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Foreword

In December, 2009, Lee Sommers, Director of the Colorado Agricultural Experiment Station announced that the Western Colorado Research Center (WCRC) Rogers Mesa site will be closed effective June 30, 2010. This closing is necessitated by budget reductions at Colorado State University and will result in the elimination of two staff positions.

The Orchard Mesa and Fruita sites will remain open. Over the long run, the programs and staff at these sites are planned to be consolidated at Orchard Mesa. The consolidation is dependent upon obtaining funding for new buildings at Orchard Mesa. In the current budget environment, it is not likely that such funding will become available in the foreseeable future.

Harold Larsen, Professor and WCRC Interim Manager retired in April, 2010. Lee Sommers intends to evaluate WCRC programs with respect to meeting clientele needs before making a decision on filling this position. The funding for this position will not be eliminated but the program evaluation will determine what expertise is needed to best serve clientele.

A survey of fruit growers was conducted in winter 2010 to determine the sources of WCRC information to growers that are effective. Based upon the survey results, Code-a-Phone service has been eliminated. References to Code-a-Phone on the WCRC web site are being re-titled as Fruit Facts. The principal sources of grower in-season information effective May 1, 2010 will be the Fruit Facts emails and posting to the WCRC web site, <http://www.colostate.edu/programs/wcrc>.

A field day will be conducted at the Orchard Mesa site on Thursday, July 8, 2010 from 3-7pm. Information on the field day will be posted on the WCRC web site, as well as through other announcements to growers and the general public.

Dr. Frank Johnson

Associate Director, Agricultural Experiment Station

Interim Manager, Western Colorado Research Center

Site descriptions

Fruita Site

1910 "L" Road
Fruita, CO 81521
Tel (970) 858-3629 fax (970) 858-0461

The Fruita site is located 15 miles northwest of Grand Junction. With an average growing season of 180 days at an elevation of 4600 ft, a diversity of agronomic research is conducted at the Western Colorado Research Center at Fruita, including variety performance trials in alfalfa, corn silage, corn grain, canola, grasses, small grains; new and alternative crops; irrigation; cropping systems; soil fertility; and new crop trait evaluation. The Colorado Foundation Bean Program is located at Fruita. The specialized laboratory facilities at Fruita allow research to be conducted on tissue culture and natural rubber extraction and quantification in various plant species.

Orchard Mesa Site

3168 B1/2 Road
Grand Junction CO 81503
Tel (970) 434-3264 fax (970) 434-1035

The Orchard Mesa site is located 7 miles southeast of Grand Junction. Site elevation is approximately 4700 ft. with an average growing season of 182 frost-free days. The research conducted at this site includes tree fruits, wine grape production, dry bean variety increases, and ornamental horticulture. This site has alternative crops (e.g. pistachio nuts and edible honeysuckle), greenhouses, offices and laboratory facilities.

Rogers Mesa Site

30624 Highway 92
Hotchkiss, CO 81419
Tel (970) 872-3387 fax (970) 872-3397

The Rogers Mesa site is located 17 miles east of Delta and 3 miles west of Hotchkiss at approximately 5800 ft. above sea level. With an average growing season of 150 days, research conducted at this site was historically focused on tree fruit cropping at high altitude. The programs have expanded into grape production at high altitude, forage crops, organic, and alternative crop research. Rogers Mesa has an arboretum, laboratory, offices, and greenhouse facility located on site.

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Dr. Gennaro Fazio – Pomologist, U.S. Dept. of Agriculture, Geneva, NY
Derek Godsey – Coors Agronomist
Mike Williams – Farmer cooperator

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Advisory Committee

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

The members of the WCRC Advisory Committee for 2008 are listed below. Committee members serve voluntarily without compensation. WCRC Advisory Committee meetings are open to the public. For the current membership list please visit our web page: <http://www.colostate.edu/programs/wcrc/>.

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The 2008 NC-140 Apple Rootstock Trial: 2nd Year Results

Ramesh R. Pokharel¹ and Harold J. Larsen²

Summary

Second year data were collected for the 2008 NC-140 apple rootstock trial in Colorado. For the Brookfield Gala grafted on 24 different rootstocks, rootstock JTB had the greatest 2nd year growth tree circumference (cm) while rootstock 3041 (previously designated as G.41) had the smallest 2nd year growth in tree circumference. Four rootstocks remained sucker free whereas rootstock 6874 produced 1.6 suckers per tree. Thirteen rootstocks continue to have 100% survival while rootstock 6143 has the highest tree mortality (33.3%).

Introduction

Past research has shown that rootstocks react differentially to soil pH conditions (Sas Paszt & Mercik, 2004; Robinson, et al., 2003). Apple rootstock P22 was the most tolerant to strong soil acidification, followed by M9. M26 had the least tolerance to soil acidity; at pH 3.6, it had the highest concentrations of Al and Mn in the roots and shoots. Leaves of apple rootstocks grown in the most acidic soil contained the highest concentrations of Al and Mn when compared to rootstocks grown at pH 6.0. Both 'Jonagold' and 'Gala' grafted on P22 rootstock had the highest number of flowers and fruitlets, with less on M9 and the fewest on M26. This previous work elsewhere clearly illustrates the potential for finding a rootstock better suited to different soil pH conditions. Crop/ variety/

rootstock combinations best suited to high pH are the best solution for fruit growers in areas with high soil and water pH problems, such as in Western Colorado. Thus, an apple rootstock study was initiated in 2008 to evaluate rootstocks suited to high soil pH condition.

Materials and Methods

A total of 24 apple rootstocks of different origins, sources and programs were obtained and grafted to Brookfield Gala. The USDA Geneva Apple Rootstock Genetic Materials pool provided trees on 23 different rootstocks and a commercial nursery provided trees on the M6 standard rootstock. All were planted at the WCRC - Orchard Mesa site (Grand Junction, CO) of Colorado State University in 2008. A completely randomized block design was established with 5-10 replications based on the available rootstock numbers. Tree trunks were marked at 18" (45 cm) from the ground with a permanent marker. Initial trunk circumferences (in cm) were measured shortly after planting and tree initial growth, at the end of year one growth in Feb. 2009, and at the end of the second year growth (Oct. 2009). Differences in tree circumference measurements (year 1 measurement – initial and year 2 – year 1 measurement) were calculated. Averages were calculated using an Excel spreadsheet, but mean separation was not done due to high variability in replication numbers.

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Mention of a trade name or proprietary product does not imply endorsement by the authors, the Agricultural Experiment Station, or Colorado State University.

Results and discussion

In first year, tree circumference increased an average of 0.60 cm across all rootstocks; individual rootstock trunk circumference growth was highly variable (Table 1). Rootstock 7707 and JTB had the greatest growth followed by rootstock M.6, Maruba, Naga, Nic, etc., while rootstock 3041 had smallest growth (Table 1). In the second year, trees on JTE-B, M.6, 7707, and 5046 had the greatest increase in growth and

trees on rootstock 3041 had the least circumference growth (Table 1). Trees on four rootstocks remained sucker free through their 2nd year. For the remaining rootstocks, sucker numbers ranged from 0.1 to 1.6 suckers per tree with trees on rootstock 6874 having the highest sucker numbers. Tree mortality ranged from 0-33.3% where 13 rootstocks had no tree mortality (Table 1). This study will be continued for several years.

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References

- Robinson, T, L. Anderson, A. Azarenko, B. Barritt, T. Baugher, G. Brown, G. Couvillon, W. Cowgill, R. Crassweller, P. Domoto, C. Embree, A. Fennell, E. Garcia, A. Gaus, R. Granger, G. Greene, P. Hirst, E. Hoover, S. Johnson, M. Kushad, R. Moran, C. Mullins, S. Myers, R. Perry, C. Rom, J. Schupp, K. Taylor, M. Warmund, J. Warner, and D. Wolfe. 2003. Performance of Cornell-Geneva apple rootstocks with 'Liberty' as the scion in NC-140 trials across North America. *Acta Hort.* 622:521-530.
- Sas Paszt, L. and Mercik, S. 2004. The response of apple rootstocks P22, M9 and M26, and apple tree cultivars 'Jonagold' and 'Gala' to soil acidification. *Acta Hort.* (ISHS) 636:167-172

Table 1. Initial trunk circumference measurements and first and second year circumference growth^x of Brookfield Gala apple grafted to 24 rootstocks, including one standard M.6 rootstock planted in 2008 at the Colo. St. Univ. - W. Colo. Research Center, Grand Junction, CO. Trunk measurements were taken 45 cm (18") above the graft union.

Rootstock	Initial circum. (cm) ^y	Circumference Growth ^x , Year 1 (cm)	Circumference Growth ^x , Year 2 (cm)	Sucker number	Mortality (%)
3007	4.0	0.5	2.6	0.0	0.0
3041 ^z	5.3	0.2	2.2	0.0	0.0
4214	4.6	0.3	4.0	0.4	28.6
4814	4.7	0.8	4.0	0.4	22.2
5046	5.1	0.5	4.1	0.8	14.3
5087	4.8	0.0	2.7	0.0	14.3
5179	3.8	0.3	2.4	0.0	0.0
5890	5.6	0.8	3.9	0.3	0.0
5935	4.8	0.5	3.1	0.5	0.0
6006	5.1	0.7	3.9	0.5	11.2
6143	5.4	0.6	3.2	0.8	33.3
6253	4.9	0.4	3.5	0.2	0.0
6874	4.5	0.7	3.2	1.6	12.5
7707	2.7	1.5	4.2	0.3	0.0
B.118	5.8	0.5	3.8	0.0	0.0
B.9	3.5	0.8	3.5	0.2	0.0
G.16	5.5	0.5	3.2	0.1	14.3
G.30	3.1	0.6	3.6	0.2	0.0
G.65	4.3	0.6	3.6	0.2	16.7
JTE-B	4.8	1.5	4.5	0.1	11.2
M.6	4.9	0.8	4.4	0.3	10.0
Maruba	3.2	0.8	3.5	0.1	0.0
Naga	4.9	0.8	3.9	0.1	0.0
Nic29	2.6	0.6	3.6	0.0	0.0

^x Circumference growth = year (n) measurements – year (n-1) measurements, where n = end of current year and n-1 = end of previous year; for Year 1, n-1 is initial trunk circumference measurement after planting.

^y Values corrected from those reported in the 2008 Annual Report.

^z Previously designated as G.41.

Co-Establishment of Legumes and Corn in a Living Mulch Cropping System under Furrow Irrigation

Calvin H. Pearson¹, Joe Brummer², and Andy Beahm²

Summary

A living mulch cropping system consists of two crops growing in the same field during the same growing season and one crop continues to grow after the other crop is harvested. One of the crops in a living mulch cropping system is typically a cash crop such as corn for grain and the other crop is often a legume that provides benefits to the growing cash crop. In living mulch cropping systems the legume crop is often planted and established prior to planting the cash crop. If both the legume and cash crop could be established at the same time this would be advantageous to the grower. The objective of this study was to evaluate a method of planting to establish the two crops (legumes and corn for grain) at the same time during the 2009 growing season at the Western Colorado Research Center at Fruita, Colorado. In this one-year study, both legumes and a corn grain crop were successfully established at the same time in a living mulch cropping system. Grain yields and other yield parameters for co-established and conventional corn were similar. The living legume mulch appeared to be a significant source of N for the corn crop. There was no significant difference between co-established and conventionally-grown legumes for dry matter of corn stalks, corn cobs, and total corn stover. The forage quality of the legumes as a living mulch in corn was high. In 2010, we will co-establish both legumes and corn using equipment that can plant both crops in a single operation and band-apply herbicide over the corn row.

Introduction

Cover crops have been used for many years in agricultural systems, primarily to protect and improve soil properties. A cover crop is a living ground cover planted into or after a main crop. The cover crop is typically killed prior to planting the next crop. In recent years, there has been growing interest in the use of perennial

plants as a specialized cover crop known as a “living mulch.” As the name implies, a living mulch co-exists with the associated grain or other cash crop during the growing season and continues to grow after the crop is harvested (Figure 1). Concisely stated, a living mulch is a permanent cover crop that improves soil quality and is often a plant species that fixes atmospheric N (Duiker and Hartwig, 2004). A comprehensive review of cover crops and living mulches has been provided by Hartwig and Ammon (2002).

Living mulches provide benefits not only to the soil but also provides benefits to the associated crop plant (Table 1). Furthermore, the living mulch provides a high quality forage supply that can be hayed or grazed either in the spring or following removal of the grain crop in the fall (Figure 2). The use of legume living mulches for corn production is particularly beneficial because the legume provides protein to supplement corn stover when grazed following grain harvest of corn.

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Figure 1. Legume growth in a co-established study with corn grown for grain at Fruita, Colorado in 2009. Photo by Calvin Pearson just prior to harvest of corn grain.

A few potential drawbacks to living mulch cropping systems include living mulches compete with the annual crop (i.e. acts as a weed in the system). Therefore, perennial crop plants must often be suppressed to reduce the competitive effects on the cash crop. Adequately suppressing the living mulch without killing it is the key to making these systems work. Suppression can be accomplished using a number of management techniques such as herbicides, strategic grazing, close mowing, and minimum or strip tillage.

Another drawback is that some perennial plants used as living mulches are difficult and/or slow to establish. Additionally, new management skills may need to be acquired by farmers when working with living mulch cropping systems. Also, water requirements for living mulch cropping systems are often higher in order to adequately sustain both crops.

Perennial grasses, such as orchardgrass (*Dactylis glomerata*), can be used in living mulch systems, but legumes are more commonly used because of their ability to fix nitrogen (Singer and Pedersen, 2005). The most common legumes used in living mulch systems include alfalfa (*Medicago sativa*) (Eberlein et al., 1992), birdsfoot trefoil (*Lotus corniculatus*), crownvetch (*Coronilla varia*), kura clover (*Trifolium ambiguum*), red clover (*Trifolium pratense*), white clover (*Trifolium repens*), and

several others (Schtenkamp and Moomaw, 1989).

Table 1. Potential benefits of a living mulch cropping system.

Benefits
Reduced soil erosion due to the year-round cover provided by the perennial mulch.
Improved soil health (i.e. structure) due to little or no tillage in the system.
Increased soil organic matter (i.e. carbon sequestration).
Reduced nitrate leaching when using deep rooted perennials that scavenge available N that leaches beyond the root zone of the annual crop.
N-fixation when using perennial legumes as the living mulch.
Increase in beneficial insects and decrease in pest insects.
Weed suppression.
Value-added grazing crop.

Although various legumes have been successfully used as living mulches, species such as crownvetch, kura clover, and white clover possess traits that make them particularly well suited. These three species spread vegetatively by rhizomes (crownvetch and kura clover) or stolons (white clover) which allows them to persist without annual reseeding. Plants such as alfalfa and birdsfoot trefoil are bunch-type species and must be reseeded as the stand declines. Crownvetch has been shown to work well in the northeastern US, but does not establish and persist well in most areas of Colorado. White clover establishes well in Colorado, but may form too dense of a sod and become too vigorous to be preferred as a living mulch.

Ilnicki and Enache (1992) found that subterranean clover (*Trifolium subterraneum* L.) provided excellent weed control when grown with several different crops including field corn, sweet corn, soybeans, summer squash (*Cucurbita pepo* L.), spring cabbage (*Brassica oleracea capitata* L.), snap beans (*Phaseolus vulgaris* L.), and tomatoes (*Lycopersicon*



Figure 2. Cattle grazing corn stover during the winter months in the Grand Valley of western Colorado.

esculentum Mill) without reducing yields in many cases.

Kura clover has been used successfully in the upper Midwest as a living mulch with corn (Zemenchik et al., 2000) and has been recently tested in western Colorado where it performed well. Once established, kura clover is persistent because of its extensive rhizome system. This rhizome system contains a large number of buds at various depths in the soil which allows kura plants to initiate new growth when damaged by livestock, machinery, or freezing. Albrecht et al. (2000) and Taylor (1995) noted that the underground mass (roots and rhizomes) of mature stands of kura clover can be as high as 9 tons per acre which has implications for carbon sequestration in agricultural systems.

The main drawback to using kura clover is its low seedling vigor which makes establishment a challenge. Albrecht (2000) noted that the same basic goals that apply to establishing legume crops also apply to kura clover: (1) ensure good seed-to-soil contact when planting, (2) inoculate with the appropriate *Rhizobia* to stimulate nitrogen fixation, and (3) control competition from weeds or other forage plants after emergence. Mixing birdsfoot trefoil or red clover with kura at the time of seeding has resulted in higher forage production during the establishment year without creating significant negative effects on long-term kura clover performance.

Planting a seed mixture of kura, red, and white clover has been used successfully to establish kura clover in Colorado. The red and



Figure 3. Planting legume seed in 2009 using a cone planter at the Western Colorado Research Center at Fruita.

white clover typically establishes quicker than kura, but are shorter lived, especially red clover. These two species of clover provide ground cover and weed suppression during the first couple of years, which gives kura clover time to establish. Growers must pay close attention to management during the year of seeding in order to successfully establish kura clover as well as most other legume species that may be used for living mulches.

Living mulch cropping systems established under furrow irrigation require the management of crop residue and living plant material to permit irrigation in furrows during the cropping season. Pearson et al. (2002) developed guidelines for using conservation tillage for managing plant material when irrigating in furrows.

In living mulch cropping systems the legume crop is often planted and established prior to planting the cash crop. If both the legume and cash crop could be established at the same time this would have economic and management advantages to the grower. The objective of the co-establishment research at WCRC-Fruita in 2009 was to evaluate the potential for establishing legume species and grain corn in a living mulch cropping system when both crops were planted at the same time.

Materials and Methods

Co-establishment of legumes and corn for grain in a living mulch cropping system was evaluated at the Western Colorado Research Center at Fruita during 2009 at an elevation of 4590 feet. The previous crop was soybean.

Prior to planting, a broadcast application of 200 lbs/acre of 18-46-0 was made on April 22, 2009. No other fertilizer was applied to the co-establishment plot area during the growing season.

A seed mixture of kura clover, white clover, and red clover was planted on May 5, 2009 at 8 lbs/acre using a cone planter (Figure 3).

Corn (Grand Valley Hybrid 22B50) was planted on May 7, 2009 using a Buffalo-till planter (Fleischer Manufacturing, Inc., Columbus, NE, model no. 7010-6-30). At planting, a 6-inch band of Harness® 20G [acetochlor, 2-chloro-N-ethoxymethyl-N-(2-ethyl-6-methylphenyl)acetamide] was applied over the corn seed row on the top of each 30-inch bed. The granular herbicide was applied through the auxiliary boxes mounted at the back



Figure 4. Co-establishment of corn and legumes on each side of the corn row during 2009 at the Western Colorado Research Center at Fruita.

of the Buffalo-till planter. The application rate was 5.2 grams 0.2 oz./100 feet of row. This rate was equivalent to 2 lbs. of Harness®/acre.

The study was furrow-irrigated with siphon tubes from a concrete ditch with irrigation water from the Colorado River delivered through a

canal system. Onager miticide [hexythiazox, trans-5-(4-chlorophenyl)-N-cyclohexyl-4-methyl-2-oxothiazolidine-3-carboxamide] was applied at 12 oz./acre in 20 gallons of water per acre for mite control on July 1, 2009 using a ground applicator.

An area adjacent to the co-establishment block was prepared for planting using conventional, clean tillage. Production practices for the conventional corn were similar to the co-establishment with the following exceptions. Glyphosate herbicide (isopropylamine salt) as Glystar Plus was applied on June 4, 2009 at 2 qts/acre plus 1 qt of Activator 90 and 1 gal. of URAN in 100 gallons of water. The application was 22 gallons per acre at 30 psi. Nitrogen fertilizer was applied on June 9, 2009 at a rate of 180 lbs. N/acre using urea ammonium nitrate. The nitrogen fertilizer was applied side-dress in a split application on both sides of the corn row by dribbling the fertilizer into the soil through a rolling fluted coulter equipped with a fertilizer drop tube.

Corn grain harvest occurred on October 30, 2009 using a Gleaner combine modified for harvesting small plots. Six paired replications for the co-establishment and the conventional corn, each measuring 5 feet wide by 50 feet long, were used for yield determinations and final plant populations. Grain moistures and test weights were determined using a DICKEY-John GAC2100B seed analyzer. Grain yields were



Figure 5. Corn and legume growth on each side of the corn row during the 2009 growing season at the Western Colorado Research Center at Fruita.

corrected to 15.5% moisture.

Corn and legume residue were collected on November 11, 2009 from a randomly selected 30-inch x 30-inch area. All corn and legume plant material was hand collected. Legumes and corn stubble were cut to ground level. Residue was separated by corn and legumes, oven dried at 55°C, and weighed.

Dried legumes were ground in a Wiley mill (Wiley Model 4, Arthur H. Thomas Co., Philadelphia, PA) followed by additional grinding in a cyclone mill (Cyclotec Model 1093, Foss Corp., Eden Prairie, MN), both fitted with 2 mm screens. NDF and ADF were determined after Van Soest et al. (1991) using the ANKOM filter bag procedure (Model No. ANKOM 200, ANKOM Technology, Macedon, NY). Total nitrogen was determined using the Dumas combustion method (Ethridge et al., 1998). A Leco C and N analyzer (Model CN 2000, Leco Corp., St. Joseph, MI) was used to perform the analysis, and crude protein was calculated from % N.

Data were analyzed by a paired T-test using Analytical Software Statistix 9 program (Analytical Software, 2008) to determine treatment effects.

Results and Discussion

Adequate irrigation water was available during the growing season and was not a limiting factor for crop production. Ten irrigations were applied to both co-establishment and conventional corn during the 2009 growing season. Irrigations began with the germination application and ended with the last irrigation in late September. The average irrigation set was 17.7 hours. Both corn and legumes established well (Figures 4 and 5).

There were no significant differences between co-established and conventionally-grown corn for plant population, grain moisture at harvest, and grain yield (Table 2). Test weight for co-established corn was 2.2% lower than that for conventionally-grown corn (Table 2).

Conventionally-produced corn received a total of 216 lbs N/acre while the co-established corn received only 36 lbs N/acre of commercial

fertilizer. Certainly, there was N contribution from the previous soybean crop, but this would have been available to both the co-established and conventionally-grown corn. Therefore, the living legume mulch was a significant source of N for the corn crop. In the upper Midwest, nitrogen fertilizer rates in a corn/kura clover system have been reduced to as little as 50 lbs/acre while maintaining grain yields equivalent to conventionally fertilized corn. Zemenchik et al. (2001) found that the fertilizer contributions from kura clover and birdsfoot trefoil in Wisconsin ranged from 74 and 325 kg N ha⁻¹, respectively, depending on the associated grass crop. Nitrogen contributions from kura clover were higher than that of birdsfoot trefoil.

There was no significant difference between co-established and conventionally-grown legumes for corn stalks, corn cobs, and total corn stover (Table 3). Corn leaves for co-established corn was 21.2% lower than that for conventionally-grown corn (Table 3). The reason for the lower amount of leaves in the co-established corn is not readily apparent, but could have been caused by sampling error.

The forage quality of the legumes produced as a living mulch in corn was high (Table 4). Singer and Moore (2010) also found that a variety of living mulch species produced high quality forage.



Figure 6. Strip tillage of kura clover performed just prior to planting corn at the Western Colorado Research Center at Fruita.

In a living mulch system that includes corn, many producers traditionally graze the corn stover in the fall with cattle. In a previous trial in western Colorado, an average of 775 lbs/acre of kura clover and 2.5 tons/acre of corn stover was available for grazing following grain harvest. In our co-establishment study, 415 lbs/acre of legumes and 3.2 tons/acre of corn stover was available for grazing follow corn grain harvest (Tables 3, 4). For maximum forage benefit from the clover, grazing should occur in the fall before the clover dies back from frost/freezing conditions. Corn stover may provide some insulation to the clover allowing it to stay greener into the fall.

Intensive grazing with livestock could possibly be used to suppress the living mulch in the spring. This practice has not been tested in Colorado. Care must be taken not to graze when the soil is too wet to avoid compaction problems. In addition, many legumes such as the clovers and alfalfa can cause bloat when grazed by ruminants, so measures such as supplementing with grass hay or Bloat Guard™ blocks containing poloxalene should be used. Grazing of the legume is another way of adding value or profit to this cropping system while achieving the needed suppression.

Development of herbicide resistant crops such as Roundup Ready corn and soybeans has created new options for reducing competition from the living mulch (Zemenchik et al., 2000; Affeldt et al., 2004). Trials in western Colorado working with a corn/kura clover system have shown that early spring suppression of the clover is critical. Many clovers (and legumes in general) are fairly resistant to Roundup and rates as high as 1.5 to 2 qts/acre may be required to adequately suppress them. This application needs to be applied at least 2 weeks prior to seeding the annual crop.

Roundup Ready corn has received more testing in Colorado in living mulch systems than other cash crops. Soybeans were successfully included in a living mulch cropping system study in 2009 at the Western Colorado Research Center at Fruita. Similar to corn, Roundup Ready varieties of soybeans are well suitable because Roundup can be sprayed over the crop

to suppress the living mulch plant species. A corn/soybean rotation may be a preferred way to utilize a living mulch system.

Depending on degree of suppression achieved earlier in the spring, additional suppression of the living mulch will generally be required at time when the annual crop is planted. Both strip application of herbicides and strip tillage have worked well in western Colorado to minimize yield reductions in a corn/kura clover system. Strip tillage in an 8-inch band just prior to planting corn has given the most consistent yield results (Figure 6). Applying Gramoxone herbicide at planting time has shown limited potential because the burn-down effect is often short lived and may not give the annual crop enough time to establish before living mulch plants recover.

Once the canopy of the annual crop begins to close, no further suppression is generally needed (Figures 7, 8). If the living mulch recovers too quickly and begins to compete with the annual crop between planting and canopy closure, then an additional herbicide application may be needed. This is readily accomplished if Roundup can be applied over a Roundup Ready crop.

Asparagus production was reduced by half when grown in unsuppressed living mulches in Year 1 compared to growth with no mulch (Paine et al., 1995). In Year 2, asparagus growth was 75% when grown with a clover and mixed



Figure 7. Low weed pressure in a closed corn canopy in a living mulch of corn and legumes in 2009 at the Western Colorado Research Center at Fruita.



Figure 8. Low weed pressure in a closed corn canopy in a living mulch of corn and legumes in 2009 at the Western Colorado Research Center at Fruita.

mulches. Despite a reduction in yield, weed control was better when asparagus was grown in a living mulch of clover and mixed mulches compared to asparagus grown without mulch. Weed control in our co-established living mulch



Figure 9. Field view of the co-establishment study at harvest in 2009 at the Western Colorado Research Center at Fruita.

cropping system was very good (Figure 9).

Based on one year of data, both legumes and a corn grain crop can be established at the same time. In our research, we planted the legumes and corn in separate field operations. In comparing corn yields and most other yield parameters the results for co-established and conventional corn were similar.

Living mulch cropping systems require more intensive management to minimize the potential for yield reductions of the annual, cash crop from competition associated with the perennial crop. The gain in high quality forage available for grazing in spring and fall is an added bonus that can offset additional inputs required to make this system successful.

Teadale et al. (2007) compared no-tillage and organic cropping systems for grain production and soil improvement that also included a living mulch system using crownvetch. They concluded that if adequate weed control could be obtained, reduced-tillage organic systems should be capable of producing yields and improved soil quality similar to conventional no-tillage systems. Additionally, they further state that if conventional no-tillage systems included additional organic inputs or rotational living crops (living mulches) conventional, no-tillage systems should also produce high yields and high soil quality.

It is possible that given time and additional research, conventional and organic agriculture, will eventually become more similar than they are dissimilar. The bridge between these two approaches to agriculture may well include living mulch technology.

In 2010, we will co-establish both legumes and corn using equipment that can plant both crops in a single operation and band-apply herbicide over the corn row.

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References

- Affeldt, R.P. K.A. Albrecht, C.M. Boerboom, and E.J. Bures. 2004. Integrating herbicide-resistant corn technology in a kura clover living mulch system. *Agron. J.* 96:247-251.
- Albrecht, K.A. 2000. Establishing kura clover stands, p. 133-135. In: Proc. 24th Forage Production and Use Symp., Wisconsin Forage Council. January 24-25, 2000, Wisconsin Dells.
- Albrecht, K.A., R.A. Zemenchik, C.M. Boerboom, R.P. Affeldt, and P. Pedersen. 2000. Corn production in a kura clover living mulch, p. 6-11. In: Proc. Iowa Forage Conf., Iowa Forage and Grassland Council. November 20-21, 2000, Pella, IA.
- Analytical Software, 2008. Analytical Software Statistix 9: User's manual. Analytical Software, Tallahassee, FL.
- Duiker, S.W. and N.L. Hartwig. 2004. Living mulches of legumes in imidazolinone-resistant corn. *Agron. J.* 96:1-21-1028.
- Eberlein, C.V., C.C. Sheaffer, and V.F. Oliveira. 1992. Corn growth and yield in an alfalfa living mulch system. *J. Prod. Agric.* 5:332-339.
- Etheridge, R.D., G.M. Pesti, and E.H. Foster. 1998. A comparison of nitrogen values obtained utilizing the Kjeldahl nitrogen and Dumas combustion methodologies (Leco CNS 2000) on sample typical of an animal nutrition analytical laboratory. *Animal Feed Science and Technology* 73:21-28.
- Hartwig, N.L. and H.U. Ammon. 2002. 50th anniversary-invited article: cover crops and living mulches. *Weed Sci.* 50:688-699.
- Illicki, R.D. and A.J. Enache. 1992. Subterranean clover living mulch: an alternative method of weed control. *Agric., Ecosystems and Environment* 40: 249-264.

- Paine, L., H. Harrison, and A. Newenhouse. 1995. Establishment of asparagus with living mulch. *J. Prod. Agric.* 8:35-40.
- Pearson, Calvin H., Charles A. Holcomb, A. Wayne Cooley, and John E. Murray. 2002. Guidelines for Using Conservation Tillage Under Furrow Irrigation. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Report TR02-6. Fort Collins, Colorado.
- Schtenkamp, G.W. and R.S. Moomaw. 1989. No-till corn production in a living mulch system. *Weed Tech.* 3:261-266.
- Singer, J.W. and K.J. Moore. 2010. Living mulch nutritive value in a corn-soybean-forage rotation. *Agron. J.* 102:282-288.
- Singer, J.W. and P. Pedersen. 2005. Legume living mulches in corn and soybean. PM-2006. Iowa State Univ. Ext., Ames, IA.
- Taylor, N.L. 1995. Kura clover. New Crop FactSHEET, Purdue University, <http://www.hort.purdue.edu/newcrop/cropfactsheets/KuraClover.html>. Accessed June 11, 2009.
- Teasdale, J.R., C.B. Coffman, and R.W. Mangum. 2007. Potential long-term benefits of no-tillage and organic cropping systems for grain production and soil improvement. *Agron. J.* 99:1297-1305.
- Van Soest, P.J., J.B. Robertson, and B.A. Lewis. 1991. Symposium: carbohydrate methodology, metabolism, and nutritional implication in dairy cattle. *J. Dairy Sci.* 74:3583-3597.
- Zemenchik, R.A., K.A. Albrecht, and M.K. Schultz. 2001. Nitrogen replacement values of kura clover and birdsfoot trefoil in mixtures with cool-season grasses. *Agron. J.* 93:451-458.
- Zemenchik, R.A., K.A. Albrecht, C.M. Boerboom, and J.G. Lauer. 2000. Corn production with kura clover as a living mulch. *Agron. J.* 92:698-705.

Table 2. Agronomic performance of corn grown when co-established with a living mulch of clovers and under conventional clean tillage at the Western Colorado Research Center at Fruita during 2009.

Living mulch	Grain moisture	Plant population	Grain yield	Grain yield	Test weight
	%	plants/acre	lbs/acre	bu/acre	lbs/bu
Co-establishment	13.5	35,516	9,827	175	61.8
Conventional	13.4 NS	35,864 NS	11,291 NS	202 NS	63.2*

NS, Means within a column are not significantly different at the 10% level of probability.

*, Means within a column are significantly different at the 10% level of probability.

Table 3. Forage production of corn residue when co-established compared to conventionally-grown corn grown at the Western Colorado Research Center at Fruita during 2009.

Living mulch	Corn leaves	Corn stalks	Corn cobs	Total corn stover
	t/acre	t/acre	t/acre	t/acre
Co-establishment	1.2	1.4	0.6	3.2
Conventional	1.5*	1.4 NS	0.5 NS	3.4 NS

NS, Means within a column are not significantly different at the 10% level of probability.

*, Means within a column are significantly different at the 10% level of probability.

Table 4. Forage quality of legumes when co-established with grain corn at the Western Colorado Research Center at Fruita during 2009.

Forage yield (lbs/acre)	NDF (%)	ADF (%)	N (%)	C (%)	Crude protein (%)
415	43.9	26.7	2.6	42.5	17.2

Performance of Fall-Planted Malting Barley at Fruita, Colorado 2008-2009

Calvin H. Pearson^{1,2}

Summary

Grain yields of malting barley varieties evaluated in a spring-planted trial in 2007 at the Western Colorado Research Center at Fruita were low. Fall-planted malting barley would be expected to yield higher than spring-planted barley. The objective of this 2-year field study conducted during the 2008 and 2009 growing seasons was to evaluate four MillerCoors malting barley varieties when fall-planted in the Grand Valley of western Colorado. Planting occurred during mid October and harvest occurred during mid- to late July each year, depending on the harvest maturity of each variety. Weed control was excellent in both years. Adequate irrigation water was available during both growing seasons and was not a limiting factor for crop production. No winter injury or winter kill was observed for any of the malting barley varieties in both years. M116 had the highest 2-year average yield at 9181 lbs/acre (192 bushels/acre) and Charles had the lowest 2-year average yield at 6075 lbs/acre (126 bushels/acre). Most of the malting barley varieties in each of the two years met malting barley standards. All four malting barley varieties had protein concentrations below 13.5%. The results of this research indicate that fall-planted malting barley with several of the new MillerCoors varieties has commercial crop production potential for the Grand Valley and other similar locations in western Colorado.

Introduction

Grain yields of malting barley varieties were low in a spring-planted trial conducted in 2007 at the Western Colorado Research Center (WCRC) at Fruita (Pearson, 2008). These results were similar to those of other research conducted in past years in the Grand Valley with spring-planted wheat and barley.

Fall-planted malting barley would be expected to yield much higher than spring-planted barley. In recent years, new malting barleys have been developed by MillerCoors and the performance of these varieties is not known



Figure 1. Malting barley grown at the CSU Western Colorado Research Center at Fruita on June 9, 2009. Photo by Calvin Pearson.

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under high yield conditions. The objective of this field study was to fall-plant four malting barley varieties from MillerCoors over a 2-year testing period at the Western Colorado Research Center at Fruita. The first year of this two-year testing was conducted in 2008 (Pearson, 2008) and this report presents results for 2009 and a two-year summary of this research study.



Figure 2. Malting barley grown at the CSU Western Colorado Research Center at Fruita during 2009.
Photo by Calvin Pearson.

Materials and Methods

Four malting barley varieties were evaluated at the Western Colorado Research Center at Fruita during 2008 and 2009. As per MillerCoors protocol, the experiment was arranged in the field in four blocks, each with an area of nearly 0.5 acres. Each barley variety was planted in a single block. The previous crop was dry bean in both years. Planting occurred on October 16, 2007 and October 16, 2008 at 120 lbs seed/acre.

The experiment was furrow-irrigated with gated pipe using irrigation water from the Colorado River delivered through a canal system.

Prior to planting in the fall, a broadcast application of 200 lbs/acre of 18-46-0 was made each year. A spring top-dress application of urea was applied on March 5, 2008 (42 lbs N/acre) and on March 13, 2009 (50 lbs N/acre).

An application of 0.6 oz/acre of Harmony Extra and 8 oz/acre of 2,4-D (4 lbs per gallon) plus 1 qt of Activator 90 in 100 gallons of water was applied on April 17, 2008 at 23 gallons per acre and 30 psi for weed control.

On April 2, 2009 an application of 0.6 oz/acre of Harmony Extra and 10 oz/acre of 2,4-D (4 lbs per gallon) was applied at 22 gallons per acre and 25 psi for weed control.

Malting barley was harvested using an International 1440 combine and the harvest date was dependent on the harvest maturity of each variety. Grain for each of the four malting barley varieties was loaded into separate 3,000 lb capacity steel bins. The bins were weighed separately and gross weights were subtracted from a tared bin weight to determine grain yields.

Grain moistures and test weights were determined using a DICKEY-John GAC2100B seed analyzer. Grain yields of each variety were corrected to 12% moisture.

Results and Discussion

Weed control in all four barley varieties was excellent throughout the growing season in both years (Fig. 1).

Adequate irrigation water was available during both growing seasons and was not a limiting factor for crop production. Seven irrigations were applied to the malting barley in 2007 and six irrigations were applied in 2008 (Table 1).

No winter injury or winter kill was observed for any of the four malting barley varieties in both years. Overall, spring in 2008 and in 2009 was cool during April, May, and on into June, which favored small grain production.

Charles headed first on May 11, 2008 and M116 headed last on May 17, 2008 (Table 2). In 2009, Charles headed two days earlier than the other varieties (Table 2).

Charles was also the first variety to reach harvest maturity on July 11, 2008 and M116 and M037 reached harvest maturity 6 to 7 days later in 2008. In 2009, Charles and M083 matured slightly earlier than M116 and M037 (Table 2).

Charles was the tallest variety and M116 was the shortest in both years (Table 3). The other two varieties were intermediate in plant height.

Lodging was greatest for Charles in both years averaging 5.8 (Table 3). The lodging in Charles made combine harvesting more difficult in both years. Lodging in the other three

varieties was low and did not create problems during harvest.

Grain moisture, grain yield, and test weight for the four malting barley varieties are shown in



Figure 3. Malting barley grown at CSU Western Colorado Research Center at Fruita during 2009 Note the lodging in Charles (left side of the photo). Photo by Calvin Pearson.

Table 4. Grain moistures of the four malting barley varieties ranged from 8.3% for Charles to 9.9% for M116 in 2008 and in 2009 grain moisture ranged from 6.4% for Charles to 8.3% for M083 and M037.

The highest yield obtained during the 2-year testing period was 10,441 lbs/acre (218 bushels/acre) for M116. The lowest yield obtained during the 2-year testing period was 4673 lbs/acre (97 bushels/acre) for Charles. M116 had the highest 2-year average yield at 9181 lbs/acre (192 bushels/acre) and Charles had the lowest 2-year average yield at 6075 lbs/acre (126 bushels/acre). The 2-year average yield difference between the two varieties was 66 bushels/acre. M083 and M037 had 2-year average grain yields of 8040 lbs/acre (168 bushel/acre) and 7864 lbs/acre (164 bushels/acre), respectively.

In a previous trial conducted in western Colorado at Montrose, the high grain yield for this spring-planted malt barley was 141 bushels/acre (Pearson, 1999). Yields of fall-

planted malting barley at Fruita exceeded the yields at Montrose by a substantial amount.

The 2-year average test weight for Charles was lower than other varieties at 43.6 lbs/bushel,



Figure 4. Malting barley grown at the CSU Western Colorado Research Center at Fruita during 2009. Note the lodging in Charles (left side of the photo). Photo by Calvin Pearson.

likely an effect from lodging (Table 4). Two-year average test weights of the other three varieties was near 50 lbs/bushel or greater.

Malting barley did not experience any rain damage prior to or at harvest in 2008. The grain had a bright, uniform golden color. In 2009, there were rain events close to harvest that dulled, yellowed, and caused some grain staining. Good quality malting barley should have test weight of 50 lbs/bu or higher, plumpness of 85% or higher, and protein concentration below 13.5%. Thus, by these standards several of the malting barley varieties in each of the two years met malting barley standards (Table 5).

The only instance where plumpness fell below standard was Charles in 2008. All other varieties in both years including Charles in 2009 had plumpness values above 85%. M116 had the highest 2-year average plumpness at 93.0%.

All four malting barley varieties in both years had protein concentrations below 13.5% (Table 5). M037 had the highest 2-year average



Figure 5. Combine harvesting of malting barley during 2009 at the CSU Western Colorado Research Center on July 22, 2009. Photo by Calvin Pearson.

protein concentration at 11.0% and M116 had the lowest protein concentration at 9.4% (Table 5).

Grain yields of the fall-planted malting barley varieties in 2008 and 2009 in the Grand Valley were good to excellent. The results of this research indicate that fall-planted malting barley using these new MillerCoors varieties has commercial crop production potential for the Grand Valley and other similar locations in western Colorado.

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References

- Pearson, C.H. 1999. Variety performance test of malting barley in western Colorado 1998. p. 22-23. *In*: Western Colorado Research Center 1998 Research Report. Colorado State University, Agricultural Experiment Station and Cooperative Extension, Technical Report TR99-12. Fort Collins, Colorado.
- Pearson, C.H. 2008. Spring-planted malting barley at Fruita, Colorado 2007. p. 63-65. *In*: Western Colorado Research Center 2007 Research Report. Colorado State University, Agricultural Experiment Station and Extension, Technical Report TR08-10. Fort Collins, Colorado.
- Pearson, C.H. 2009. Fall-planted malting barley at Fruita, Colorado 2008. p. 7-10. *In*: Western Colorado Research Center 2008 Research Report. Colorado State University, Agricultural Experiment Station and Extension, Technical Report TR09-12. Fort Collins, Colorado.

Table 1. Irrigations for malting barley grown at Fruita, Colorado during the 2008 and 2009 growing seasons.

Irrigation number	Date	Set time (hours)
2008		
1	10/18/07	22.0
2	4/19/08	18.0
3	4/30/08	15.5
4	5/12/08	18.5
5	5/27/08	16.0
6	6/12/08	16.0
7	6/24/08	17.5
2009		
1	10/20/08	27
2	4/8/09	16
3	4/23/09	16
4	5/7/09	19
5	5/22/09	17
6	6/9/09	16

Table 2. Heading dates, harvest maturity dates, and harvest dates of MillerCoors malting barley varieties grown at Fruita, Colorado during the 2008 and 2009 growing seasons.

Variety	Heading date	Harvest maturity date	Harvest date
2008			
Charles	May 11	July 11	July 11
M083	May 13	July 14	July 14
M116	May 17	July 17	July 17
M037	May 14	July 18	July 21
2009			
Charles	May 3	July 3	July 9
M083	May 5	July 3	July 8
M116	May 5	July 6	July 8
M037	May 5	July 6	July 8

Table 3. Plant height and lodging of MillerCoors malting barley varieties grown at Fruita, Colorado during the 2008 and 2009 growing seasons.

Variety	2008	2009	Ave
Plant height (feet)			
Charles	3.2	3.0	3.1
M083	2.9	2.5	2.7
M116	2.7	2.3	2.5
M037	3.0	2.6	2.8
Lodging (0.2-9.0) ¹			
Charles	5.6	6.0	5.8
M083	1.2	0.6	0.9
M116	1.2	0.6	0.9
M037	0.8	1.3	1.0

¹Lodging, 0.2=no lodging, 9.0=completed lodged.

Table 4. Grain moisture at harvest, grain yield, and Test weight at harvest of MillerCoors malting barley varieties grown at Fruita, Colorado during the 2008 and 2009 growing seasons.

Variety	2008	2009	Ave
Grain moisture at harvest (%)			
Charles	8.3	6.4	7.4
M083	8.7	8.3	8.5
M116	9.9	8.1	9.0
M037	9.1	8.3	8.7
Grain yield (lbs per acre)			
Charles	7477	4673	6075
M083	9639	6440	8040
M116	10441	7921	9181
M037	9128	6599	7864
Grain yield (bu/A)			
Charles	156	97	126
M083	201	134	168
M116	218	165	192
M037	190	137	164
Test weight (lbs/bu)			
Charles	45.5	41.8	43.6
M083	51.7	51.3	51.5
M116	49.7	49.9	49.8
M037	51.8	51.3	51.6

Table 5. Grain moisture and test weight when quality analysis was performed, and protein and plumpness of MillerCoors malting barley varieties grown at Fruita, Colorado during the 2008 and 2009 growing seasons.

Variety	2008	2009	Ave
Grain moisture when quality analysis performed (%)			
Charles	8.8	8.3	8.6
M083	8.5	8.6	8.6
M116	8.3	8.2	8.2
M037	10.0	8.7	9.4
Test weight when quality analysis performed (lb/bu)			
Charles	52.5	43.3	47.9
M083	52.2	52.3	52.2
M116	46.0	50.3	48.2
M037	49.7	52.1	50.9
Protein (%)			
Charles	10.4	11.2	10.8
M083	11.4	9.4	10.4
M116	9.3	9.4	9.4
M037	11.4	10.5	11.0
Plumpness (%)			
Charles	82.7	86.1	84.4
M083	89.3	92.6	91.0
M116	89.8	96.3	93.0
M037	87.4	91.9	89.6

Alternative Management of Cytospora Canker in Stone Fruits in Colorado

Ramesh R. Pokharel¹ and Harold J. Larsen²

Summary

Preliminary studies have been conducted to evaluate topical application of six plant oils for efficacy against Cytospora canker of stone fruit in western Colorado. Neem, camphor, thyme, clove, and cinnamon oils were applied at 1% v/v; mustard oil was applied at 25% v/v. Treatment solutions were prepared in water and in alcohol separately w/ 5% white latex paint as a carrier liquid and applied to drip via a hand-pump sprayer to existing Cytospora cankers on June Pride and Cresthaven peach and Bing sweet cherry trees. Water only and alcohol plus water (1:1) were applied as controls. Initial disease incidence and severity (as reflected in the gum exudation and canker extent), assessed just before treatment application in Feb. 2008, were greater in sweet cherry than in peach.

Disease symptom expression (gum exudation) and canker growth were evaluated and measured again in Dec. 2008. Mustard, cinnamon, and clove oil consistently reduced or eliminated gum exudation and halted canker size expansion in peach but not sweet cherry. In cherry, existing gum exudates dried out and canker size expansion appeared to cease, but gum exudation began again outside the original canker boundaries. Possible explanations include a difference in the causal fungi between peach and sweet cherry and a reduction in treatment efficacy due to the severity of initial canker infection (cherry worse than peach). Further studies will repeat these studies and also look at the causal fungi for differences in susceptibility to these plant oils. Identification of effective management options may benefit both organic and conventional stone fruit growers.

Introduction

Cytospora canker causes economic losses worldwide in stone fruits and pome fruits by seriously limiting the productivity and longevity of the trees (Biggs 1989). The greatest economic damage occurs when perennial cankers develop in orchards of *Prunus persica* (L.) Batsch (peach), *P. avium* (L.) L. (sweet cherry), and *P.*

domestica L. (plum). The disease affects more than 60 genera of hardwood and conifer trees and is a major problem in all stone fruits and a minor problem in pome fruits.

High incidences of Cytospora canker were recently observed in peach, cherry, apricot, and plum in western Colorado fruit orchards, with substantial mortality of both young trees (as young as 2 years old) and mature trees in western Colorado (Pokharel and Larsen, 2008). Most research on Cytospora canker has focused on peach, perhaps because of the high incidence of Cytospora canker. Since peach trees usually have only three to four main scaffold limbs, loss of one or two of these main limbs to Cytospora canker represent a 25 to 50% loss in fruit production. In addition to reduction in fruit production, Cytospora canker shortens tree life almost by half. Replacing dead trees in an orchard makes orchard management expensive and difficult. According to growers in Colorado,

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Mention of a trade name or proprietary product does not imply endorsement by the authors, the Agricultural Experiment Station, or Colorado State University.

Cytospora canker is the most important disease impacting stone fruit.

Benlate followed by Topsin M are the only chemical pesticides recommended for the control of Cytospora canker management. Benlate is no longer available on the market. These management practices for this disease are inconsistently effective and uneconomical, especially when the disease is well established in an orchard. In absence of high disease pressure, Cytospora canker is relatively negligible in orchards.

Management methods adopted by some growers include avoiding wounding trees during mowing and trimming to help prevent new infections in orchards. However, these are inadequate measures in orchards where the disease is well established. Other orchard management practices, such as irrigation and variety selection may have an indirect role in disease development and spread. Chemical management strategies may benefit only conventional growers whereas non-chemical means of disease management may help both conventional and organic growers. This study investigated the use of different plant oils against Cytospora canker activities as a part of management studies testing several chemicals and non-chemical strategies.

Materials and Methods

Two experiments were conducted in June Pride peach and Bing cherry orchards at the WCRC-Roger Mesa research site to test the efficacy of different plant oils with water and water plus alcohol (1:1) as carrier materials. Trees with different severity levels due to naturally infected Cytospora canker were randomly assigned for each treatment. In general, cherry had higher severity (higher gummosis, higher number of infection court and larger area covered by disease) of Cytospora as compared to peach when the treatments were applied.

The following treatments were applied during Mar. 2008. Each treatment was mixed with 5% latex paint to mark the sprayed trees. Peach (June Pride) and cherry (Bing) were tested with mustard oil 25% v/v, neem oil 10% v/v, clove oil 5% v/v, cinnamon oil 1% v/v, camphor

oil 1% v/v and thyme oil 1% v/v in water only and 1:1 water ethyl alcohol against pure water, pure alcohol and 1:1 alcohol water ratio. These oils were sprayed with a hand sprayer on the trunks of five single-tree replicates in a completely randomized block design in orchards naturally infected with Cytospora Canker.

During application of these oil products, neem oil could not be diluted well as it formed large clumps of glue-like substances. Thus, we excluded the neem oil from our experiment. However, frequent shaking of the hand sprayer had to done to ensure the sufficient mixing of the oil in water. Application of different plant oils was not as easy as for other chemicals because of nature of oil.

Since it is difficult to get numerical data in such studies, reduction in gummosis and canker enlargement were the major observations used to determine the efficacy of these plant and mineral oils. The fungal activities (gummosis, drying of gums and further gum production) were recorded just before application of such oils in March and after almost a year during December of 2009.

Results and discussion

The results of the treatments were compared using visual observation on gummosis activities before and after treatment application. Water alone or alcohol alone did not stop the activities of gummosis, drying of gums, extra gum production, and canker expansion (Fig. 1).

Reduced activities of fungus, characterized by drying of gum and cessation of canker growth and new gum production, were observed with clove oil, cinnamon oil, camphor and mustard oil in peaches (Figs. 2 to 4) when water and alcohol (1:1 ratio) were used as carrier liquid. Camphor oil both in water alone and 1:1 in water plus alcohol was equally effective. But in cherry, existing gum exudates dried out and canker expansion appeared to stop, but gum production began again a month or two after treatment (Fig 5). In the same experiments, applications of clove oil after the gum and bark surface were scraped off stopped gum production and canker expansion. It is possible that removal of gum and bark surface (which tends to shed water in cherry) might have

enabled good contact between the infected tissues with the fungus and the applied clove oil, thereby killing the fungus. Further study of the effect of these oils on fungal activities is needed, including further testing with different concentrations. Precaution should be taken not

to use higher concentration that might cause burning or leaf scorching. These materials could provide a potential option to organic growers since currently there is no option to control this disease in organic fruit production systems.

Acknowledgments

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References

- Biggs, A.R. 1995. Canker Blight and wood rots: *Lucostroma* canker. In J.M. Ogawa, F.I. Zehr, G.W. Bird, D. R.Ritchie, K. Uriu and J. Uyemoto (Eds.) *Compendium of Stone Fruit Diseases*. APS Press, St Paul, MN
- Pokharel, R. R. and H.J. Larsen. 2009. Efficacy of plant and mineral oil against *Cytospora* canker in peach. *Phytopathology* 99: S103. (Abstract)



Figure 1. *Cytospora* canker on June Pride peach tree. Canker active (non-dried gum with continued gum production and canker size expansion) as seen 10 months after treatment in trees treated with water only or water and alcohol (1:1).



Figure 2. Cytospora canker on June Pride peach tree 10 months after application of cinnamon oil in water and alcohol (1:1). Note the dried gum and lack of new gum production and canker size expansion. (Photo by R. Pokharel)



Figure 3. Cytospora canker on June pride peach tree 10 months after treatment with clove oil in water and alcohol (1:1). Note drying of gum and stopping of gum production and canker size expansion. (Photo by R. Pokharel)



Figure 4. Cytospora canker on June Pride peach tree 10 months after application of cinnamon oil in water and alcohol (1:1). Note the dried gum and lack of new gum production and canker size expansion. (Photo by R. Pokharel)



Figure 5. Cytospora canker on Bing sweet cherry tree 5 months after application of cinnamon oil in water and alcohol (1:1). Note the dried gum and lack of canker size expansion and also the renewed production of new gum. (Photo by R. Pokharel)

Dr. Horst W. Caspari

2009 Research Projects*

Viticulture and enology programs for the Colorado wine industry (Colorado Wine Industry Development Board; H. Larsen, S. Menke, R. Pokharel & R. Zimmerman, CSU)*
Coordinated wine grape variety evaluations in the western US (Viticulture Consortium West)
Coordinated wine grape variety evaluations in the western US (Colorado Association for Viticulture and Enology; formerly Rocky Mountain Association of Vintners and Viticulturists)

*Sponsors/Cooperators are noted in parentheses.

2009 Publications

Conference Papers:

Einhorn, T., H.W. Caspari, and S. Green. 2009. Estimation of containerized single-stem and split-rooted, non-fruiting apple tree water use using miniaturized heat pulse probes. *Acta Horticulturae* 846:285-291.

Non-Refereed WEB Publications:

Caspari, H. 2009. 2008 Grower Survey. on the web at:

www.colostate.edu/programs/wcrc/pubs/viticulture/Survey2008.pdf

Caspari, H., and A. Montano. 2009. Cold hardiness of own-rooted grapevine buds grown at the Western Colorado Research Center - Orchard Mesa near Grand Junction, Colorado, 2008/09 (14 updates during 2009). On the web at:

www.colostate.edu/programs/wcrc/pubs/viticulture/coldhardiness08.pdf

Caspari, H., and A. Montano. 2009. Cold hardiness of grapevine buds grown at the Western Colorado Research Center - Rogers Mesa near Hotchkiss, Colorado, 2008/09 (10 updates during 2009). On the web at:

www.colostate.edu/programs/wcrc/pubs/viticulture/coldhardinessrm08.pdf

Caspari, H., and A. Montano. 2009. Cold hardiness of grapevine buds grown at the Western Colorado Research Center - Orchard Mesa near Grand Junction, Colorado, 2009/10 (8 updates during 2009). On the web at:

www.colostate.edu/programs/wcrc/pubs/viticulture/coldhardiness09.pdf

Caspari, H., and A. Montano. 2009. Cold hardiness of grapevine buds grown at the Western Colorado Research Center - Rogers Mesa near Hotchkiss, Colorado, 2009/10 (5 updates during 2009). On the web at:

www.colostate.edu/programs/wcrc/pubs/viticulture/coldhardinessrm09.pdf

Dr. Stephen D. Menke

2009 Technical Publications

Colorado Winery Baseline Survey Assessment, *Western Phytoworks, Fall 2009*, ed. R. Pokharel, Colorado Sensory Wine Quality Assessment Program: Part 1, Sensory Faults Panel Training Curriculum, *CSU Enology Program Annual Report*, S.D. Menke *et al*,

2009 Research Projects

Create and deliver portion of USAID educational program to Serbian winegrape industry, (USAID, M. Chien, P. Bell, T. Wolf, P. Chabot, D. Dmitrijevic, Z. Jovanovic, US Embassy in Belgrade)

Baseline survey of Colorado wineries: status of wine quality and winery economic status (H. Caspari, H. Larsen, S Wallner/ Western Colorado Research Center/Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture,)

Production of varietal and blended experimental wines from WCRC grapes (H. Caspari/Western Colorado Research Center, Grande River Winery/ Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture)

Development of Colorado Wine Quality Training and Assessment Program (D. Caskey, H. Caspari, M. Mazza/ Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture,)

Establishment of baseline aroma profiles for several Colorado varietal wines by GC/MS analysis (H. Caspari, J. Weinke/ Western Colorado Research Center/Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture,)

Development of proposal for enology, culinary, and agri-tourism center, with CSU commercial shared-premises winery (S Smith, N. Shepherd-Smith/ S Wallner, F. Johnson, L. Sommers, C. Beyrouthy, Western Colorado Research Center /Grande River Winery, Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture,)

Microorganism ecology of grapevine rhizosphere and grape bunch by vineyard location and seasonal timing (J. Vivanco, H. Caspari/Peach Fork Farms, Whitewater Hill Vineyards, Western Colorado Research Center/Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture)

2010 Continuing Research Projects

Production of varietal and blended experimental wines from WCRC grapes (H. Caspari/Western Colorado Research Center, Grande River Winery/ Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture)

Establishment of baseline aroma profiles for several Colorado varietal wines by GC/MS analysis (H. Caspari, J. Weinke/ Western Colorado Research Center/Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture,)

Development of proposal for enology, culinary, and agri-tourism center, with CSU commercial shared-premises winery (S Smith, N. Shepherd-Smith/ S Wallner, F. Johnson, L. Sommers, C. Beyrouthy, Western Colorado Research Center /Grande River Winery, Colorado Wine Industry Development

Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture,)

Microorganism ecology of grapevine rhizosphere and grape bunch by vineyard location and seasonal timing (J. Vivanco, H. Caspari/Peach Fork Farms, Whitewater Hill Vineyards, Western Colorado Research Center/Colorado Wine Industry Development Board, Colorado Association of Viticulture and Enology, CSU Department of Horticulture and Landscape Architecture)

*Cooperators/collaborators/sponsors are noted in parentheses

Dr. Calvin H. Pearson

2009 Research Projects

Crops and Cropping Systems in Western Colorado for Traditional/Alternative and Industrial/Bioenergy Uses

Hybrid Poplar Study Outcomes and Impact

Short-term, intensive culture of woody crop species was first considered 30 years ago as a rapid means to produce feedstock for fiber and energy applications. Production of hybrid poplar (*Populus* spp.) was initiated on large-scale, short-term intensive culture in the 1990s on farmland where agronomic crops have traditionally been produced. Production practices for short-term, intensive rotations with hybrid poplar typically have high plant densities of approximately 1700 trees per hectare when production cycles are completed in less than 8 years. An irrigated study was conducted at the Western Colorado Research Center at Fruita for 6 years to evaluate eight hybrid poplar clones under short-term, intensive culture. The eight clones included in the study were *Populus nigra* x *P. maximowiczii* (NM6), *P. trichocarpa* x *P. deltoides* (52225, OP367), and *P. deltoides* x *P. nigra* (Norway, Noreaster, Raverdaus, 14274, 14272). Data were collected for growth, aerial biomass yield, dry matter partitioning, carbon sequestration, and insect and disease infestation. Of the eight clones tested, OP367 was the most adapted and productive clone in this short-term, intensive culture system in the arid environment of the Grand Valley of western Colorado as evidenced by its productive growth, yield, insect resistance, winter hardiness, and tree architecture.

In the past, hybrid poplar has been grown for a variety of uses and more recently hybrid poplar has been promoted as a source of biofuel and for carbon sequestration. Various plant species, including hybrid poplar, have been evaluated for their potential to sequester C, but little data are available on how poplar clones differ in the ability to sequester C. OP367 and 52225 consistently had larger tree diameters than other hybrids for each of the six years. Averaged across clones, yield was 58.4 Mg per hectare. OP367 had the highest yield at 72.2 Mg per hectare and 14274 had the lowest yield at 41.0 Mg per hectare. The yield of OP367 was 1.8 times greater than that of 14274. Carbon yield over the 6 years of testing was highest for OP367 at 33.4 Mg C per hectare and lowest for 14274 at 18.8 Mg C per hectare.

Other researchers found that above-ground tree components for 13-year-old hybrid poplar in southern Ontario, Canada sequestered 15.1 Mg C per hectare when grown at a density of 111 trees per hectare. In our 6-year hybrid poplar study, OP367, the clone with the highest aerial C production, sequestered 33.4 Mg C per hectare during this growth period. The tree density used in our study was 1,681 trees per hectare. Our data are for C production of trunk and branches, and does not include C for leaves and roots. In work by other researchers, they found that leaves of hybrid poplar contributed approximately 10% to total aerial C and that 85% of the total tree C was stored in aerial biomass with the remaining 15% being stored in roots. Even without the C contribution from leaves and roots in our study, short term intensive culture production of hybrid poplar has potential to sequester considerably more C than traditional hybrid poplar production systems.

Researchers have postulated that short rotation woody crops, such as hybrid poplar, and other herbaceous crops could assimilate 50 MMT C per year if grown on 10 M hectares. These researchers used a net C assimilation rate of 5 Mg per hectare per year in their calculations. Their assumption of 5 Mg per hectare per year is similar to what we found for some of the hybrid poplar clones grow in western Colorado. The findings obtained in our study are valuable to aid economists in developing crop enterprise budgets for hybrid poplar grown under short-term, intensive culture. If C sequestration is a production objective for hybrid poplar, it is important to realize that hybrid poplar clones do not sequester C equally and that it is important to select a suitable clone for planting. Carbon production among the clones in our study ranged from 33.4 Mg per hectare for OP367 to 18.8 t per hectare for 14274, a difference of 14.6 Mg per hectare. Thus, the most productive poplar clone in our study increased C sequestration by as much as 90% compared to the least productive clone. Furthermore, data obtained in this study is of value to

policymakers and others as issues related to carbon sequestration, such as carbon offsets and credits, are debated and considered.

2009 Research Projects*

Winter wheat cultivar performance test – Hayden (Mike Williams, Dr. Scott Haley)
Malting barley cultivar evaluation and demonstration – Fruita (Coors Brewing Co.)
Alfalfa variety performance test (2008-2010) – Fruita (seed companies, breeding companies, private industry)
Alfalfa germplasm evaluations 2007-2009 – Fruita (Dr. Peter Reisen, Forage Genetics)
Evaluation of alfalfa genetic material 2008-2010 – Fruita (Dr. Peter Reisen, Forage Genetics)
Canola cultivar performance test – Fruita (Dr. Jerry Johnson, Kansas State Univ.)
Evaluation of corn hybrid breeding material evaluation – Fruita (Grand Valley Hybrids)
Corn grain variety performance test – Delta (Grand Valley Hybrids)
No-till crop production using a kura clover living-mulch system – Fruita (Dr. Joe Brummer, Dr. Neil Hansen)
Establishment of legume species for use in living mulch crop production systems – Fruita (Dr. Joe Brummer, Dr. Neil Hansen)
Co-establishment of legumes and corn in a living mulch cropping system under furrow irrigation (Dr. Joe Brummer)
Rubber and resin analysis of guayule tissue using the ASE 200 (Yulex Corporation)

2010 Research Projects* (Continuing, New, or Planned)

Winter wheat cultivar performance test – Hayden (Mike Williams, Dr. Scott Haley)
Alfalfa variety performance test (2008-2010) – Fruita (Dr. Jerry Johnson, seed companies, breeding companies, private industry)
Evaluation of alfalfa genetic material 2010-2012 – Fruita (Dr. Peter Reisen, Forage Genetics)
Evaluation of alfalfa genetic material 2008-2010 – Fruita (Dr. Peter Reisen, Forage Genetics)
Alfalfa germplasm evaluations 2009-2011 – Fruita (Dr. Peter Reisen, Forage Genetics)
Evaluation of perennial plant species and production input for sustainable biomass and bioenergy production in Western Colorado – (Western Colorado Carbon Neutral Bioenergy Consortium)
Application of bio-stimulant and harvest energy in winter wheat as a sustainable nutrient input – Hayden (Enviro Consultant Service, LLC)
Application of bio-stimulant and harvest energy products in pasture grass as a sustainable nutrient input – Fruita (Enviro Consultant Service, LLC)
An automated control valve for gated pipe to increase furrow-irrigation efficiency – Fruita (Fine Line Industries and Bureau of Reclamation)
Oat cultivar performance test – Fruita
Canola cultivar performance test – Fruita (Dr. Jerry Johnson, Kansas State Univ.)
Evaluation of corn hybrid breeding material evaluation – Fruita (Grand Valley Hybrids)
Corn grain variety performance test – Delta (Grand Valley Hybrids)
Vertical temperature variation in a corn canopy – Fruita
Legume species for living mulch crop production systems – Fruita (Dr. Joe Brummer, Dr. Neil Hansen)
Co-establishment of legumes and corn in a living mulch cropping system under furrow irrigation (Dr. Joe Brummer)

*Cooperators/collaborators/sponsors are noted in parentheses.

2009 Publications

- Pearson, C.H. and D.J. Rath. 2009. A hydraulic press for extracting fluids from plant tissue samples. *Industrial Crops and Products* 29:634-637.
- Pearson, C.H. 2009. Western Colorado alfalfa variety performance test at Fruita 2009. [Online] Available at <http://www.csucrops.com/alfalfa.html>. (verified 24 Dec. 2009).
- Pearson, C.H. 2009. Winter wheat variety performance test at Hayden, Colorado 2009. [Online] Available at <http://www.csucrops.com/wheat.html>. (verified 24 Dec. 2009).
- Pearson, Calvin. 2009. 2009 National winter canola variety trial. Fruita, CO. p. 34-35. M Stamm and Cynthia La Barge (senior authors). Report of Progress 1026. Kansas State Univ., Agricultural Experiment Station and Cooperative Extension Service. Manhattan, KS. (I conducted a variety trial at Fruita and the data were published in this report along with numerous other locations around the country.)
- Pearson, Calvin. 2009. 2008 National winter canola variety trial. Fruita, CO. p. 43-44. M Stamm and Cynthia La Barge (senior authors). Report of Progress 1009. Kansas State Univ., Agricultural Experiment Station and Cooperative Extension Service. Manhattan, KS. (I conducted a variety trial at Fruita and the data were published in this report along with numerous other locations around the country.)
- Pearson, Calvin. 2009. Alfalfa Continues to be a Valuable Crop for Western Colorado. *In: Western PhytoWorks* (Ramesh Pokharel, ed.). Spring 2009. Newsletter of the Western Colorado Research Center, Agricultural Experiment Station, Colorado State University.
- Pearson, Calvin. 2009. Management of Alfalfa Forage Trials Changed during 2009. *In: Western PhytoWorks* (Ramesh Pokharel, ed.). Fall 2009. Newsletter of the Western Colorado Research Center, Agricultural Experiment Station, Colorado State University.
- Pearson, C.H., and J.E. Brummer. 2009. Evaluation of teff as an alternative crop for western Colorado 2008. p. 17-20. *In: Western Colorado Research Center 2008 Research Report*. Colorado State University, Agricultural Experiment Station and Extension, Technical Report TR09-12. Fort Collins, Colorado.
- Pearson, C.H., and J.J. Johnson. 2009. Winter canola variety performance trials at Fruita, Colorado 2005-2008. p. 21-24. *In: Western Colorado Research Center 2008 Research Report*. Colorado State University, Agricultural Experiment Station and Extension, Technical Report TR09-12. Fort Collins, Colorado.
- Pearson, C.H., S.D. Haley, and J.J. Johnson. 2009. Winter wheat variety performance trial at Fruita, Colorado 2008. p. 25-29. *In: Western Colorado Research Center 2008 Research Report*. Colorado State University, Agricultural Experiment Station and Extension, Technical Report TR09-12. Fort Collins, Colorado.
- Pearson, C.H. 2009. Fall-planted malting barley at Fruita, Colorado 2008. p. 7-10. *In: Western Colorado Research Center 2008 Research Report*. Colorado State University, Agricultural Experiment Station and Extension, Technical Report TR09-12. Fort Collins, Colorado.
- Pearson, C.H. 2009. Seed yield, oil content, and oil yield of sunflower at Fruita, Colorado. p. 11-16. *In: Western Colorado Research Center 2008 Research Report*. Colorado State University, Agricultural Experiment Station and Extension, Technical Report TR09-12. Fort Collins, Colorado.

Dr. Ramesh Pokharel

2009 Research Projects

Internally funded projects (on- going as PI; collaborators in parenthesis)

Cytospora management - Study of chemicals (new materials) and plant oils for the management of Cytospora disease in stone fruits”.

Nematode management - Efficacy of chemicals such as Basamid and Vydate to plant parasitic nematode, especially the dagger nematodes in fruits and other crops.

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

Replant management - Effect of soil solarization, mustard green manure, chicken manure, compost and mustard meal cake for the management of replant problems in peach Funded by SAI, EPA (Dr. Harold Larsen).

Rasp leaf virus and dagger complex - Incidence and severity of cherry rasp leaf virus in western Colorado fruit orchards”. (Drs. Raymond Mock and Ruhui Li, USDA, Beltsville, MD)

Study of rasp leaf virus and dagger nematode (vector) relationship of cherry.” (Dr. [Inga Zasada](#), USDA, ARS, Corvallis, Oregon).

Evaluation of cherry rootstock susceptibility to dagger nematode and cherry rasp leaf virus acquisition.

Evaluation of resistance of Citation Z inter-stem combination in cherry; pot-in-pot experiment.

Alternative crops - Study on adaptive performance of alternative fruit crops (Goji berry, edible honey suckles, berries, pistachio and Asian pears) to western Colorado.”

Vegetables (onion) - Increase efficacy of biofumigation by soil sterilize and integrating with Brassica seed meal cake and poultry manure to manage soil-borne problem in onion (Robert Hammon,). Funded by EPA, PESP (PESP, EPA ongoing).

Other on-going projects - Diversity of plant parasitic nematodes in Alfalfa hay and variability of alfalfa stem nematode (*Andrea Skantar*, USDA, Beltsville, MD)

Effect of soil and plant health on peach yield and disease incidence.

Chemical and non-chemical alternatives to manual thinning in peaches.

Evaluation of apple rootstock performance in saline soils of western Colorado.

Evaluation of peach rootstock experiment 2009; NC 140 collaborative project.

Peach physiology study experiments in 2009; NC 140 collaborative project.

Evaluation of cherry varieties and rootstocks under “Upright Fruiting Offshoots, (UFO)” training system in western Colorado.

Peach cold hardy study and evaluation of coffee byproduct to reduce soil pH study.

Evaluation of blueberry varieties in western Colorado condition.

Publications

Refereed:

Pokharel, R. R. 2009. Damage of root-knot nematode (*Meloidogyne graminicola*) to rice in fields with different soil types. *Nematologia Mediterranea*. 37: 203-217.

Pokharel, R. R. and H.J. Larsen. 2009. Efficacy of plant and mineral oil against Cytospora canker in peach. *Phytopathology* 99: S103.

Pokharel, R. R. and H. J. Larsen, S. Palanisamy. 2009. Efficacy of Bio-fumigation and soil solarization for the management of dagger nematode in Fruits. (In press).

Pokharel, R. R., G. S. Abawi, J. M. Duxbury, X. Wand, J. Brito. 2010. Variability and determination of two races in *M. graminicola*. Australasian Journal of Plant Pathology (Online Abstract).

Annual reports:

Pokharel, R. R. 2009. Plant parasitic nematodes and plant health of Western Colorado home and golf lawns. Western Colorado Research Center, Colorado State University. Annual report, TR 09-12; 39-44.

Pokharel, R. R. and H.J. Larsen. 2009. Evaluation of apple rootstocks planted in high pH soil. Western Colorado Research Center, Colorado State University. Annual report, TR 09-12: 63-66.

Pokharel, R. R. and H. J. Larsen. 2009. Incidence, severity and non-chemical management of Cytospora canker in stone fruits. Western Colorado Research Center, Colorado State University. Annual report, TR 09-12:55-62.

Pokharel, R. R., H. J. Larsen, and B. Braddy. 2009. Efficacy of plant and mineral oils, and Tergitol on peach blossom thinning. Western Colorado Research Center, Colorado State University. Annual report, TR 09-12:67-76.

Pokharel, R. R. H.J. Larsen, B. Hammon, T. Gourd and, M. Bartolo. 2009. Plant parasitic nematodes, soil and root health in Colorado onion fields. Western Colorado Research Center, Colorado State University. Annual report, TR 09-12; 39-44.

Other reports:

Pokharel, R.R. 2009. Monitoring weather and mildews helps avoid developing resistance mildew race Bi-annual Bulletin of WCRC. Fall 2009 pp 3-4.

Pokharel, R. R. 2009. Plastic Color and Layer Number can Influence Soil Temperatures Needed for Effective Soil Solarization. Bi-annual Bulletin of WCRC. Spring 2009 pp 2.

Dr. Rick Zimmerman

2009 Research Projects

Development and Integration of Pest Management Strategies for High Value Cropping Systems: Fruit and Vegetables

European Earwig Study

European earwig, *Forficula auricularia*, populations are causing significant economic damage in organic peach production. Control is difficult in organically managed peach orchards because the earwigs feed on ripe fruit at the time of harvest. Preharvest intervals preclude the use of insecticides at harvest time. Earwigs eat large shallow holes in the peach making the fruit non-marketable. Some growers have reported over 50% damage from the earwigs. In 2009, a study was conducted to determine if traps baited with 2 organic insecticides would be effective at reducing earwig populations in a block of organic peaches. Three blocks (33m x 33m) were randomly selected within an organic peach orchard. On August 1st, 5 earwig traps were manufactured from rectangular PVC planks. The traps were placed in the respective blocks in order to determine the pre-treatment earwig populations. The traps were baited with wheat bran. The traps were collected after three days and the numbers of earwigs in each trap were counted and released back into the respective blocks. The mean number earwigs trapped were 98.2 in block A, 94.2 in block B and 86 in block C. On August 3 the insecticide bait stations were placed back into the blocks. The bait stations in the control block contained untreated wheat bran. The insecticides used were Entrust WP (88g/a) (a.i. 80% spinosyn A and D, Dow AgroSciences) and Pyrellin EC (4.6 l/ac) (a.i. 0.6% pyrethrins, 0.5% rotenone, Webb Wright Corp.) The bait stations were changed every 5 days for three weeks up to harvest. At harvest time, 5 untreated baited traps were placed into each of the blocks. After three days, the number of earwigs in each trap was counted.

There was a significant reduction in the number of earwigs trapped in both treated blocks. The mean number of earwigs trapped in the Entrust baited stations (block A) was 7.2 and in the Pyrellin treated bait stations (block B) the average was 14.8. The mean number of earwigs in the traps located within the control block (block C) was 106. 10 trees were randomly selected from each treatment and the control. 25 peaches were then randomly selected from each tree and evaluated for earwig damage. The mean percentage of damaged fruit/tree in the respective blocks was Entrust(1%), Pyrellin(3%), and the control (23%).

This study indicates the potential benefit of the use of bait stations for the control of European earwigs in organic peach orchards. Earwig bait stations could be an important part of an integrated pest management program for organic peaches located in western Colorado. Soft approaches to pest management which are not intrusive onto adjoining properties, are becoming increasingly important as prime orchard farmland is becoming suburbanized. Bait stations are also a low cost option for control of earwigs. The drawback to the use of bait stations is labor costs associated with replacing the bait in the station. However, this could be reduced through the use of automation. Bait stations could be filled on a periodic basis from a pre-filled hopper feeding into the bait station itself.

Publications

Zimmerman, R. 2009. Effects of Different Ground Management Techniques on Bacteria, Fungal and Protozoan Populations in an Organic Apple Orchard. R. Godin and H. Larsen [Eds.]. Technical Report TR09-12. Western Colorado Research Center, Agricultural Experiment Station, Colorado State University.

2008 Research Projects:*

Impact of different organic soil amendments on nematode populations. (Pokharel, R.).

Using trap crops to manage beet leafhopper populations and the transmission of beet curly top virus to commercial tomato plantings.

Utilizing the interactions between sunflowers, sunflower aphids and European paper wasp as a method for minimizing European paper wasp feeding damage on table and wine grapes.

Evaluation of Cobalt insecticide for control of corn earworm, *Heliothis zea*, in sweet corn.

Potential of strip planting of buckwheat to provide nectar and pollen to native natural enemies and honeybees

Survey for exotic lepidopteran and coleopteran pests of fruit and ornamental plantings. Delta County, Colorado. (Cooperative Agricultural Pest Survey, NAPIS, USDA/APHIS).

Survey for European corn borer in commercial Western Colorado Sweet Corn fields. (Western Colorado Sweet Corn Administration Committee).

*Collaborators and sponsors in parentheses

Reports

Zimmerman, R. 2008. Survey Results: Exotic Lepidopteran and Coleopteran Pests of Fruit and Ornamental Plantings. Delta County, Colorado. Prepared for: the Cooperative Agricultural Pest Survey, NAPIS, USDA/APHIS.

Zimmerman, R. 2008. Survey Results: European Corn Borer in commercial Western Colorado Sweet Corn fields. Prepared for: the Western CO Sweet Corn Admin. Com. and the Colorado State Dept. of Agriculture.