research was to determine the effects of TDZ on organogenic regeneration of sunflower cotyledons in tissue culture. We conducted three experiments with TDZ. The effect of shoot regeneration from cotyledons with TDZ in the media was studied in Experiment 1. The effect of six concentrations of TDZ on callus formation and interactions of TDZ with two auxins was studied in Experiment 2. In Experiment 3, solid medium; liquid medium; and liquid, shaken medium were examined along with the effects of TDZ as the cytokinin.

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Materials and Methods

Experiment 1

Forty seeds of sunflower cultivar 665 were soaked in 100 ml of 2% sodium hypochlorite and stirred in a 600 ml beaker on a stir plate (Torrey Pines Scientific, Solana Beach, CA) for 20 minutes. Seeds were transferred to a biosafety hood (Thermo Forma, Model 1284, Mariotta, OH) and manually stirred for 3 minutes in 100 ml of 70% ethanol (ETOH). The ETOH was poured from the beaker and 100 ml of 3.5% sodium hypochlorite was added and the beaker containing the seeds was shaken for 1 hour on setting number 2 on a Vortex Genie 2. The bleach was poured out of the beaker and 100 ml of SdH_20 was poured into the beaker. The seeds were stirred manually for 1 minute. The distilled water was decanted off and an additional 100 ml of SdH_20 was added and stirred for 1 minute. This was repeated for a total of 4 baths.

Seeds were then placed in seed germination (SG) media. The SG media was autoclaved at 250 °F for 20 minutes at 15 psi and poured into Petri dishes. Each plate contained 40 ml of SG media and 5 seeds (Table 1). The SG medium used was described by Fiore et al. (1997).

Plates were wrapped in Parafilm and kept in the dark in vented cardboard boxes at 28 °C, in the tissue culture chamber (Conviron TC30, Winnipeg, Manitoba) for 2-3 days. The pericarp and seed coat were removed and discarded. The embryos and radicals were excised and discarded.

The cotyledons were cut transversally into 4 explants (Fig. 1). Explants, totaling 156, were placed 5 to a plate on shoot induction media (SI, Table 1) for 4 days, 16/8 hours light/dark, 28 °C, in the growth chamber. The SI medium used was described by Baker et al. (1999), containing M&S salts (Murashige and Skoog, 1962) and modified as described in Table 1. Each plate contained 40 ml of SI media. Media was autoclaved at 250 °F for 20 minutes at 15 psi. Explants were subcultured on fresh SI media for 6 additional days.

Explants were subcultured to SI media without TDZ or any other cytokinin for an additional 11 days. Explants were cultured on SI media for a total of 20 days. Shoots were transferred to shoot development media (Baker et al., 1999) (SD, Table 1) and allowed to develop.

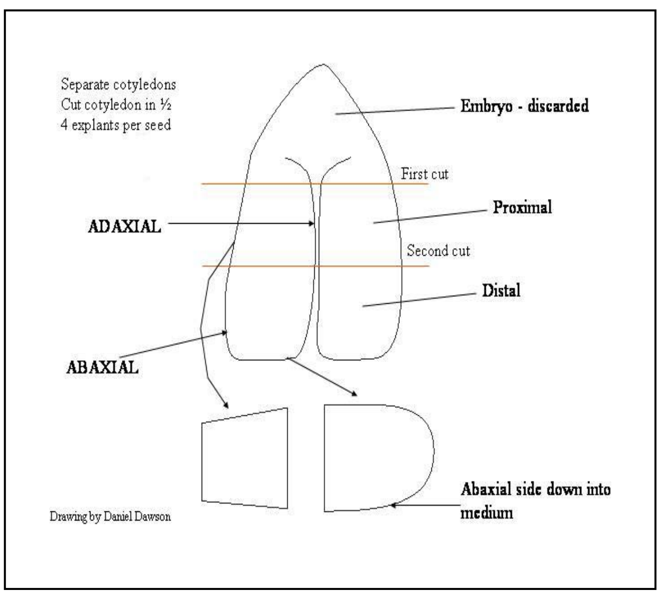

Fig. 1. Four explants were created from each sunflower seed as illustrated in the diagram above.

Experiment 2

Seventy-five seeds of sunflower cultivar 665 were prepared as described in Experiment 1. Seeds were placed in SG media (Table 1) in the dark for 3 days.

Three hundred explants were prepared as in Experiment 1 and as shown in Figure 1. Five explants were placed in 40 ml of SI media (Table 2) in each Petri dish with half of the explants receiving NAA as the auxin and half receiving PAA. Six TDZ treatments were evaluated and the amount of TDZ used in the treatments ranged from 0 mg/L to 8.0 mg/L with 10 replications per treatment (Table 3). The basal medium used was described by Baker et al., (1999), containing M&S salts & vitamins (Murashige and Skoog, 1962) and modified as described in Table 2.

A batch of SI media was prepared and split in half before adding auxins. NAA was added to one half and PAA to the other half and was stirred on a stir plate. Both NAA and PAA batches were each split into 6 equal parts and the designated amounts of TDZ were added (Table 3). The media was autoclaved at 250 °F, for 20 minutes, at 15 psi. Each Petri dish contained 40 ml of media. Fifty explants were placed 5 to a plate for each TDZ treatment level.

All plates were placed in the chamber, 16/8 hours, day/night, at 28 °C, for 27 days. After the first 14 days, all explants were subcultured to fresh SI media (Table 2). On Day 28 all explants were transferred to the same SI media as in Table 2, without cytokinins.

Experiment 3

Forty-five seeds of sunflower cultivar 665 were prepared similarly as in Experiments 1 and 2 and placed in SG media (Table 1) for 3 days in the dark. Explants were prepared as shown in Figures

Fig. 2. Fifty explants were shaken for 3 days with a Vortex Genie 2 as described in Experiment 3.

1 and 2. The pericarp and seed coat were removed and discarded. Embryos and radicals were excised and discarded.

Shoot induction media was prepared as one batch (Table 4) and then autoclaved in 5 separate 250 ml containers. Two containers for liquid shoot induction media, two containers for solid shoot induction media, and one container for shaker shoot induction media. Media was autoclaved at 250 °F, for 20 minutes at 15 psi. The basal medium used was described by Baker et al. (1999), containing M&S salts & vitamins (Murashige and Skoog, 1962) and modified as described in Table 4.

Three treatments were evaluated. Treatments were: 1) Solid media, 2) Liquid media, not shaken, and 3) Liquid media, shaken. Liquid media was based on that used by Chraibi et al., (1992) and modified as in Table 4. For Treatments 1 and 2, fifty explants were placed, five to a plate, in 10 plates with 40 ml of media (Table 4). These plates were wrapped in Parafilm and placed on the floor of the biosafety hood. For Treatment 3, fifty explants were placed in 5, 50 ml centrifuge tubes, with 40 ml of SI (Table 4) media and 10 explants in each centrifuge tube.

The centrifuge tubes were shaken on a Vortex Genie 2 (setting #2), for 3 days while in the biosafety hood (Fig. 2).

All explants, for all three treatments, were placed on media that was solidified with 8 grams of agar (Table 4, solid) for 3 additional days. The explants were then moved to media that did not contain TDZ or $AgNO_3$, but did contain 1.0 mg/L of BA (Table 5), and observed for 33 more days.

Results and Discussion

Shoot production was very low in all three experiments compared to other protocols we have used for cultivar 665. In Experiment 1, only three shoots were produced on 156 explants. In Experiments 2 and 3, seven shoots were produced (Table 6 and Table 7).

Experiment 1

Nine days after explants were grown in medium without cytokinin, three shoots were observed (Fig. 3). All explants were grainy, brittle, and had a gel-like coating. Fifty-eight of the explants produced callus that was dense and dark green. Ninety-eight explants produced callus that was vitrified, translucent, and light green. These three shoots did not develop roots.

Experiment 2

At 14 days, two explants on NAA media without TDZ were developing roots. One explant on NAA with 0.5 mg/L of TDZ developed nodules. None of the explants on PAA with 0.5 mg/L of TDZ developed nodules or shoots. Eleven explants on NAA with 1.0 mg/L of TDZ developed nodules. Thirteen explants on PAA with 1.0 mg/L of TDZ developed nodules. All the explants on 2.0 mg/L to 8.0 mg/L of TDZ with NAA were vitrified, without nodules, or shoots. The PAA explants at 2.0 mg/L to 8.0 mg/L of TDZ were denser, but did not produce shoots or nodules.

By 17 days there were four NAA explants on 0 mg/L of TDZ that had roots, the other explants changed little in appearance.

At 26 days, one explant on NAA with 2.0 mg/L of TDZ developed hairs, even though the tissue was very friable. PAA with 2.0 mg/L of TDZ also had one explant with hairs and there was primordial tissue development. Primordial tissue was not observed in 2.0 mg/L of TDZ with NAA explants.

Fig. 3. A shoot produced using 0.25 mg/L of TDZ in Experiment 1, (magnification 10x).

Explants on NAA with 4.0 mg/L of TDZ had numerous nodules and were beginning to show some necrosis around the edges.

The treatment of PAA with 4.0 mg/L of TDZ had explants with craters in them and the explants were starting to become necrotic. There was no sign of nodules or primordial tissue development.

Explants on NAA with 8.0 mg/L of TDZ had one explant with hairs and primordial tissue but the rest of the explants were vitrified and becoming necrotic. Explants produced with PAA at 8.0 mg/L were smooth surfaced, without shoots, hairs, or primordial tissue development.

At 32 days, there were 6 explants grown on NAA without TDZ that had roots. The PAA explants without TDZ were all necrotic. They did not produce roots.

Explants grown on NAA and PAA with 0.5 mg/L of TDZ had numerous nodules, and the NAA explants had some hairs.

By Day 41, in Experiment 2, three shoots developed (Table 6) after being on cytokinin-free media for eleven days. These three shoots developed in three different media treatments. In 2.0 mg/L of TDZ with NAA (Fig. 4) a rosette shoot was produced. In 2.0 mg/L of TDZ with PAA (Fig. 5) a shoot developed which was covered in fine hairs. In 8.0 mg/L of TDZ with NAA a single shoot developed. The shoot did not develop beyond 2 mm (Fig.6).

Shoot development after the removal of the cytokinin is a demonstration of habituation. In *Phaseolus lunatus*, it has been shown, that cytokinin-dependent tissue becomes cytokinin independent after being grown on media containing TDZ (Capelle et al., 1983). It is possible that TDZ (which is a phenylurea derivative) is not affected by adenine-cytokinin oxidases. It is also possible that TDZ may be able to "stimulate endogenous cytokinin metabolism or

Fig. 4. Sunflower rosette shoot grown on 2.0 mg/L of TDZ with NAA at 11 days in Experiment 2.

alter endogenous cytokinin metabolism" (Mok et al., 1987). In either case, further investigation at lower TDZ concentrations, is needed to determine if the habituation of TDZ at lower concentrations will assist sunflower in reliable shoot production. Concentrations of 0.002 to 0.088 mg/L of TDZ have been successfully used in recalcitrant woody plant species including rose which demonstrated little shoot formation on BA-containing media (Lu, 1993). Concentrations of 0.05 mg/L of TDZ were used effectively in common beans (Great Northern 'Tara' and 'Xan-159'). In geranium, 0.22 mg/L of TDZ was effective (Lu, 1993).

<u>Experiment 3</u>

A shoot (Table 7) did develop on one explant in the "solid" media (Fig. 7). The shoot was 5 mm long with thick pubescence. Three explants developed rosette shaped shoots. Twelve other explants developed nodules with hairs but did not develop shoots. All of the explants that grew on "solid" medium developed ridges. These explants had denser tissue than the explants grown on "shaker" and "liquid" medium. When the 5 mm shoot in Fig. 7 was moved to SD medium, it continued to develop but roots did not develop (Fig. 8).

The explants grown on "liquid" medium, developed smaller ridges than the explants grown on "solid" medium. Only 6 out of 44 explants developed dense tissue, while the rest of the explants were translucent. The explants grown on "liquid" medium did not develop any shoots.

Forty eight of the 49 responding explants that grew on "shaker" medium developed necrosis. One explant developed some density, but all the other explants were translucent. The explants

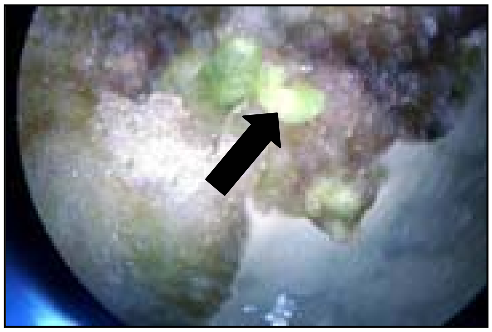

Fig. 5. A shoot grown on PAA with 2.0 mg/L of TDZ in Experiment 2.

Fig. 6. An immature shoot with hairs and primordial tissue grown on 8.0 mg/L of TDZ with NAA in Experiment 2.

grown on “shaker” medium did not develop any shoots.

We suspect that habituation of TDZ and the cytokinin (BA) that was added in the final (SI) medium (Table 5), inhibited the production of multiple shoots.

The explants in all three experiments developed large amounts of callus. The explants were grainy and friable. Low shoot count, high callus growth, and friable explant material are symptoms that there is excessive cytokinin present (Mohamed et al., 1992). Even though TDZ has been shown here to develop shoots in sunflower, the large amounts of callus formation and low shoot count demonstrates the need to reduce the amount of TDZ for sunflower tissue culture.

The findings of these studies showed that sunflower shoots can be produced when TDZ is used in the tissue culture media. Reducing TDZ concentration and exposure time may increase the amount of shoot production in sunflower.

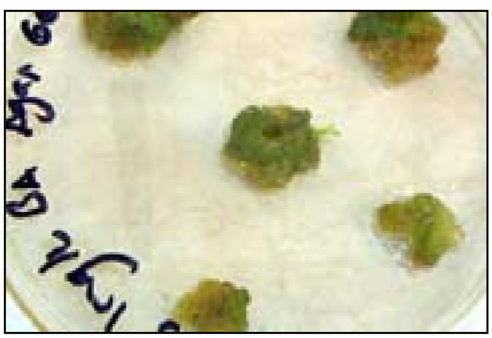

Fig. 7. A shoot grown on 0.1 mg/L of TDZ on solid medium in Experiment 3.

Fig. 8. The mature shoot from Fig. 7 in SD media in Experiment 3.

Acknowledgments

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References

Baker, C.M., N. Munoz-Fernandez, and C.D. Carter. 1999. Improved shoot development and rooting from mature cotyledons of sunflower. Plant Cell, Tissue and Organ Culture. 58:39-49.

Capelle, S.C., D.W.S. Mok, S.C. Kirchner, and M.C. Mok. 1983. Effects of thidiazuron on cytokinin autonomy and the metabolism of N^6-(Δ^2-isopentenyl[8-^{14}C]adenosine in callus tissues of *Phaseolus lunatus* L. Plant Physiol. 73:796-802.

Chraibi, B.M.K., J. Castelle, A. Latche, J. Roustan, and J .Fallot. 1992. Enhancement of shoot regeneration potential by liquid medium culture from mature cotyledons of sunflower (*Helianthus annuus*, L.). Plant Cell Rep. 10:617-620.

Fellman, C.D., P.E. Read, and M.A. Hosier. 1987. Effects of thidiazuron and CPPU on meristem formation and shoot proliferation. HortScience. 22:1197-1200.

Fiore, M.C., T. Trabace, and F. Sunseri. 1997. High frequency of plant regeneration in sunflower from cotyledons *via* somatic embryogenesis. Plant Cell Reports. 16:295-298.

Huetteman, C. A. and J.E. Preece. 1993. Thidiazuron: a potent cytokinin for woody plant tissue culture. Plant Cell, Tissue and Organ Culture. 33:105-119.

Lu, C. 1993. The use of thidiazuron in tissue culture. In Vitro Cell Dev. Biol. 29P:92-96.

Mohamed, M.F., P.E. Read, and D.P. Coyne. 1992. Dark preconditioning, CPPU, and Thidiazuron promote shoot organogenesis on seedling node explants of common and faba beans. J. Amer. Soc. Hort. Sci. 117:668-672.

Mohamed, M.F., .D.P. Coyne and P.E. Read. 1993.Shoot organogenesis in callus induced from pedicel explants of common bean (*Phaseolus vulgaris* L.). J. Amer. Soc. Hort. Sci. 118:158-162.

Mok, M.C., D.W.S. Mok, J.E. Turner, and C.V. Mujer. 1987. Biological and biochemical effects of cytokinin-active phenylurea derivatives in tissue culture systems. HortScience. 22:1194-1197.

Mok, M.C., D.W.S. Mok, D.J. Armstrong, K. Shudo, Y. Isogai, and T. Okamoto. 1982. Cytokinin activity of N-phenyl-N'-1,2,3-thiadiazol-5-ylurea (Thidiazuron). Phytochemistry. 21:1509-1511.

Murashige T. and F. Skoog. 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. Physiol. Plant. 15:473-497.

Table 1. Seed germination (SG), shoot induction (SI), and shoot development (SD) media used in Experiment 1 for sunflower explants grown in tissue culture at the Western Colorado Research Center at Fruita, Colorado.

Components	SG media 1000 ml	SI media 1000 ml	SD media 1000 ml
MS salts	4.3g	4.3g	4.3 g
KNO_3	NA[†]	5.0g	5.0g
Casein hydrolysate	NA	0.5g	0.5g
Myo-inositol	0.1g	0.1g	0.1g
Sucrose	30g	30g	30g
Thiamine	0.4mg	NA	NA
GA_3	NA	0.1mg	NA
NAA	NA	0.9mg	0.01mg
TDZ	NA	0.25mg	NA
BA	NA	NA	0.5mg
pH	5.7	5.7	5.7
Agar	8g	8g	6g

[†]not applicable

Table 2. Shoot induction media (SI), used in Experiment 2 for comparing the effects of NAA and PAA along with TDZ on sunflower cotyledons at the Western Colorado Research Center at Fruita, Colorado.

Components + NAA	1000 ml	Components + PAA	1000 ml
MS salts & vitamins	4.3g	MS salts & vitamins	4.3g
Sucrose	30g	Sucrose	30g
KNO_3	5g	KNO_3	5g
Myo-inositol	0.1g	Myo-inositol	0.1g
Casein hydrolysate	0.5g	Casein hydrolysate	0.5g
GA_3	0.1mg	GA_3	0.1mg
NAA	0.9mg	PAA	5mg
TDZ	See Table 3	TDZ	See Table 3
pH	5.7	pH	5.7
Agar	8g	Agar	8g

Table 3. Auxin (NAA/PAA) and cytokinin (TDZ) amounts used in Experiment 2 in shoot induction (SI) media on sunflower cotyledons at the Western Colorado Research Center at Fruita, Colorado. (see Table 2)

NAA mg/L	TDZ mg/L	PAA mg/L	TDZ mg/L
0.9	0	5.0	0
0.9	0.5	5.0	0.5
0.9	1.0	5.0	1.0
0.9	2.0	5.0	2.0
0.9	4.0	5.0	4.0
0.9	8.0	5.0	8.0

Table 4. Shoot induction media composition for Experiment 3 used on sunflower cotyledons at the Western Colorado Research Center at Fruita, Colorado.

Components	Solid (control) 1000 ml	Liquid & Shaker 1000 ml
MS salts & vitamins	4.3g	4.3g
KNO_3	5.0g	5.0g
Casein hydrolysate	0.5g	0.5g
Myo-inositol	0.1g	0.1g
Sucrose	30g	30g
GA_3	0.1mg	0.1mg
NAA	0.9mg	0.9mg
TDZ	0.1mg	0.1mg
$AgNO_3$	5µM	5µM
pH	5.7	5.7
Agar	8g	NA

Table 5. Shoot induction media used after the $AgNO_3$ and TDZ was removed from the media in Experiment 3 on sunflower cotyledons at the Western Colorado Research Center at Fruita, Colorado.

Components	1000 ml
MS salts & vitamins	4.3g
KNO_3	5g
Casein hydrolysate	0.5g
Myo-inositol	0.1g
Sucrose	30g
GA_3	0.1mg
NAA	0.9mg
TDZ	N/A
$AgNO_3$	N/A
BA	1.0
pH	5.7
Agar	8g

Table 6. Number of explants and number of shoots produced at 41 days when grown in tissue culture media containing TDZ at the Western Colorado Research Center at Fruita, Colorado in Experiment 2.

NAA mg/L	TDZ mg/L	# of explants	# of shoots	PAA mg/L	TDZ mg/L	# of explants	# of shoots
0.9	0	50	5 exps† w/roots	5.0	0	50	0
0.9	0.5	50	0	5.0	0.5	50	0
0.9	1.0	50	0	5.0	1.0	50	0
0.9	2.0	50	1 rosette	5.0	2.0	50	1
0.9	4.0	50	0	5.0	4.0	50	0
0.9	8.0	50	1	5.0	8.0	50	0

†explants

Table 7. Number of explants and number of shoots produced when grown in tissue culture media containing TDZ at the Western Colorado Research Center at Fruita, Colorado in Experiment 3.

0.1 mg/L of TDZ	# of explants	# of shoots
Solid medium	50	4
Liquid medium	44	0
Shaker medium	49	0

Dry Bean Variety Performance Test at Montrose, Colorado 2003

Calvin H. Pearson,[1] Mark A. Brick, Jerry J. Johnson, J. Barry Ogg, and Cynthia L. Johnson[2]

Summary

A dry bean variety performance test was conducted at the Keith Catlin Farm in Montrose, Colorado during the 2003 growing season. Overall seed yields in the trial were good. Average seed yield was 2878 lbs/acre and yields ranged from a high of 3709 lbs/acre for 99195 to a low of 2327 lbs/acre for Buckskin.

Introduction

Dry bean variety performance tests conducted in the dry bean producing areas of Colorado are important to provide farmers with information that has been obtained under local conditions. It is also important to test yield performance in the seed-producing areas of the state. Seed growers must be assured that yields of popular dry varieties will also be profitable for seed production.

Thus, crop production information can be used by farmers when selecting varieties to plant on their farms, to seedsmen in knowing which varieties to grow for seed production, to companies to determine which varieties to market and in which locations varieties are best adapted, and to university personnel in developing new dry bean varieties and in educating people about them.

Dry bean variety performance tests conducted throughout the state also allows for data to be collected from several locations and in several environments in just one year's time, which provides considerable information about the performance of dry bean lines and varieties in diverse environments.

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[2] Respectively, Professor/Research Agronomist, Professor – Plant Breeding, Extension Crop Production Specialist, Research Associate, and Research Associate; all Department of Soil and Crop Sciences, Colorado State University, Ft. Collins, CO.

Materials and Methods

A dry bean variety performance test was conducted at the Keith Catlin Farm in Montrose, Colorado during 2003. The experiment was a randomized complete block with three replications. Eighteen varieties and advanced breeding lines were included in the 2003 trial. Plot size was 10-feet wide by 35-feet long (4, 30-inch rows). The previous crop was spring barley. Fertilizer applied was 20 gallons/acre of 10-21-0-5S preplant broadcast. MicroTech herbicide at 2 qts/acre and Sonalan at 0.5 pts/acre as a tank mix were applied preplant broadcast and incorporated. Planting occurred on 5 June 2003 with an air planter modified for planting plots. Seeding rate was approximately 85,120 seeds/acre. A side-dress application of Disyston at 1 pt/acre was applied to control leaf miner, Mexican bean beetle, and for mite control. The experiment was furrow-irrigated. Plots were cut on 16 Sept. 2003 with a

Fig. 1. Cutting dry beans at Fruita, Colorado in 2001 using a Pickett One-Step rod cutter windrower constructed for small plot reserach.

Pickett One-Step™ rod cutter windrower (Fig. 1) and threshed on 24 Sept. 2003 using a Hege small plot combine equipped to harvest dry beans.

Results and Discussion

Weed control in the plot area was good with the exception of a few small, spotty patches of Canada thistle. The 2003 cropping season in western Colorado was very dry and hot. Adequate irrigation water was available during the growing season and water was not a limiting factor for crop production.

Yield in the study averaged 2878 lbs/acre and ranged from a high of 3709 lbs/acre for 99195 to a low of 2327 lbs/acre for Buckskin (Table 1). The dry bean line, 99195, yielded 232 lbs/acre more than the variety/line with the second highest yield (00167). Seeds/lb ranged from a large seed size of 1057 seeds/lb for CO96731 to a small seed size of 1381 seeds/lb for 00167. For more information and results on dry bean testing in Colorado visit the web site at: http:www.colostate.edu/Depts/SoilCrop/extension/CropVar/index.html

Table 1. Pinto Bean Variety Performance Trial at Montrose[1] in 2003.

Variety	Yield	Seed/lb
	lb/acre	No.
99195	3709	1257
00167	3477	1381
00195	3248	1298
99204	3230	1167
99236	3181	1231
CO96731	2995	1057
CO96753	2978	1067
CO12650	2934	1275
99211	2872	1104
CO83783	2756	1064
CO83778	2733	1098
99218	2732	1163
CO96737	2711	1109
Montrose	2640	1201
Bill Z	2465	1281
Poncho	2450	1193
Grand Mesa	2361	1264
Buckskin	2327	1212
Average	**2878**	**1190**
CV(%)	7	
LSD (0.30)	169	

[1]Trial conducted on the Keith Catlin farm.

Acknowledgments

We thank Keith Catlin for allowing us to conduct this study on his farm. Appreciation is also extended to Lot Robinson and Fred Judson (Western Colorado Research Center staff), and Daniel Dawson (part-time hourly employee) who assisted with this research. We express appreciation to the Colorado Dry Bean Administrative Committee for funding this research. Thanks to Carroll Bennett for digitizing and manipulating the picture used in this report.

Small Grain Variety Performance Tests at Hayden, Colorado 2003

Calvin H. Pearson,[1] Scott D. Haley, Jerry J. Johnson, and Cynthia L. Johnson[2]

Summary

Each year small grain variety performance tests are conducted in the Hayden, Colorado area to identify varieties that are adapted for commercial production in northwest Colorado. Three small grain experiments [winter wheat, spring wheat, and AGRO polyacrylamide (PAM)] were conducted at Hayden in 2003. The 2003 growing season was very dry and yields in the trials were low. The 2003 results provide information about the performance of wheat varieties under severe stress conditions. Grain yield in the winter wheat variety performance test averaged 2320 lbs/acre (38.7 bu/acre). The highest yielding entry in the winter wheat test was CO980630 at 2881 lbs/acre (48.0 bu/acre) with six entries outyielding other varieties. Grain yield in the spring wheat variety performance test averaged 1431 lbs/acre (23.9 bu/acre). Grain yield ranged from a high of 1633 lbs/acre (27.2 bu/acre) for Oxen to a low of 1284 lbs/acre (21.4 bu/acre) for IDO377S, but there were not statistically significant differences in grain yield among the eight varieties.

An AGRO by N rate study was conducted at Hayden during 2003 in a two-factor experiment. The two factors were: 1) PAM applied at rates of 0, 2, and 6 lbs/acre of AGRO and 2) nitrogen rates applied at 0, 10, 20, 30, and 40 lbs N/acre using ammonium nitrate as the N source. Grain yield was reduced by 0.11 bu./acre with each additional pound of nitrogen applied per acre within the range of nitrogen used in this study. The application of AGRO PAM did not affect grain yield significantly. There was a slight increase of 1.5 bu./acre in grain yield at the 2 lbs/acre application rate of AGRO over the check treatment but this increase was not statistically significant. These findings indicate the need for further study on applying AGRO PAM in dryland winter and spring wheat in northwest Colorado.

Introduction

Growers in northwest Colorado are limited to only a few crops to grow because of constraints created by dryland production conditions, a short growing season, limited precipitation, and isolation to markets for their crops. The principal cash crop grown in northwest Colorado is wheat. Alternative crops are of interest to growers in northwest Colorado. Alternative small grains, such as malting barley, triticale, and specialty wheats (i.e., hard white wheats) are of interest to growers because these crops are often sold into specialty markets which demand a premium selling price. New crop production inputs and practices are also of interest to growers in northwest Colorado if these inputs and practices are determined to be profitable and environmentally sound. Growers in this region of Colorado are supportive of agronomic research that provides them with science-based information. They can use this information to assist them in making crop production decisions. During 2003, we conducted winter and spring small grain variety tests that included not only traditional small grains but also some of these specialty wheats. We also conducted an experiment to evaluate the application of AGRO PAM and nitrogen on grain yield of spring wheat grown under the dryland conditions of northwest Colorado.

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Materials and Methods

Winter Wheat Variety Performance Test

Twenty-six winter wheat varieties and lines were evaluated during the 2003 growing season at the Mike and Dutch Williams Farm near Hayden, Colorado. The experiment design was a randomized complete block with four replications. Plot size was 4-ft. wide by 40-ft. long with six seed rows per plot. The seeding rate was 56 lbs/acre and planting occurred on 25 Sept. 2002. Herbicide (2,4-D at 8 oz/acre) was applied aerially on 26 May 2003. No insecticides or fertilizers were applied. Harvest occurred on 13 Aug. 2003 using a Hege small plot combine (Fig. 1).

Fig. 1. Harvesting winter wheat plots at Hayden, Colorado on 13 Aug. 2003.

Spring Small Grain Variety Performance Tests

Eight spring wheat entries were evaluated during the 2003 growing season at the Dutch and Mike Williams Farm near Hayden, Colorado. The experiment design was a randomized complete block with four replications. Plot size was 4-ft. wide by 40-ft. long with six seed rows per plot. Planting occurred on 21 May 2003. Spring wheat was planted at 60 lbs seed/acre. Herbicide (2,4-D amine at 6 oz/acre) was applied using ground equipment on 20 June 2003. No fertilizer or insecticides were applied to the spring wheat plots. Harvest of the spring wheat plots occurred on 5 Sept. 2003 using a Hege small plot combine.

AGRO PAM and Nitrogen Fertilizer Study

An AGRO by N rate study was conducted on the Dutch and Mike Williams Farm at Hayden, Colorado during 2003 in a two-factor experiments. The two factors were: 1) AGRO PAM applied at rates of 0, 2, and 6 lbs/acre of AGRO and 2) nitrogen application rates at 0, 10, 20, 30, and 40 lbs N/acre applied using ammonium nitrate as the N source. A soil sample was obtained within the plot area prior to planting. Soil was sampled to a depth of 8 inches. Approximately 20 random soil cores were obtained across the plot area and bulked together. Following air drying a subsample of soil was analyzed at the Colorado State University Soil Testing Lab.

The spring wheat variety ‘Dirkwin’ was planted at 60 lbs of seed/acre. Treatments were applied by mixing the seed, AGRO, and nitrogen fertilizer in the same packet and the entire contents were applied through the planter during planting. Planting occurred on 21 May 2003 using a cone planter. Harvest occurred on 5 September 2003 with a Hege plot combine. Grain samples were cleaned in the laboratory using a small Clipper cleaner to remove plant tissue that remained in the grain following combining. Grain moisture and test weight were determined with a Seedburo GMA-128 seed analyzer. Grain yields were calculated at 12% moisture content.

Results and Discussion

The summer of 2003 in the Craig/Hayden area was hotter than in many other years. The average maximum temperature in July 2003 was 91.4° F (Fig. 2). Precipitation during the 2003 growing season for the months of January through October totaled 14.76 inches with April receiving the most precipitation at 3.85 inches and July receiving the least amount of precipitation at only 0.18 inches (Fig. 3). Precipitation in the Craig/Hayden area varies considerably from month to month and year to year and is the most limiting factor for small grain production. The monthly precipitation in 2003 depicts the variability that often occurs in the area (Fig. 3). Variability in precipitation can occur both temporally and spatially, thus, the amount of precipitation received on a particular farm can vary considerably from the amounts recorded at a weather station.

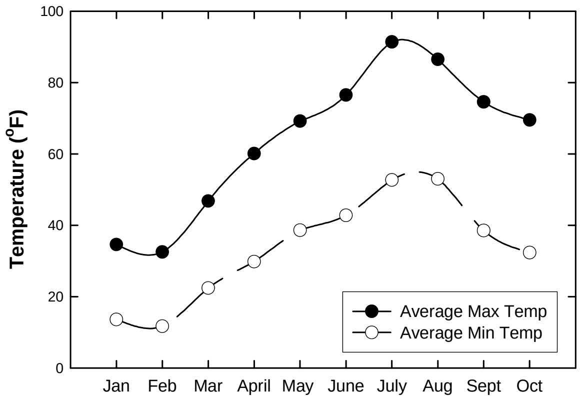

Fig. 2. Average maximum monthly and average minimum monthly temperatures for January through October 2003 at Hayden, Colorado.

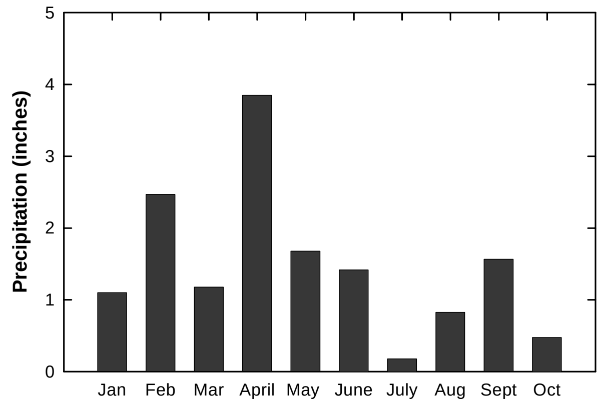

Fig. 3. Monthly precipitation for January through October 2003 at Hayden, Colorado.

Winter Wheat Variety Performance Test

Grain moisture in the winter wheat variety performance test at Hayden averaged 9.8% (Table 1). Grain moisture content ranged from a high of 10.5% for Gary to a low of 9.3% for CO99141. Grain yields of the winter wheat varieties averaged 2320 lbs/acre (38.7 bu/acre). Grain yields ranged from a high of 2881 lbs/acre (48.0 bu/acre) for CO980630 to a low of 1869 lbs/acre (31.2 bu/acre) for CO970547-2 (Fig. 3). Six varieties outyielded other entries. Test weights averaged 60.2 lbs/bu. Test weights ranged from a high of 61.1 lbs/bushel for Hayden and Lakin to a low of 58.0 lbs/bu. for Moreland. Planted height averaged 25.0 inches. Plant height ranged from a high of 30.9 inches for Hayden to a low of 21.5 inches for CO99W329. There was no lodging in the winter wheat variety performance test in 2003. Protein concentration averaged 12.5%. Protein concentration ranged from a high of 14.3% for CO970547-7 and CO99314 to a low of 11.3% for Deloris, Moreland, and IDO571.

Spring Wheat Variety Performance Test

Grain moisture in the spring wheat variety performance test averaged 10.2% (Table 2). were no significant differences among spring wheat varieties for grain yield. Test weight averaged 57.6 lbs/bu. Test weight ranged from a high of 60.2 lbs/bu. for Forge to a low of 54.3 lbs/bu. for Dirkwin. Plant height averaged 13.6 inches. There were no significant difference among spring wheat varieties for plant height. There was no lodging in the spring wheat variety performance test in 2003. Protein concentration averaged 16.6%. Protein concentration ranged from a high of 17.2% for IDO566 to a low of 15.9% for Forge.

AGRO PAM and Nitrogen Fertilizer Study

The report from the CSU Soil Testing Laboratory showed the soil in the plot area had a pH of 6.0, 1.8 mmhos/cm, 5.5% organic matter, 8.4 ppm NO^3-N, 6.7 ppm P, 322 ppm K, 2.4 ppm Zn, 67.4 ppm Fe, 36.5 ppm Mn, and 1.5 ppm Cu.

The application of nitrogen and AGRO did not significantly affect (P = 0.05) grain moisture, test weight, or plant height. The average grain moisture in the study was 10.5%, test weight averaged 53.8 lbs/bu., and plant height averaged 12 inches.

The application of nitrogen in spring wheat at Hayden, Colorado in 2003 did not increase grain yields (Fig. 4). In fact, grain yield was reduced by 0.11 bu./acre with each additional pound of nitrogen applied per acre within the range of nitrogen applied in this study. The soil in the plot area was low in nitrate-nitrogen, but it had a high organic matter content compared to many other soils in the area.

The application of AGRO PAM did not affect grain yield significantly (p = 0.05), but there was a slight increase of 1.5 bu./acre in grain yield over the check treatment at the 2 lbs/acre application

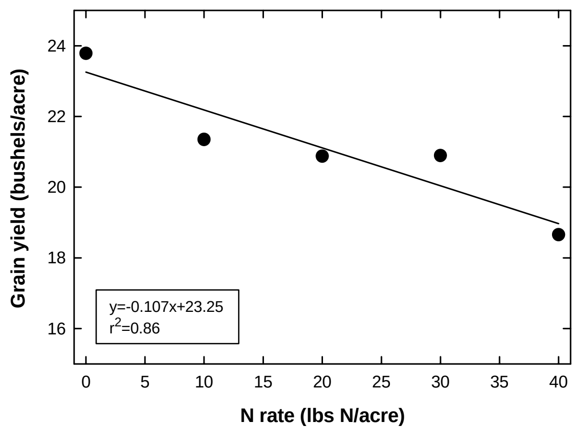

Fig. 4. The effect of nitrogen application on grain yield of spring wheat at Hayden, Colorado during 2003.

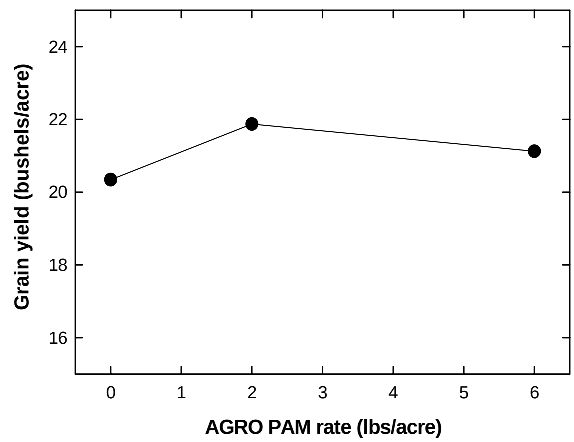

Fig. 5. The effect of applying AGRO PAM on grain yield of spring wheat at Hayden, Colorado during 2003.

rate of AGRO, but this increase was not statistically significant (Fig. 5). Research conducted by Carlyle Thompson at Kansas State Univ. from 1996-2000 over numerous locations showed that net returns from applying 1 or 2 lbs/acre of AGRO in wheat ranged from a less than $1.00/acre up to $13.00/acre. Based on the research results in Kansas and the 2003 findings at Hayden, further study on applying AGRO in dryland winter and spring wheat in northwest Colorado appears warranted.

Acknowledgments

Farmer-cooperators for the winter wheat variety, spring wheat variety, and AGRO tests were Dutch and Mike Williams. We thank Dutch and Mike for their willingness to participate with us in conducting this research. We also thank C.J. Mucklow, CSU Cooperative Extension, for his assistance with our small grain research in northwest Colorado. Appreciation is also expressed to Lot Robinson, Fred Judson (Western Colorado Research Center staff), and Daniel Dawson (part-time hourly employee) who assisted with this research. Special appreciation is extended to the Colorado Wheat Administrative Committee for funding this research. Thanks to Stockhausen and Lloyd Garner for supplying the AGRO PAM. Lastly, thanks to Carroll Bennett for digitizing the photograph used in this report.

Table 1. Winter wheat variety performance at Hayden, Colorado in 2003. Farmer-Cooperators: Mike and Dutch Williams.

Variety	Market class[1]	Grain moisture	Grain yield		Test weight	Plant height	Protein
		(%)	lbs/acre	bu/acre	lbs/bu	inches	%
CO980630	HRW	10.0	2881	48.0	60.8	24.9	11.5
Above	HRW	9.5	2668	44.5	60.3	24.7	12.2
Golden Spike	HWW	10.0	2654	44.2	59.5	28.1	11.4
CO99W183	HWW	9.6	2595	43.2	59.4	24.5	11.7
Deloris	HRW	9.5	2587	43.1	60.1	29.0	11.3
CO99177	HRW	9.5	2566	42.8	59.9	25.4	13.1
CO980607	HRW	10.1	2520	42.0	60.9	23.3	11.9
Lakin	HWW	10.4	2437	40.6	61.1	23.8	12.9
Ankor	HRW	9.7	2390	39.8	60.7	24.9	11.8
CO99W192	HWW	9.5	2379	39.7	59.0	24.5	12.3
CO99314	HRW	9.8	2357	39.3	60.0	23.5	14.3
CO99141	HRW	9.3	2319	38.6	60.6	24.2	13.9
Moreland	HRW	9.9	2313	38.6	58.0	23.3	11.3
Gary	HWW	10.5	2274	37.9	59.7	27.1	10.7
CO99W277	HWW	10.0	2257	37.6	60.4	25.8	13.1
Fairview	HRW	9.6	2255	37.6	60.1	28.4	12.3
CO980376	HRW	9.7	2251	37.5	60.9	24.3	12.2
IDO571	HRW	9.9	2185	36.4	60.0	25.3	11.3
CO99W188	HWW	9.4	2180	36.4	60.2	22.8	12.6
CO970547	HRW	9.7	2162	36.1	61.0	24.5	13.0
Avalanche	HWW	9.8	2135	35.6	61.0	25.3	12.9
CO970547-7	HRW	9.9	2128	35.5	60.0	24.4	14.3
CO99W254	HWW	9.5	2099	35.0	61.0	22.7	13.2
CO99W329	HWW	10.0	1992	33.2	60.9	21.5	12.2
Hayden	HRW	9.5	1880	31.3	61.1	30.9	13.3
CO970547-2	HRW	10.2	1869	31.2	59.4	23.8	13.8
Ave.		9.8	2320	38.7	60.2	25.0	12.5
LSD (0.05)		0.3	353	5.9	0.9	1.5	
CV (%)		2.5	10.8	10.8	1.1	4.3	

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

Table 2. Spring wheat variety performance test at Hayden, Colorado 2003. Farmer-Cooperators: Mike and Dutch Williams.

Barley variety	Market class[1]	Grain moisture	Grain yield		Test weight	Plant height	Protein
		(%)	lbs/acre	bu/acre	lbs/bu	inches	%
Oxen	HRS	10.1	1633	27.2	57.3	13.2	16.8
Lolo	HWS	9.9	1529	25.5	59.3	12.9	16.6
IDO592	HRS	10.7	1458	24.3	56.1	15.2	16.9
IDO566	HRS	10.2	1435	23.9	58.1	13.3	17.2
IDO593	HRS	10.1	1386	23.1	57.0	14.7	16.1
Forge	HRS	10.2	1378	23.0	60.2	12.9	15.9
Dirkwin	HRS	10.5	1348	22.5	54.3	13.0	16.3
IDO377S	HWS	10.1	1284	21.4	58.2	13.8	16.8
Ave.		10.2	1431	23.9	57.6	13.6	16.6
LSD (0.05)		NS	NS	NS	1.4	NS	
CV(%)		3.9	10	10.4	1.6	8.6	

[1] HRS = hard red spring wheat; HWS = hard white spring wheat.

Application of Crop Modeling for Sustainable Grape Production: Year Two Results

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

Summary:

Initial incidence of grape powdery mildew in 2003 was detected belatedly and infection levels at one of the cooperating vineyards grew to severe levels before control was obtained. Control costs (material costs only) were higher than last year as a consequence, and no substantial cost difference was found between the grower standard program and the integrated disease management program. Earlier detection might have provided opportunity for earlier control with lower cost control materials. Use of basal shoot leaves adjacent to the cordon arms might well provide an earlier detection of infection and will be incorporated into the detection program for 2004. Both the server and software have been upgraded so that "live" weather data from five vineyard sites are now accessible to growers via a dedicated web site.

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:

Four cooperator vineyards were identified with 2 acres of a single grape variety (three Chardonnay, vineyards A, B, & C, and one Sauvignon blanc, vineyard D). Grower 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 (1 acre) and to use the control program designated by the researchers for the other half of the block (1 acre, which included the site of a remote weather station described below). The spray programs varied from one spray per season to eight sprays per season (Tables 1 - 5).

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Table 1. Powdery mildew spray programs used at cooperator vineyard A during the 2003 season.

Grower's Standard Mildew Program			Integrated Disease Management Program		
Date	Materials & rates used	Cost[z]	Date	Materials & rates used	Cost[z]
4/29	Sulfur 6F @ 0.5 gal/a	$2.38	4/29	Sulfur 6F @ 0.5 gal/a	$2.38
5/12	Sulfur 6F @ 0.5 gal/a	$2.38			
5/17	Sulfur 6F @ 0.5 gal/a	$2.38	5/17	Sulfur 6F @ 0.5 gal/a	$2.38
5/31	Sulfur 6F @ 0.5 gal/a	$2.38			
6/12	Nova 40W @ 3 oz./a	$12.90	6/16	Nova 40W @ 3 oz./a	$12.90
6/27	Sovran 50W @ 4 oz./a + Stylet-Oil @ 1.0% v/v	$40.15	6/27	Sovran 50W @ 4 oz./a + Stylet-Oil @ 1.0% v/v	$40.15
7/14	Kaligreen 82W @ 5 lb./a + Stylet-Oil @ 1.5% v/v	$51.50	7/14	Kaligreen 82W @ 5 lb./a + Stylet-Oil @ 1.5% v/v	$51.50
7/30	Sovran 50W @ 4 oz./a + Stylet-Oil @ 1.0% v/v	$40.15	7/30	Sovran 50W @ 4 oz./a + Stylet-Oil @ 1.0% v/v	$40.15
Total Spray Program Cost		**$ 154.20**	Total Spray Program Cost		**$ 149.45**

[z] Costs per acre for spray material only.

Table 2. Powdery mildew spray programs used at cooperator vineyard B during the 2003 season.

Grower's Standard Mildew Program			Integrated Disease Management Program		
Date	Materials & rates used	Cost[z]	Date	Materials & rates used	Cost[z]
5/14	Thiolux 80DF @ 5 lbs/a	$ 4.25	5/14	Thiolux 80DF @ 5 lbs/a	$ 4.25
5/29	Bayleton 50DF @ 4 oz./a	$15.74			
6/30	Stylet-Oil @ 1.5% v/v	$ 14.14			
			7/9	Kaligreen 82W @ 3.5 lb/a + Stylet-Oil @ 1.5% v/v	$ 34.96
7/25	Nova 40W @ 5 oz./a + Stylet-Oil @ 1.25% v/v	$ 33.28	7/25	Nova 40W @ 5 oz./a + Stylet-Oil @ 1.25% v/v	$ 33.28
8/13	Sovran 50W @ 4.5 oz./a + Stylet-Oil @ 1.5% v/v	$ 42.99	8/13	Sovran 50W @ 4.5 oz./a + Stylet-Oil @ 1.5% v/v	$ 42.99
Total Spray Program Cost		**$ 110.40**	Total Spray Program Cost		**$ 115.49**

[z] Costs per acre for spray material only.

Table 3. Powdery mildew spray programs used at cooperator vineyard C during the 2003 season.

Grower's Standard Mildew Program			Integrated Disease Management Program		
Date	Materials & rates used	Cost[z]	Date	Materials & rates used	Cost[z]
5/24	Sulfur 6F @ 0.5 gal/a	$ 2.90			
6/7	Nova 40W @ 2.5 oz./a	$ 10.75			
6/22	Sovran 50W @ 2 oz./a	$ 12.83			
7/5	Sulfur 6F @ 0.5 gal/a	$ 2.90			
7/19	Kaligreen 82W @ 5 lb/100 gal + Stylet-Oil @ 1% v/v	$26.99	7/19	Stylet-Oil @ 1.5% v/v	$ 13.27
8/2	Kaligreen 82W @ 5 lb/100 gal + Stylet-Oil @ 1% v/v	$ 26.99	8/2	Kaligreen 82W @ 5 lb/100 gal + Stylet-Oil @ 1% v/v	$ 26.99
Total Spray Program Cost		**$ 83.36**	Total Spray Program Cost		**$ 40.26**

[z] Costs per acre for spray material only.

Table 4. Powdery mildew spray programs used at cooperator vineyard D during the 2003 season.

Grower's Standard Mildew Program			Integrated Disease Management Program		
Date	Materials & rates used	Cost[z]	Date	Materials & rates used	Cost[z]
7/30	Thiolux 80DF @ 3 lbs/a	$ 2.55	7/30	Thiolux 80DF @ 3 lbs/a	$ 2.55
Total Spray Program Cost		**$ 2.55**	Total Spray Program Cost		**$ 2.55**

[z] Costs per acre for spray material only.

Table 5. Comparison of number of sprays applied and costs per acre for four cooperator vineyards in western Colorado that used the grower's standard program and the integrated (model-driven) program to control grape powdery mildew during the 2003 season.

	Grower's Standard Program		Model-driven Program	
	No. Sprays	Cost[z]	No. Sprays	Cost[z]
Vineyard A	8	$ 154.20	6	$ 149.45
Vineyard B	5	$ 110.40	4	$ 115.49
Vineyard C	6	$ 83.36	2	$ 40.26
Vineyard D	1	$ 2.55	1	$ 2.55

[z] Costs per acre for spray material only.

Automated AdCon weather stations were installed at two vineyards in 2002 and two in 2003. The stations each were equipped with air temperature, humidity, leaf wetness, rain gauge, wind speed and direction, and solar radiation sensors and ability to send data back to a base station via radio telemetry on 15-minute intervals. The base station database was then accessed using the Thomas-Gubler and the Kast powdery mildew disease models to assess mildew infection risk.

A field scout assessed powdery mildew infection incidence and severity on variable intervals, typically at least once and often twice a week, using the most recently fully expanded leaf for observations. Incidence and severity of powdery mildew infections on shoots and leaves were recorded throughout the 2003 season up to and slightly beyond harvest.

Data was analyzed via SAS statistical software with means separated at the P>0.05 level.

Results:

Weather conditions during 2003 saw some slight easing of the severe drought conditions (experienced in 2001 - 2002) in the early spring months as grapes began bud burst. However, these wet weather periods early in the season were also accompanied by temperatures below the 50 ºF threshold for powdery mildew infections. Thus, the first infection period did not occur until June 20th and 21st. The first mildew infections found in the field evaluations occurred on June 26th at only one of the cooperating vineyards. Infections appeared at a second vineyard on the July 3rd evaluation, at a third vineyard location on July 13th, and did not appear at the fourth vineyard until July 17th (Figs. 1 - 2). The first three vineyards in which powdery mildew was detected were older, established vineyards while the final vineyard in which mildew was detected was relatively young (<3 yrs old) with initially sparse canopy development early in the season. In fact, mildew incidence and severity never exceeded 40% in the young vineyard while incidence and severity in the older vineyards reached 48 - 85% by early August. Veraison occurred August 11-12 at vineyards A, B, & C (Chardonnay plots) and August 7 in vineyard D (Sauvignon blanc plots).

It was evident as the season developed that the initial infections (June 20th and 21st) were not found although the scout carefully examined the canopies after the infectin period. This probably was due to the observation protocol that designated observations be made on the upper shoot growth. However, we believe that the intitial infection may have occurred on leaves near the cordons in the lower part of the canopy. Had the lower leaves adjacent to the cordon arms been selected for the observations, the initial infections might have been detected sooner and controls applied on a more efficacious timing. Thus, the initial protocol used at the start of the 2003 season will be modified to utilize the basal leaves for initial infection detection in the future.

The impact of the failure to detect infections as early as needed is reflected in the increased control costs in the integrated disease management plots in vineyards A and B (Table 5). While it is possible that costs for control will be high in both approaches during a season in which powdery mildew infection begins early, there should be a significant reduction in the amounts and costs of mildewcides applied under the IDM program (compared to the grower standard program) when disease incidence does not begin until mid-summer. Unfortunately, in 2003, the infections went undetected until the levels were high enough to require a more intensive (and expensive) control program to "catch up" with the disease. On the other hand, control costs with the IDM program on vineyard C were about half that of the standard program. In addition, it should be noted that Table 5 lists costs for materials only, i.e. labour and equipment costs are not included. Except in vineyard C, up to four additional sprays were applied in the grower standard program so that the costs savings of the IDM program are higher than what is indicated by Table 5.

Figures 1 and 2 and Tables 1 to 5 also demonstrate big differences in powdery mildew incidence and severity, as well as associated control costs, between vineyards. With Sauvignon blanc (Vineyard D), a variety that is somewhat less susceptible than Chardonnay, powdery mildew control required only a single spray. A calendar-type spray program would have resulted in 5-7 additional applications with little or no benefit. This clearly illustrates the potential savings that a model-driven program can provide under conditions of low disease pressure.

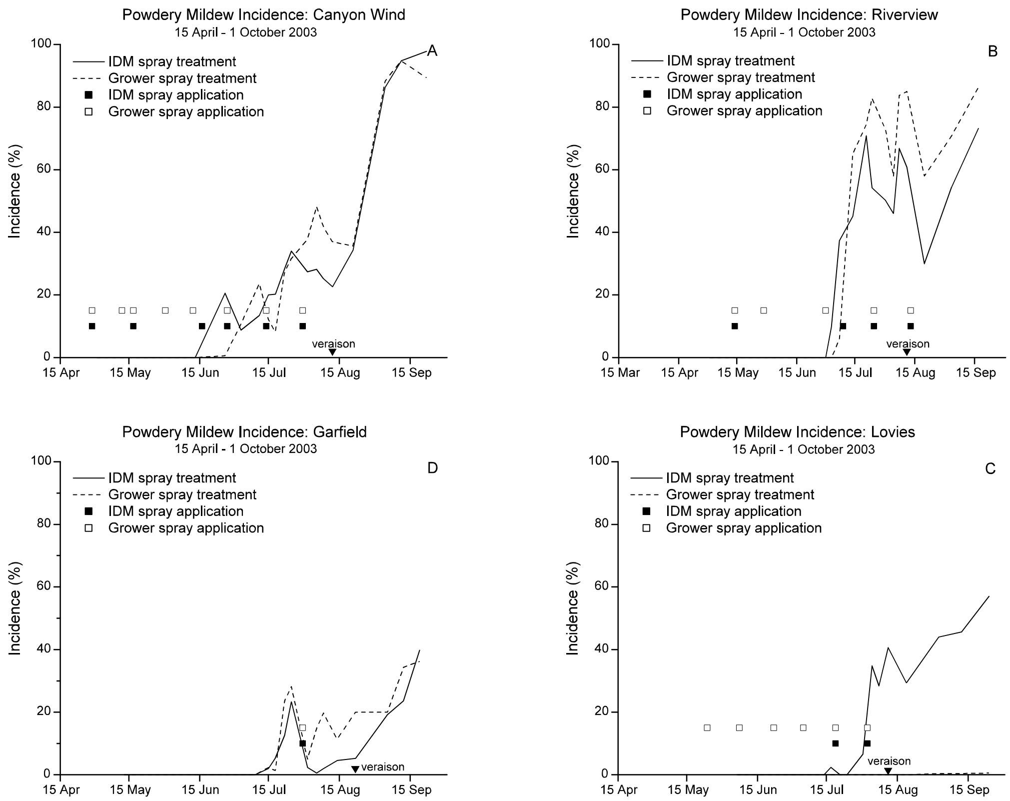

Fig. 1. Incidence of grape powdery mildew on Chardonnay (A, B, C) and Sauvignon blanc (D) leaves at four Colorado vineyards in 2003. At each site, the grower's standard spray program was compared to a reduced (IDM) spray program. Spray applications are indicated by a "□" (grower program) and a "■" (IDM program). Clockwise from top left: Canyon Wind Cellars vineyard, Grande River Vineyards - Riverview vineyard, Lovie's vineyard, and Garfield Estates vineyard.

Outreach:

Producers were informed of the project plans at the Spring meeting of the Rocky Mountain Association of Vintners and Viticulturists (RMAVV) held April 20, 2003. A progress report was given at the Summer RMAVV meeting held July 27th, 2003. The season-long results were shared with producers at the fall RMAVV meeting held Nov. 15th, 2003.

The concept of Integrated Disease Management and the results from the 2002 season were presented to New Mexico growers and winemakers at the New Mexico Grape Growers & Winemakers Conference in Albuquerque, February 21-22, 2003 (Caspari & Larsen, 2003).

For the first two seasons the data acquisition and modeling software ran on an old computer in the viticulture lab. Due to the limited capabilities of this old computer, access to the data was via dial-up connection and was limited to the participating vineyards. Following several weeks of testing, both a new web server and new software were purchased in the fall of 2003. RMAVV members now have access to "live" weather data from five vineyard sites on a dedicated web page. Access to the data requires a password. The present configuration has three

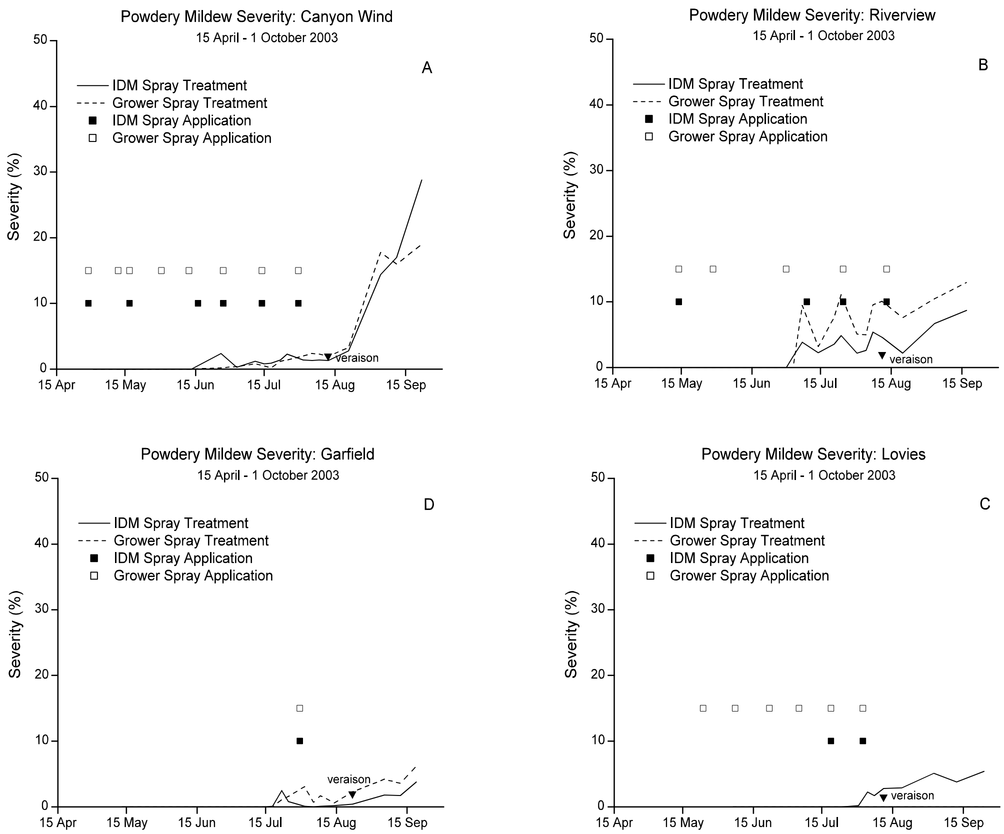

Fig. 2. Severity of grape powdery mildew on Chardonnay (A, B, C) and Sauvignon blanc (D) leaves at four Colorado vineyards in 2003. At each site, the grower's standard spray program was compared to a reduced (IDM) spray program. Spray applications are indicated by a "□" (grower program) and a "■" (IDM program). Clockwise from top left: Canyon Wind Cellars vineyard, Grande River Vineyards - Riverview vineyard, Lovie's vineyard, and Garfield Estates vineyard.

"seats", i.e. up to three growers can access the data simultaneously. In the future, access may be extended by purchasing additional seats.

Results from the previous year have been posted on the RMAVV web page

www.rmavv.org

A major update of the "Viticulture" section on the WCRC web page www.colostate.edu/programs/wcrc/viticulture/viticulture.html has been done recently. There currently are seven documents online related to powdery mildew, including two annual reports for the present study.

The study's technical advisors also had numerous informal meetings with the grower cooperators throughout the season.

Impact:

As mentioned in the Annual Report 2002, one of the grower cooperators (Canyon Wind Cellars) did apply the IDM strategy on his entire vineyard. He has now used the IDM program on the entire vineyard for the second year with the exception of the "grower" area in the study block.

In an attempt to gain baseline data on the number of sprays currently used by Colorado grape growers, we added a question to that effect to the Colorado Grape Grower Survey 2003. Preliminary data from the survey show a range from 0-10 sprays applied during the 2003 season.

Acknowledgments:

Field evaluations were done by Cate Hight and Francois Raimbaud. Sprays were applied by the field staff of the cooperating vineyards: Canyon Wind Cellars, Garfield Estates Winery and Vineyard, Lovie's Vineyard, and Grande River Vineyards (Riverview Block). Cooperation provided by Norm Christianson and Ben Parsons (Canyon Wind Cellars), Bob Paxton and Brandon Armitage (Garfield Estates), Ken Loveland (Lovie's Vineyard), and Jim Mayrose and Stephen Smith (Grande River Vineyards, Riverview Block).

Funding for this project came from a variety of sponsors. Funding for the field scout was provided through a Pesticide Special Study grant from the United States Environmental Protection Agency (Region 8). Other operating costs were partially covered by a grant from Colorado State University's Specialty Crops Program awarded to the Rocky Mountain Association of Vintners and Viticulturists (RMAVV), and matching funds from RMAVV, by the Colorado Wine Industry Development Board, and CSU's Agricultural Experiment Station.

Publications:

Caspari, H.W & Larsen, H. J. 2003. Application of crop modeling for sustainable grape production. pp. 24 - 28 *in*: Proc. SW Regional Vine and Wine Conf., Feb. 21 & 22, 2003, Albuquerque, NM. 108 pp.

Efficacies of Alternative Control Materials for Grape Powdery Mildew in Western Colorado

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

Summary and Recommendations:

Evaluation of "soft" options for control of powdery mildew of grape in western Colorado found no differences provided by the materials included in the study between levels of mildew incidence and severity on Chardonnay grape in 2003. Materials evaluated included oil (paraffinic and jojoba) products, a $KHCO_3$ product, a *Bacillus subtilis* product, and a rotational program that rotated myclobutanil, kresoxim-methyl, and paraffinic oil.

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.

As the wine grape industry expands in Colorado, interest in "softer" approaches to control grape powdery mildew is increasing. This includes materials such as paraffinic oils and plant oils, potassium bicarbonate, and biocontrol materials such as *Bacillus subtilis* and other products. The present study was done to evaluate the efficacy of these materials and compare them against the more standard control options used in western Colorado.

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[2] Respectively, Research Fruit Pathologist / Extension Fruit Disease Specialist and Viticulturist, Department of Horticulture and Landscape Architecture, Colorado State University.

Materials and Methods:

The study was established in a block of Chardonnay grapes at the Western Colorado Research Center – Orchard Mesa, located southeast of Grand Junction, CO.

Three powdery mildew sprays were applied during 2003: June 25-26th, July 11th, and July 30th (Table 1). A grape leafhopper spray of imidacloprid was applied at the rate of 52.54 gm a.i./ha on July 30th. The six powdery mildew spray programs were as follows: 1) non-sprayed control; 2) a rotational program that rotated myclobutanil (Nova) with kresoxim-methyl (Sovran) and with paraffinic oil (Stylet-Oil), 3) $KHCO_3$ (Kaligreen), 4) paraffinic oil (Stylet-Oil), 5) jojoba oil (Erase), and 6) *Bacillus subtillis* (Serenade). The rates for these materials are listed in Table 1. Powdery mildew infection was evaluated on six leaves (using the most recent fully expanded leaf on shoots) for incidence and severity on six dates: 6/24, 7/1, 7/9, 7/23, 7/29, and 8/25/2003.

Data was analyzed via SAS statistical analysis program software using a p>0.05 threshold for means testing.

Results and Discussion:

The 2003 season was again very hot and dry, at least during the early portion of the growing season. The dry conditions delayed onset of powdery mildew infection as no significant (2.5 mm or more) rainfall occurred in conjunction with temperatures averaging between 10 and 25 ^{o}C (the

Table 1. Mildewcide application dates, materials, and rates used in the experimental vineyard plots at W. Colorado Research Center – Orchard Mesa, Grand Junction, CO during the 2003 growing season.

Trt No.	Treatment Program Type	Spray Dates	Materials & rates used
1	Control	Non-treated control	None
2	Rotation Program	6/25-26/2003 7/11/2003 7/30/2003	a. Nova (myclobutanil) 40W @ 5 oz. / acre (=140 g a.i./ha) b. Sovran (kresoxim-methyl) 50WG @ 4 oz. / acre (= 140 g a.i./ha) c. Stylet-Oil (paraffinic oil @ 1% vol./vol.)
3	Kaligreen	a. 6/26/2003 b. 7/11/2003 c. 7/30/2003	Kaligreen (potassium bicarbonate) 82W @ 5 lb. / acre (= 4.6 kg a.i./ha)
4	Stylet-Oil	a, b, c	Stylet-Oil (paraffinic oil) @ 1% vol./vol.
5	Erase	a, b, c	Erase (jojoba oil) @ 0.5% vol./vol.
6	Serenade	a, b, c	Serenade (*Bacillus subtilis*) 10W @ 6 lbs. / acre (= 673 g a.i./ha)

general conditions necessary for initial infection to occur) until June 20th. Vine shoot growth was better during the early season in 2003 than it was in 2002, but canopy coverage was slow to develop. This likely was a carryover effect from the severe drought conditions experienced in 2002. Initial powdery mildew counts made June 24th found no mildew infections on any leaves within the study plots (Table 2). Mildew infections began showing up in substantial amounts by early July, but dropped at the end of July after 2 weeks of temperatures of 100 ^{o}F or above during mid-July. Mildew infections increased in incidence and severity by late July and continued to build throughout August and were extremely high by late August.

An infection period occurred at the site on June 20-21. This was exacerbated by a water line break at the head of the vineyard which allowed water to run down one aisle to such a volume that standing water was present for several days after the line was shut off and repaired. The initial mildew infection and highest incidence and severity was localized in the two rows either side of the break and continued down the row from the top approximately 150 ft of the total 400 ft row length. Infection and severity dropped off greatly as one moved away from the inundated aisle area. The incidence and severity was sufficiently great to cause severe infection and injury on fruit clusters within the severely affected area; much of the fruit was rendered unuseable.

The association of the water break with higher mildew incidence and disease severity points out the role of water in hydrating the overwintering cleistothecia and inducing ascospore release as a cause of primary mildew infection in arid areas such as western Colorado. Typically, no flag shoots are found early in spring in this area. This means initial infections typically are ascospore infections that depend wholly upon hydration events after initiation of shoot growth. If such hydration events do not occur, then ascospore infections do not occur. Thus, control programs can focus on occurrence of hydration events to time initiation of spray applications. And this can reduce the number of applications per year and lower producer costs. (See Larsen & Caspari, 2004)

The decline in Mildew incidence and severity at the end of July likely is a result of the very high daytime temperatures (100+ ºF) experienced for two weeks in mid-July.

Mildew spray materials differ substantially in efficacy periods and costs per spray materials (Table 3). In addition, they represent different chemistries and modes of action, and have different risk of resistance development. It is recommended to rotate chemistry groups, not just products, and not use DMI's or strobilurins for repeat (successive) sprays.

Acknowledgments:

Assistance for field counts of powdery mildew were provided by Cate Hight and Francois Raimbaud; sprays were applied by Brian Braddy and John Wilhelm, WCRC-OM technical support staff.

Literature Cited

Larsen, H. J. and H. W. Caspari. 2004. Application of Crop Modeling for Sustainable Grape Production: Year Two Results. p. 29 - 34 *in*: Larsen, H. J. [Ed.]. Western Colorado Research Center Research Report, 2003. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn., Colo. St. Univ., Ft. Collins. 60 p. (on the web at: (http://www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)

Table 2. Incidence (%) and Severity (% surface infected) of foliar mildew infections as affected by treatment program at the W. Colorado Research Center at Orchard Mesa, Grand Junction, CO during the 2003 growing season.

Treatment Program	6/24/2003	7/1/2003	7/9/2003	7/23/2003	7/29/2003	8/25/2003
	Incidence (%)					
Control	0.0	10.00	42.32	6.93	9.24	92.30
Rotation Program	0.0	10.80	41.55	2.31	7.69	96.92
Kaligreen	0.0	2.80	30.03	1.54	4.62	97.69
Stylet-Oil	0.0	0.80	33.88	1.54	9.23	93.07
Erase	0.0	4.00	35.40	1.54	5.39	92.30
Serenade	0.0	6.40	42.33	0.00	7.70	86.92
	Severity (%)					
Control	0.0	0.50	2.84	0.12	0.43	31.80
Rotation Program	0.0	0.94	2.56	0.03	0.24	28.86
Kaligreen	0.0	0.08	1.28	0.06	0.15	31.56
Stylet-Oil	0.0	0.05	1.61	0.03	0.29	22.71
Erase	0.0	0.33	2.16	0.03	0.18	27.21
Serenade	0.0	0.23	2.57	0.00	1.17	30.60

Table 3. Comparative efficacy periods, rates and costs of control materials for grape powdery mildew in 2003.

Material	**Chemistry Group**	**Efficacy Period**	**Rate**	**Cost / acre**
Thiolux 80DF	Sulfur	7 - 10 days	2 - 5 lb/acre	$2 - 4
Sulfur 6F	Sulfur	7 - 10 days	3 - 6 qt/acre	$4 -8
Sulfur 90W	Sulfur	7 - 10 days	5 - 10 lb/acre	$2 - 4
Bayleton 50DF	DMI	14 - 21 days	4 - 6 oz/acre	$16 - 24
Nova 40W	DMI	14 - 21 days	3 - 5 oz/acre	$13 - 22
Procure 50W	DMI	14 - 18 days	4 - 8 oz/acre	$14 - 28
Rubigan 1E	DMI	14 - 21 days	2 - 6 fl. oz./acre	$5 - 14
Stylet-Oil	Oil	14 days	1 - 2 ga.l/100 gal. (1 - 2% vol/vol)	$15 - 30
Erase	Oil	14 days	1 - 2 qts/acre	$24 - 45
Kaligreen 82W	Bicarbonate	10 - 14 days	2.5 - 5 lb/acre	$15 - 30
Abound 2.08F	Strobilurin	14 - 21 days	11 - 15 fl. oz./acre	??
Flint 50WDG	Strobilurin	14 - 21 days	2 oz/acre	$30
Sovran 50W	Strobilurin	14 - 21 days	4 oz/acre	$26
Serenade 10W	*Bacillus subtilis*	10 - 14 days	4 - 8 lb/acre	$33 - 66

2003 Observations for the1994 Dwarf Apple Rootstock Trial (NC-140 Regional Project)

Ron Godin[1]

Summary and Recommendations

The 2003 season was the tenth and final year of this rootstock trial. Trees on rootstocks M.9 Pajam 2 and M.9 RN29 produced the highest number of fruit and higher average fruit size, but also were among the largest sized trees. MARK rootstock was determined to be unacceptable because of soil-line swelling similar to crown gall. The smallest trees (and smallest yield trees) were those on P.22, B.491, and M.27 EMLA rootstocks.

Introduction and Objectives

Choice of a suitable rootstock could make the difference between an economically viable orchard and one that loses money for the orchardist. This trial was initiated by the NC-140 committee (NC-140 is composed of tree fruit researchers across the U.S. and Canada that do research on tree fruit rootstocks) to see how several dwarfing (M.9 size) rootstocks would perform over a range of climates. The objectives of this trial were to determine the adaptability of differing dwarfing apple rootstocks to Western Colorado and to determine if any of these rootstocks perform better than existing rootstocks.

Materials and Methods

This trial was planted in at the Western Colorado Research Center – Rogers Mesa site in 1994. The trial consisted of 16 rootstock clones from the semi-dwarf M.26 EMLA to the very dwarfing M.27 EMLA. The scion variety chosen was Gala (Treco Red Gala #42). It was planted in a randomized complete block design with 10 replications. Trees were supported and trained to a modified vertical axe training system. The site chosen was a replant-site with no fumigation. Trees were watered by microsprinkler irrigation. Similar plantings are replicated at 21 other sites across the U.S.

Results

The 2003 season was the tenth and final year of this rootstock trial. The cumulative results for the past 5 growing seasons (1999-2003) are presented in Table 1. Data was group in this manner to assist growers in making decision about the best performing rootstocks in this trial. None of the trees grew vigorously as anticipated. Terminal growth is not excessive and leaf size is small. The rootstock MARK was highly promoted after the preliminary 5-year report; it looked like the best rootstock. It had size control, lots of fruiting, and no staking needed. However, after 10 years, a soil-line swelling similar to crown gall made this rootstock unacceptable. With that stated, it appears that the largest trees were on V.1, M.9 RN29 and M.9 Pajam 2; the smallest trees were on P.22, B.491 and M.27 EMLA. In general, the largest trees were also the higher yielding trees. The least cumulative yield occurred with M.27 EMLA and P.22 which correlates with the small size of the trees. The M.9 Pajam 2 and the M.9 RN29 also produced the highest number of fruit with some of the higher average fruit size of the rootstocks tested (Table 1). These same two rootstocks also produced the most rootsuckers over the past 5 years (Table 1).

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Acknowledgments

Colorado Agricultural Experiment Station provided funding that supported data collection and analysis. Special thanks to George Osborn, Bryan Braddy and Kim Schultz for data collection.

Table 1. Cumulative growth and yield parameters for the final 5 years of the study 1999 - 2003 in the 1994 NC-140 dwarf apple rootstock planting at the WCRC - Rogers Mesa site.

Rootstock	1999-2003 Cumulative fruit yield (lbs/tree)		Final tree height (inches)		1999-2003 Cumulative Fruit number (apples/tree)		1999-2003 Average fruit wt. (oz)[1]		1999-2003 Cumulative Rootsuckers	
M.9 EMLA	117	bc[2]	101	cde	572	abc	3.3	abcd	25	fgh
M.26 EMLA	113	bcd	100	cde	532	cd	3.4	abcd	12	hi
M.27 EMLA	28	fg	73	g	224	f	2.1	g	26	fgh
M.9 RN29	152	a	113	abc	717	ab	3.4	abc	57	ab
M.9 PAJAM 1	116	bc	96	def	545	bc	3.5	ab	42	cde
M.9 PAJAM 2	154	a	117	ab	731	a	3.5	abc	69	a
B.9	109	bcd	106	bcd	550	bc	3.2	abcde	26	fgh
B.491	54	e	72	g	324	ef	2.7	ef	35	defg
O.3	96	cd	91	ef	574	abc	3.2	abcde	39	cdef
V.1	127	b	123	a	555	bc	3.7	a	30	efg
P.2	92	d	92	ef	572	abc	2.9	cde	6	i
P.16	54	e	74	g	362	def	2.8	de	46	bcd
MARK	50	ef	84	fg	427	cde	2.2	fg	50	bc
P.22	23	g	72	g	188	f	2.1	g	13	hi
B.469	91	d	92	ef	479	cde	3.1	bcde	22	gh
NAKBT 337	108	bcd	89	ef	511	cd	3.5	ab	49	bcd

[1] An average fruit weight of 4.4 ounces is the equivalent of a 150 count size.
[2] Values followed by different letter are significantly different at the LSD = 0.05 level.

2003 Observations for the 1998 Sweet Cherry Rootstock Trial (NC-140 Regional Project)

Ron Godin[1]

Summary and Recommendations

This is the end of the sixth year of the planting. The trees are still too young to draw conclusions and no recommendations should be made at this time.

Introductions and Objectives

Until a few years ago, there had not been a good dwarfing rootstock for cherry. Several *Prunus* species and crosses have been made that have resulted in potential dwarfing rootstocks for sweet cherry. The Gisela® series is one such example. This trial was initiated by the NC-140 committee (NC-140 is composed of tree fruit researchers across the U.S. and Canada that do research on tree fruit rootstocks) to see how these relatively new *Prunus* rootstocks would perform over a range of climates. The objectives of this trial were to determine the adaptability of differing *Prunus* rootstocks to western Colorado, to determine if these rootstocks induce dwarfing, and to determine if any of these rootstocks perform better than existing rootstocks. Similar plantings are under evaluation at several other sites across the U.S.

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Materials and Methods

This trial was planted in at the Western Colorado Research Center – Rogers Mesa site in 1998. The trial consisted of 13 *Prunus* rootstocks with a Bing scion. It was planted in a randomized complete block design with seven replications. Trees were trained to a central leader. Trees were watered by furrow irrigation until 1999 when micro-sprinklers were installed. All trees with fruit were harvested on June 18th.

Results and Discussion

Most of the tree loss in this planting is due to late fall/early winter damage in the first year of the planting. It is unclear why more loss has occurred in the Mazzard rootstock. The possibility is that they were weaker trees from the nursery. The results for tree yield parameters are presented in Table 1. Making recommendations after only 6 years worth of data is not wise. However, it is apparent that some trees are yielding better than others. Whether those particular rootstocks will be as productive in year to come is yet to be determined. The G5, G6, and G7 trees were the best producers in 2003 with the G5 having the fewest rootsuckers. The W13 continues to be the rootstock with the greatest number of suckers.

Acknowledgments

Colorado Agricultural Experiment Station provided funds that supported data collection and analysis. Special thanks to George Osborn, Bryan Braddy and Kim Schultz for data collection.

Table 1. Several growth parameters for the 2002 growing season in the 1998 NC-140 sweet cherry rootstock planting at the WCRC - Rogers Mesa site (Block 31).

Rootstock	No. still alive[1]	Average Fruit Wt. (lbs/tree)	Cumulative Yield (lbs/tree)	Average no. rootsuckers (no./tree)
Mazzard	4	1.2	4.2	6.0
Mahaleb	6	5.5	7.5	0.0
G5	6	7.5	9.3	0.0
G6	7	5.3	7.5	0.6
G7	7	6.0	7.5	14.0
Gi 195/20	7	3.8	6.4	4.3
Gi 209/1	5	1.7	2.7	1.2
Edabriz	6	4.3	6.0	4.0
W10	7	.5	7.8	2.0
W13	7	5.7	7.6	48.6
W53	6	4.4	7.1	11.1
W72	6	3.7	5.4	6.3
W158	7	2.0	5.5	8.5

[1] Out of seven originally planted trees.

Evaluation of Two Methods of Thermal Weed Control In Fruit Tree Orchards: Year 1

Rick Zimmerman[1]

Summary

Two different types of thermal weed control devices were compared for use in orchard weed control during 2003: a direct flamer unit and a prototype infrared weed flamer. The direct flamer was more effective at reducing weed cover, but the infrared unit was viewed to have lower operator risk and fire danger risk. The infrared unit also was found to concentrate the heat on the orchard floor and reduced heat exposure to tree trunks and lower canopy branches.

Introduction

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 they have biological and economical 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, and it is difficult to incorporate fertilizers or organic matter into the soil. Weed mat also harbors overwintering rodent populations which feed on the trees. 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 soil organic matter and soil structure are likely to be affected adversely.

In the last decade researchers and growers have intensified research and adaptation of thermal methods of 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 utilizes shielded burners which 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 about 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

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

This study had three objectives:

1. Compare the efficiency 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.
2. Determine optimum tractor speeds and treatment intervals to provide the best weed control with the most economical use of propane. Flamer heights will remain constant from ground level.
3. Compare the economics of both methods of thermal weed control, landscape cloth and mechanical tillage. The economics regarding the use of landscape cloth and mechanical tillage already exist for use in western Colorado orchards.

Methods:

There were a total of twelve treatments. Each treatment was replicated six times. Each treatment plot consisted of 25ft of tree row. Weed species and total weed cover were assessed at the 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.

The following treatments were applied:

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

Results:

Weed control was mixed for both types of thermal weed control devices. Overall the direct flamer was more effective at reducing weed cover than the infra-red weeder (Figure 1). 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 5 inches less than the direct flamer. In conventional orchards a weed free strip approximately 2 feet from tree is considered adequate.

Another factor that may have affected weed control was the treatments were not started until late May due to engineering problems with infra-red weeder and all treatments were ceased in early August due to hazardous fire conditions due to the drought. Treatment intervals (2 and 3 weeks) also did not have a significant impact on weed control from either thermal treatment. Speed also did not effect the amount of weed control.

After one year of study, the infra-red weeder shows great promise. It is clearly safer for the operator and reduces the fire danger in the orchards. It also concentrates the heat directly onto the orchard floor and not into the lower tree canopy or trunk.

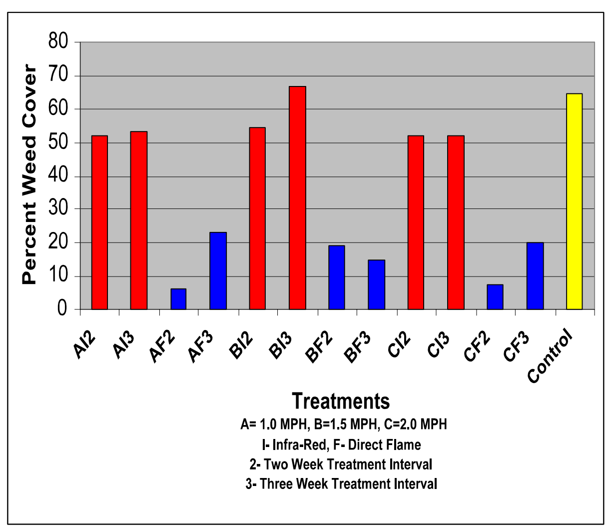

Fig. 1. Percent weed cover resulting from two different types of thermal weed control equipment: direct flame and infra-red. The amount of weed cover was measured in a 3 foot X 3 foot grid extending from the base of the tree trunk into the alleyway between the tree rows.

Dr. Horst C. Caspari

2003 Research Projects*

Viticulture and Enology Programs for the Colorado Wine Industry (Colorado Wine Industry Development Board; H. Larsen, R. Zimmerman)
Partial Rootzone Drying (Washington Tree Fruit Research Commision; P. Andrews, B. Leib, T. Auvil, J. McFerson, T. Einhorn)
Methods to delay bud break in grape (Viticulture Consortium East; H. Larsen, D. Ferree, C. Stushnoff)
Using heat-pulse technique to monitor transpiration in pecan trees under reduced irrigation conditions (Texas Water Research Institute; L. Lombardini)
Application of Crop Modeling for Sustainable Grape Production (U.S. 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.

2003 Publications

Caspari, H.W. and H.J. Larsen. 2003. Application of crop modeling for sustainable grape production. p. 29-32 *in*: Larsen, H. J. [Ed.]. Western Colorado Research Center Research Report 2002. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. St. Univ., Ft. Collins. 60 p. (on the web at: www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)
Caspari, H.W and H.J. Larsen. 2003. Application of crop modeling for sustainable grape production. p. 24 - 28 *in*: Proc. SW Regional Vine and Wine Conf., Feb. 21 & 22, 2003, Albuquerque, NM. 108 pp.
Caspari, H.W., H.J. Larsen, S. Max, & M. Zarnstorff. 2003. Evaluation of the effect of hail damage on Chardonnay grape production. p. 19 - 28 *in*: Larsen, H.J. [Ed.]. Western Colorado Research Center Research Report 2002. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn., Colo. St. Univ., Ft. Collins. 60 p. (on the web at: (http://www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)
Caspari, H.W., H.J. Larsen, S. Max, & M. Zarnstorff. 2003. Evaluation of the effect of hail damage on Chardonnay grape production. p. 29 - 40 *in*: Proc. SW Regional Vine and Wine Conf., Feb. 21 & 22, 2003, Albuquerque, NM. 108 p.
Einhorn, T. & H. Caspari. 2003. Effects of multiple feed forward mechanisms on stomatal regulation for apple trees subjected to partial rootzone drying and deficit irrigation. HortScience 38(5):712- 713 (Abstr.).

Conference papers:
Green, S., B. Clothier, B. Jardine, M. Greven, S.Neal, H. Caspari, and B. Dichio. 2003. Measurements of sap flow in grape vines. p. 123-148 *in*: Tognetti, R. and A. Raschi [Eds.]. Proc. 5th Int. Workshop Plant Water Relations and Sap Flux Measurements, 9-10 November 2000, Firenze, Italy.

Reports / Articles / Guides Published Only on WCRC Web Page

Caspari, H.W., H.J. Larsen, & R. Sharp. 2003. Specialty Crops Annual Report, 2002: Application of crop modeling for sustainable grape production. 5 p. Published as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pm2002annreport)

Caspari, H.W., H.J. Larsen, & R. Sharp. 2003. Specialty Crops Annual Report, 2003: Application of crop modeling for sustainable grape production. 5 p. Published as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pm2003annreport)

Larsen, H.J. & H.W. Caspari. 2003. Determine the impact of biocontrol treatment in the fall on the grape powdery mildew (*Uncinula necator*) pressure the following season. 2 pp. Pub. as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pmimpactbiocontrol.pdf)

Larsen, H.J. & H.W. Caspari. 2003. Determine the overwintering inoculum source(s) for grape powdery mildew (*Uncinula necator*). 1 p. Pub. as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pmoverwinteringinoculum.pdf)

Larsen, H.J. & H.W. Caspari. 2003. Soft control strategies for grape powdery mildew (*Uncinula necator*) - 2001. 7 p. Pub. as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pmsoftcontrolstrat2001.pdf)

Larsen, H.J. & H.W. Caspari. 2003. Soft control strategies for grape powdery mildew (*Uncinula necator*) - 2002. 2 p. Pub. as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pmsoftcontrolstrat2002.pdf)

Norton, A., H.J. Larsen,.& H.W. Caspari. 2003. Integrating control strategies for grape powdery mildew (*Uncinula necator*) - 2002. 2 p. Pub. as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pmintegratingcontrol.pdf)

Dr. Ron Godin

2003 Research Projects*

Organic weed control in vegetables using corn gluten meal (U.S. Environmental Protection Agency Region 8)
Organic fertility and orchard floor management for peaches
Organic table grape variety trial
Native seed production for crop diversification (USDA - Western Region SARE, Uncompaghre Plateau Project)
Brewing hops variety trial
Soil and irrigation water acidification for improved sweet corn production (Del Mesa Farm & Uncompaghre Valley Sweet Corn Growers)

*Cooperators/collaborators/sponsors are noted in parentheses.

2003 Publications

Godin, R. 2003. 2002 Observations for 1994 Dwarf Apple Rootstock Trial (NC-140 Regional Project). p. 33-34 *in*: Larsen, H.J. [Ed.]. Western Colorado Research Center 2002 Research Report. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. St. Univ., Ft. Collins. 60 p. (on the web at: www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)

Godin, R. 2003. 2002 Observations for 1998 Sweet Cherry Rootstock Trial (NC-140 Regional Project). p. 35-36 *in*: Larsen, H.J. [Ed.]. Western Colorado Research Center 2002 Research Report. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. St. Univ., Ft. Collins. 60 p. (on the web at: www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)

Pearson, Calvin H., Matthew Rogoyski, Ron Godin, Bob Hammon, and Randy Moench. 2003. Performance of Hybrid Poplar in Western Colorado, 2000-2002. p. 7-18 *in*: Larsen, H.J. [Ed.]. Western Colorado Research Center 2002 Research Report. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. St. Univ., Ft. Collins. 60 p. (on the web at: www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)

Dr. Harold J. Larsen

2003 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, D. Ferree, C. Stushnoff)
Application of Crop Modeling for Sustainable Grape Production (U. S. Environmental Protection Agency; H. Caspari)
Integrating control strategies for grape powdery mildew (USDA-CSREES, WR-IPM; A. Norton, H. Caspari)

*Sponsors / cooperators are noted in parentheses.

2003 Publications

Caspari, H.W. and H.J. Larsen. 2003. Application of crop modeling for sustainable grape production. p. 29-32 *in*: Larsen, H. J. [Ed.]. Western Colorado Research Center Research Report 2002. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn., Colo. St. Univ., Ft. Collins. 60 pp. (on the web at: www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)

Caspari, H.W and H.J. Larsen. 2003. Application of crop modeling for sustainable grape production. p. 24 - 28 *in*: Proc. SW Regional Vine and Wine Conf., Feb. 21 & 22, 2003, Albuquerque, NM. 108 pp.

Caspari, H.W., H.J. Larsen, S. Max, & M. Zarnstorff. 2003. Evaluation of the effect of hail damage on Chardonnay grape production. p. 19 - 28 *in*: Larsen, H.J. [Ed.]. Western Colorado Research Center Research Report 2002. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn., Colo. St. Univ., Ft. Collins. 60 pp. (on the web at: (http://www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)

Caspari, H.W., H.J. Larsen, S. Max, & M. Zarnstorff. 2003. Evaluation of the effect of hail damage on Chardonnay grape production. p. 29 - 40 *in*: Proc. SW Regional Vine and Wine Conf., Feb. 21 & 22, 2003, Albuquerque, NM. 108 pp.

Larsen, H.J. 2003. Fruit Industry Outlook. 2 p *in*: Weitzel, D. (Ed.) 2003. 2003 Colorado Agricultural Outlook Forum. Article available on internet at the Colorado Agricultural Forum web page: (http://www.coloagforum.com/forums/2003/relateddocs/fruitoutlook.pdf)

Larsen, H. J. [Ed.] 2003. Western Colorado Research Center Research Report 2002. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn., Colo. St. Univ., Ft. Collins. 60 pp. (on the web at: http://www.colostate.edu/programs/wcrc/annrpt/02/index.html)

Reports / Articles / Guides Published Only on WCRC Web Page

Caspari, H.W., H.J. Larsen, & R. Sharp. 2003. Specialty Crops Annual Report, 2002: Application of crop modeling for sustainable grape production. 5 p. Published as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pm2002annreport)

Caspari, H.W., H.J. Larsen, & R. Sharp. 2003. Specialty Crops Annual Report, 2003: Application of crop modeling for sustainable grape production. 5 p. Published as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pm2003annreport)

Larsen, H.J. 2003. Flea beetle on grape. 3 p. Published as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/fleabeetleongrape.pdf)

Larsen, H.J. 2003. Grape Pest Management Guide for 2003. 3 p. Pub. as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/GrapePestMgmtGuide03.pdf)

Larsen, H.J. 2003. Leaf Analysis Standards. 4 p. Pub. as a PDF file on Western Colorado Research Center web page: (http://www.colostate.edu/programs/wcrc/tissue_test_levels.pdf)

Larsen, H.J. & H.W. Caspari. 2003. Determine the impact of biocontrol treatment in the fall on the grape powdery mildew (*Uncinula necator*) pressure the following season. 2 pp. Pub. as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pmimpactbiocontrol.pdf)

Larsen, H.J. & H.W. Caspari. 2003. Determine the overwintering inoculum source(s) for grape powdery mildew (*Uncinula necator*). 1 p. Pub. as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pmoverwinteringinoculum.pdf)

Larsen, H.J. & H.W. Caspari. 2003. Soft control strategies for grape powdery mildew (*Uncinula necator*) - 2001. 7 p. Pub. as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pmsoftcontrolstrat2001.pdf)

Larsen, H.J. & H.W. Caspari. 2003. Soft control strategies for grape powdery mildew (*Uncinula necator*) - 2002. 2 p. Pub. as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pmsoftcontrolstrat2002.pdf)

Norton, A., H.J. Larsen,.& H.W. Caspari. 2003. Integrating control strategies for grape powdery mildew (*Uncinula necator*) - 2002. 2 p. Pub. as a PDF file on the W. Colo. Research Center's Viticulture web page: (http://www.colostate.edu/programs/wcrc/pmintegratingcontrol.pdf)

Dr. Calvin H. Pearson

2003 Research Projects*

Winter wheat cultivar performance test - Hayden (Mike and Dutch Williams, Dr. Scott Haley, C.J. Mucklow)
Spring wheat cultivar performance test - Hayden (Mike and Dutch Williams, Dr. Scott Haley, C.J. Mucklow)
Using polyacrylamide to increase yield in spring wheat - Hayden (Mike and Dutch Williams, C.J. Mucklow)
Long season corn grain hybrid performance test - Fruita (Dr. Jerry Johnson, seed companies)
Short season corn grain hybrid performance tests - Fruita, Delta (Wayne Brew, Dr. Jerry Johnson, seed companies)
Corn forage hybrid performance tests - Fruita, Olathe (Earl Seymour, Dr. Jerry Johnson, seed companies)
Increasing nitrogen use efficiency in corn by applying protein hydrogel in soil at planting - Fruita (Ashley Rust)
Evaluation of Golden Harvest corn hybrids for BES - Fruita (Wayne Fithian of J.C. Robinson Company)
Alfalfa variety performance test (2002-2004) - Fruita (Dr. Jerry Johnson, seed companies, breeding companies, private industry)
Alfalfa germplasm evaluations, 2002-2004 - Fruita (Dr. Peter Reisen of Forage Genetics)
Evaluation of Roundup-Ready alfalfa, 2003-2005 (2006-2008) (Forage Genetics and Monsanto)
Pinto bean cultivar performance test - Montrose (CDBAC, Dr. Jerry Johnson)
Hybrid poplar performance tests - Fruita, Orchard Mesa, and Hotchkiss (Dr. Matt Rogoyski, Dr. Ron Godin, Frank Kelsey, and staff)
Water-use efficiency of cool-season turf grass species in western Colorado - Fruita
Development of sunflower as an industrial, natural rubber-producing crop (Dr. Katrina Cornish, USDA-ARS, Albany, CA; Dr. Jay Keasling, U.C. Berkeley; Dr. Dennis Ray, University of Arizona; Dr. John Vederas, University of Edmonton, USDA-CSREES)

*Cooperators / collaborators / sponsors are noted in parentheses.

2003 Publications

Pearson, Calvin H. 2003. Letter From The Editor. Agron. J. 95:231-232.
Berrada, Abdel, Merlin Dillon, Scott Haley, Cynthia Johnson, Jerry Johnson, Calvin Pearson, Jim Quick, and Mark Stack. 2002. Making Better Decisions: 2002 Colorado Spring Wheat, Barley, and Oats Performance Trials. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Report TR03-2. Fort Collins, Colorado.
Pearson, Calvin H., Matthew Rogoyski, Ron Godin, Bob Hammon, and Randy Moench. 2003. Performance of Hybrid Poplar in Western Colorado, 2000-2002. p. 7-18 *in*: Larsen, H.J. [Ed.]. Western Colorado Research Center 2002 Research Report. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. St. Univ., Ft. Collins. 60 p. (on the web at: www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)
Pearson, Calvin H., Mark Brick, Jerry J. Johnson, J. Barry Ogg, and Cynthia L. Johnson. 2003. Results of the Cooperative Dry Bean Nursery and State Uniform Dry Bean Variety Performance Test at Fruita, Colorado 2002. p. 47-50 *in*: Larsen, H.J. [Ed.]. Western Colorado Research Center 2002 Research Report. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. St. Univ., Ft. Collins. 60 p. (on the web at: www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)

Pearson, Calvin H., Scott Haley, Jerry J. Johnson, and Cynthia Johnson. 2003. Small Grain Variety Performance Tests at Hayden, Colorado 2002. p. 51-55 *in*: Larsen, H.J. [Ed.]. Western Colorado Research Center 2002 Research Report. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. St. Univ., Ft. Collins. 60 p. (on the web at: www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)

Johnson, Jerry J., Frank C. Schweissing, Calvin H. Pearson, James P. Hain, and Cynthia L. Johnson. 2003. Making Better Decisions: 2003 Colorado Corn, Soybean, and Sunflower Variety Performance Trials. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Report TR03-10. Fort Collins, Colorado.

Johnson, Jerry J., Howard F. Schwartz, Mark A. Brick, Frank C. Schweissing, Calvin H. Pearson, Mark Stack, James P. Hain, Cynthia L. Johnson, Mark M. McMillian, Scott J. Nissen, J. Barry Ogg, and Kris Otto. 2003. Making Better Decisions: 2003 Dry Bean Variety Performance Trials. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Report TR03-09. Fort Collins, Colorado.

Dr. Matthew Rogoyski

2003 Research Projects*

Evaluation of five irrigation methods on production of container-grown cliffrose plants (Frank Stonaker, Dr. Calvin Pearson, Dr. James Klett, Frank Kelsey, and staff / Colorado Specialty Crops Program, Colorado Agricultural Experiment Station)

Evaluation of the Pot-In-Pot system for production of native woody plants. (Dr. Roger Kjelgren and Chelsea Nursery staff / USDA , Western SARE program)

Evaluation of effectivness and phytotoxicity of preemergence herbicide for container-grown crops (Dr. James Klett, David Staats, and staff / USDA IR-4 Program, Colorado Agricultural Experiment Station)

Multi-site evaluation of Plant Select ® plant material (Rob McDonald, Dr. James Klett, and staff / Colorado Nursery Association, Colorado Agricultural Experiment Station)

Production of maples trees in Pot-In-Pot system. (Dr. James Klett, Greg Litus, and staff / Colorado Nursery Association, Colorado Agricultural Experiment Station)

Hybrid poplar performance tests - Fruita, Orchard Mesa, and Hotchkiss (Dr. Calvin Pearson, Dr. Ron Godin, Frank Kelsey, and staff / Colorado Agricultural Experiment Station)

*Cooperators / collaborators / sponsors are noted in parentheses.

2003 Publications

Klett, J, D. Staats, M. Rogoyski. 2003. Preemergence weed control in container-grown herbaceous perennials and woody plants. HortScience 38(5):700 (Abstr.).

Pearson, Calvin H., Matthew Rogoyski, Ron Godin, Bob Hammon, and Randy Moench. 2003. Performance of Hybrid Poplar in Western Colorado, 2000-2002. p. 7-18 *in*: Larsen, H.J. [Ed.]. Western Colorado Research Center 2002 Research Report. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. Agric. Exp. Stn. Tech. Rpt. TR03-7. Colo. St. Univ., Ft. Collins. 60 p. (on the web at: www.colostate.edu/programs/wcrc/annrpt/02/tr03-7.pdf)

Graduate Student Committees (Thesis title)

Cummins, A. 2003. Tree Production Utilizing Pot-In-Pot Techniques. M. Sc. Thesis, Department of Horticulture and Landscape Architecture, Colorado State University, Fort Collins, Colorado

Dr. Rick Zimmerman

2003 Research Projects

Impact of green manures and weed mat on soil biota in organic peach tree orchards.
Effects of organic alternatives for weed control and ground cover management on tree fruit growth development and productivity.
The use of on-farm cover crops for fertility in organic fruit production.
Evaluation of two methods of thermal weed control in fruit tree orchards: Direct flame and infra-red.
Life history and control of the grape mealybug, *Pseudococcus maritimus*, in wine grapes.
Survey for European Corn Borer, *Ostrinia nubialis*, in all commercial sweet corn fields in Western Colorado.
Survey for the following insects: plum curculio, western cherry fruit fly, khapra beetle, Japanese beetle, glassy winged sharpshooter, apple maggot, pine shoot beetle, and various species of exotic fruit moths and wood boring beetles.

2003 Publications

Alam, M. and R. Zimmerman. 2003. Plastic mulch and subsurface drip irrigation effects on yield and brix levels of Kabocha squash. International Water and Irrigation 23(2): 37-42.