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Introduction

On October 19, 2009, the Arizona Department of Agriculture (ADA) entered into a cooperative agreement with the United States Department of Agriculture (USDA), Agricultural Marketing Service (AMS) in the amount of $1,113,922.37 in FY09 Specialty Crop Block Grant Program – Farm Bill funds to fund nineteen projects specifically designed to increase the consumption and enhance the competitiveness of Arizona Specialty Crops. Projects within the Arizona State Plan include one marketing project, four education projects and fourteen research projects and are one to three years in duration. The expiration of the grant period is September 30, 2012.

2010 Southwest Ag Summit – An Interactive Forum

This project was completed on May 31, 2010

Project Summary

The Southwest Ag Summit (SWAS), which began in 2007, has become the largest assembly of industry members in the desert southwest. Specialty crop producers gather together to learn about new and evolving research and technology in order to better compete in an expanding marketplace. An interactive forum of this magnitude requires the dedication of numerous people to ensure its success. The 2010 SWAS occurred through the efforts of specialty crop producers, industry members and research scientists who realized that considerable information exists about topics that are important to the specialty crop industry. However, in order for the information to have an impact, it must be timely and effectively disseminated in an environment that is conducive to learning.

Project Approach

The SWAS Steering Committee sought to present knowledgeable and informative speakers for the 2010 SWAS general session and workshops. Dr. Kurt Nolte, University of Arizona, Yuma County Cooperative Extension Director, began by evaluating previous Ag Summits and surveying local growers about their topics of interest. Over the course of several months and with the assistance of Dr. Charles Sanchez, Dr. John Palumbo and Martin Reid, Dr. Nolte developed a list of speakers from across the US who brought new perspectives about specialty crops to the 2010 SWAS on topics such as food safety and water and chemical management strategies. Numerous industry members and researchers also worked to expand the 2010 SWAS Field Demonstration and present real-life situations focusing on emerging technologies.

During the same time period, SWAS Steering Committee members and staff pursued outreach activities and logistic coordination to ensure a high rate of attendance and a seamless multi-day event. With assistance from Yuma County Farm Bureau, the SWAS Steering Committee increased the reach of the 2010 SWAS and invited producers and industry members from other parts of Arizona.

The 2010 Southwest Ag Summit held on March 10-11, 2010 provided a successful forum where educators, specialists, farmers, and students of the southwest desert specialty crop industry met and learned. Keynote speakers addressed the general session in the morning and specialized speakers presented information at lunch. Participants chose between six educational workshops held in both the late morning and the afternoon—three sessions in the morning and three sessions in the afternoon. At each educational workshop, four to five speakers presented information and

answered participants' questions. Topics included desert pest and disease management, fertilizer workshops, alternative desert crops and technology, food safety in leafy greens, and desert crop production. With considerable regret, due to unanticipated weather conditions the Field Demonstration portion of the 2010 SWAS had to be cancelled two days before it was scheduled to occur. (Please see **Appendix A**, the 2010 Southwest Ag Summit Program, for a complete listing of breakout session topics and speakers along with the layout of the field demonstration technologies that would have been showcased.)

Goals and Outcomes Achieved

1. Approximately 700 people from the vegetable and melon industries registered and attended the 2010 Southwest Ag Summit Academic programs. The goal was for over 650 specialty crop people to register and attend. The 2010 SWAS exceeded this goal by 7.7 %.

2. Due to extreme, unexpected weather conditions, the 2010 Southwest Ag Summit Field Demonstration did not occur. As a result, the goal of over 250 people from the vegetable and melon industries was not attained.

3. On the final day of the 2010 SWAS, participants completed a written survey that provided feedback about the Ag Summit's direct and indirect impact. (Please see **Appendix B** for a copy of the exit survey.) SWAS Steering Committee members were pleasantly surprised by the results in Figure 1 that indicate the information obtained by participants would be shared with many other people. Seventy-nine percent of the survey participants responded they would share at least half of the information they received from the 2010 SWAS with others who had not attended. As a result, academic session materials reached far beyond the actual 2010 SWAS event.

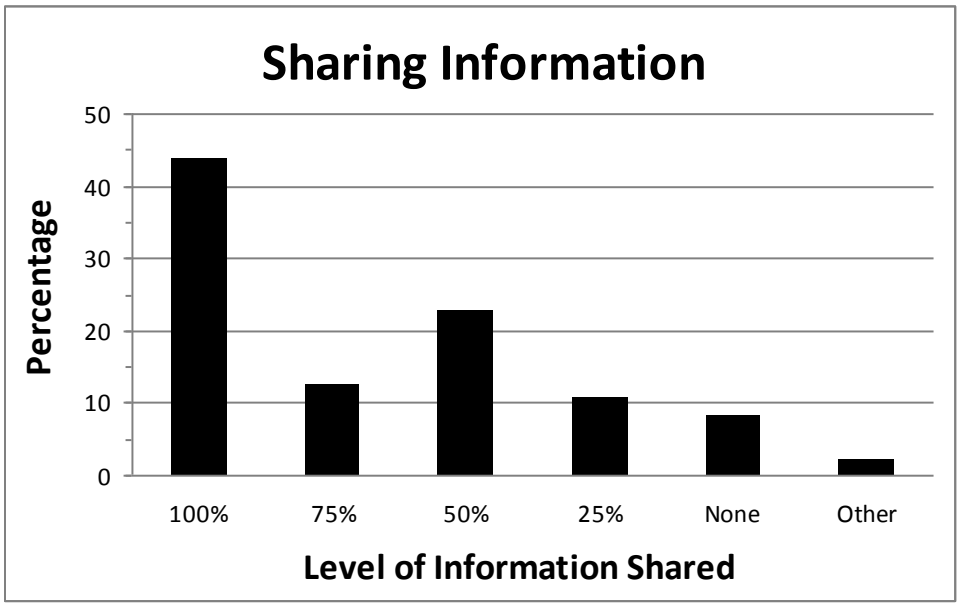

Figure 1 – Sharing Information – Survey results as shown in this graph indicate that 45% of people will share 100% of the information they received at the 2010 SWAS with staff and management. Fifteen percent of attendees will share the information with 75% of staff and management, 25% of attendees will share the information with 50% of staff and management, and 11% of attendees will share the information with 25% of staff and management.

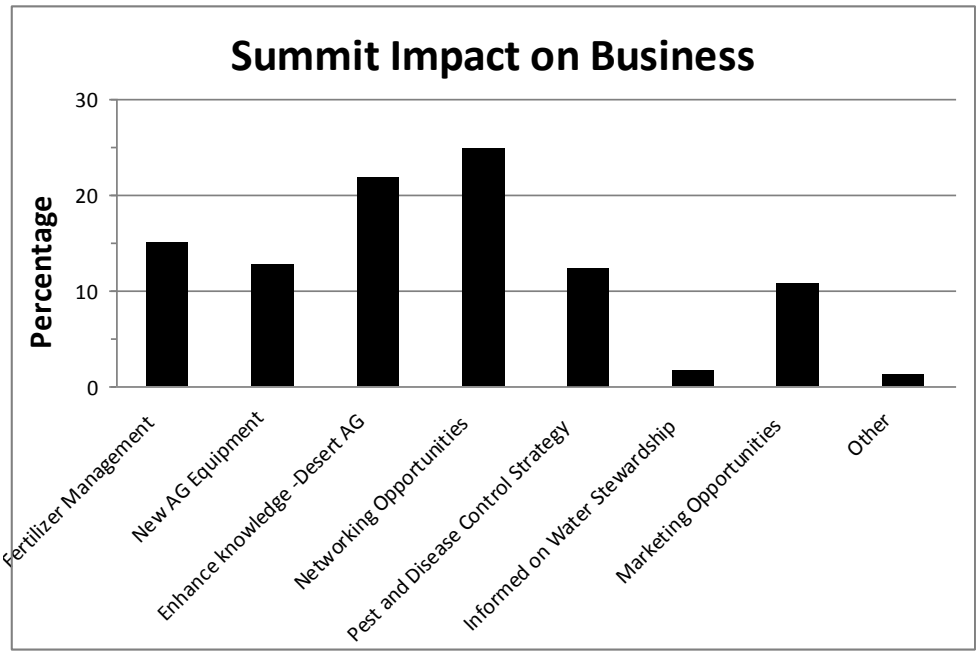

Figure 2 – Summit Impact on Business – This graph indicates the greatest effect of the Ag Summit is networking opportunities, or the interaction among members of the specialty crop industry. Participants additionally appreciated the academic presentations on enhanced knowledge about desert ag, fertilizer management, and pest and disease control strategies.

Beneficiaries

For specialty crop producers in the desert southwest region of Arizona, the potential economic impact of the 2010 Southwest Ag Summit is staggering. The USDA 2007 Census of Agriculture, National Agricultural Statistics Service website lists Yuma County as having a market value of $673,544,000 for the category of "vegetables, melons, potatoes and sweet potatoes." According to the Arizona Department of Agriculture, Citrus, Fruit and Vegetable Standardization Annual Report, there is no commercial production of potatoes and sweet potatoes in western Arizona, so the $673,544,000 value is for vegetables and melons. For 2007, the market value of Yuma County vegetables and melons was higher than any other agricultural commodity produced throughout the entire State of Arizona. In addition, Yuma County ranked 3rd out of 3,079 counties in the United States for value of sales for vegetables and melons. Yuma

County vegetable and melon production is not only economically significant to Arizona, but it is virtually unparalleled throughout the United States.

The Southwest Ag Summit reached out and encompassed specialty crop producers, research scientists, associated industry members as well as students interested in pursuing careers related to specialty crop production in the desert southwest region of Arizona. Since its inception, the SWAS's core goal has been to expand the reach of this regional event and build on its mission—to institute greater efficiencies for the vegetable and melon industries through advanced technology, improved management and enhanced growing techniques.

As already examined in Figure 1 above, there are countless beneficiaries of the 2010 SWAS who received information relevant to their specialty crop business even though they did not attend the Ag Summit.

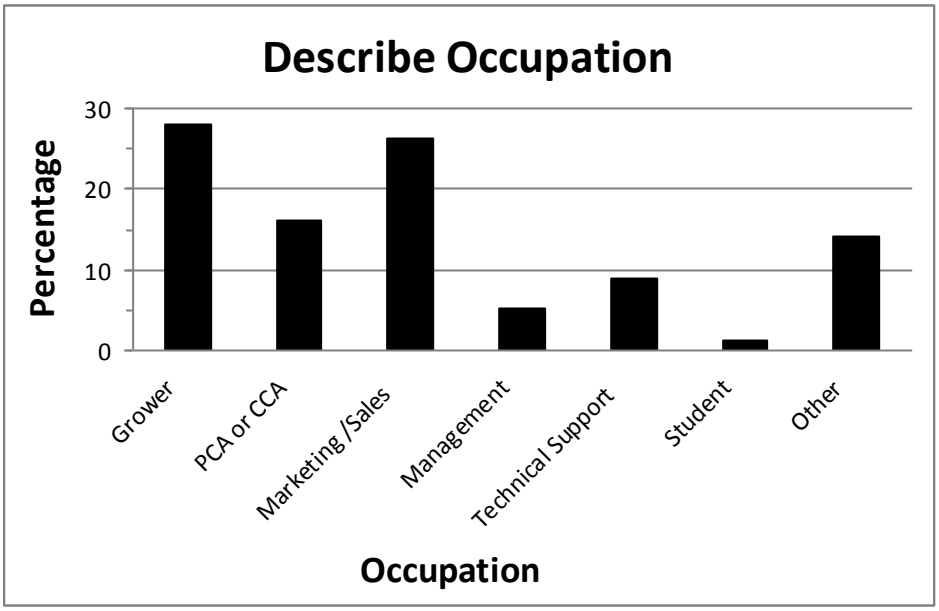

Figure 3 – Describe Occupation – This graph illustrates the results of a survey question that asked attendees to describe their occupation. Seventy percent of attendees were growers, pest control advisors or marketing representatives.

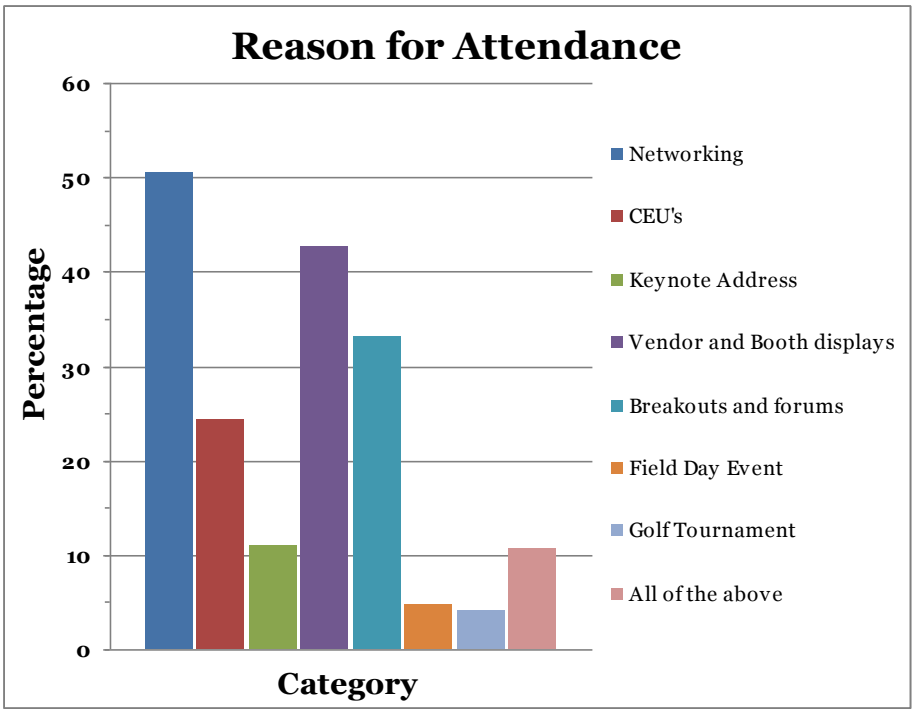

Figure 4 – Reason For Attendance – As outlined below, the participants' main reason for attending the 2010 SWAS was for networking opportunities while approximately one-third of participants attended for the education breakout and forum sessions. Many people attended the 2010 SWAS for multiple reasons.

Lessons Learned

1. As stated above, the SWAS Steering Committee was pleasantly surprised when the 2010 SWAS exceeded expectations for two of the stated goals. Attendance of people from the specialty crop industry exceeded the goal by 7.7 %. In addition, SWAS Steering Committee members were pleased by survey results indicating that 79% of the survey participants would share at least half of the information they received from the SWAS with others who had not attended.

2. The greatest disappointment of the 2010 SWAS was the cancellation of the Field Demonstration. As a result of unprecedented rains, the Field Demonstration was cancelled two days prior to when the event was scheduled. During the 2009 SWAS, participants considered the Field Demonstration as one of the most popular segments with its real-life demonstrations of new and emerging technologies. In spite of the 2010 Field Demonstration cancellation and the ever-present threat of unforeseen weather conditions, the SWAS Steering Committee once again intends to hold the Field Demonstration during the 2011 SWAS.

3. The Southwest Ag Summit continues to be the major interactive forum for the desert southwest agricultural community to learn about issues relating to specialty crops. The SWAS Steering Committee intends to apply the lessons it has learned to future events. For the 2011

SWAS, outreach efforts have been expanded in an attempt to reach a greater number of people involved with the specialty crop industry. In addition, efforts have also been made to secure informative speakers that are relevant to specialty crop producers. With each year, the SWAS Steering Committee has built on the successes of the prior year. The Southwest Ag Summit aims to continue providing pertinent and timely information for specialty crop producers thus allowing them to institute greater efficiencies through technology and better compete in an expanding global marketplace.

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Arizona Nutrition Education Gardens

This project was completed on July 31, 2011

Project Summary

This project addresses, "increasing child and adult nutrition knowledge and consumption of specialty crops." By working with teachers, students, and volunteers, this project leveraged $12,500 in grant funds with an additional $2,700 of matching funds as well as in-kind goods and services to create and sustain ten school gardens to increase consumption of fruits and vegetables, improve the attitudes toward eating fruits and vegetables, and giving hundreds of students an appreciation of where their food comes from.

Project Approach

- Designed and administered the grant application
- Recruited schools to apply
- Review applications, sourced raised beds and other materials, awarded 10 grants
- Visited 8 of 10 schools
- Created on line survey; pre/post tests
- Collected and evaluated data
- Continued communication with school garden coordinator of each school

There are no partners on this project. Western Growers Foundation (WGF) provided management time (approximately 50 hours total) as well as the book "Gardens for Learning" to each school (a value of $15 each).

We posted the application on WGF's web pages, posted information and links on Facebook, tweeted and worked with UofA Cooperative Extension (Ag Literacy News), and conducted outreach through Arizona Agriculture in the Classroom.

A total of 18 schools applied. We ranked the applicants based on factors such as existing and on-going support (both funding and gardening as well as community support), the plan they presented for the garden including water source, shaded/sun, soil and their planting guide.

It was simply a matter of timing and scheduling that we were only able to visit 8 schools. Since we plan regular school visits, the other two schools, Catalina and West Sedona will be visited in the next year.

Goals and Outcomes Achieved

Ten schools received $1,250 for garden supplies, along with raised bed kits. The schools that received the grants are:

Catalina Magnet High School	Tucson
Dunham Elementary School	Tucson
Hollinger Elementary	Tucson
Hopi Elementary School	Phoenix
Kyrene de los Cerritos Elementary School	Phoenix
StarShine Academy	Phoenix
Supai Middle School	Scottsdale
West Sedona Elementary	Sedona

The ten schools reported back in the form of surveys, letters and pre-post tests. All schools are actively engaged and planning future crops. It is this kind of enthusiasm that gives every expectation that the gardens will continue long term.

Continued communications with the schools is planned. The schools have committed to providing Western Growers Foundation with updates. Plans are being made to have Western Growers Foundation staff and/or Western Growers members visit the schools for follow-up.

Established Goals	**Actual Accomplishments**
1. 10 Arizona school gardens will be created and sustained during grant period ending 2011.	A total of 10 gardens were created and sustained during this project period, as listed above
2. 100% of the students in the program will receive nutrition education in the garden	The 10 contact teachers all reported that students received nutrition education, which included, but was not limited to cooking classes, “broccoli experiment,” and salad tastings.
3. 75% of the students will be introduced to additional academic fields in the garden	Several teachers reported lessons in science, reading, cooking, nutrition and art. We cannot confirm that 75% of the students were introduced to additional academic fields in the garden.

Established Goals	Actual Accomplishments
4. 50% of the students will have an increased understand of the importance of proper nutrition.	Students took pre and post tests to determine the quantity of servings of fruits and vegetables each consumed. One classes' students increased their servings by 47%. On average the consumption increased 33%.

Each student had a pre-test to determine how many fruits and how many vegetables they consumed "yesterday." This was compared to consumption after several months of work in the garden.

Beneficiaries

Ten schools created, and most importantly, sustained their school gardens. As mentioned, many are planning out into the future with improvements to their gardens. These improvements may include benches, shade, and more sophisticated irrigation. They are also improving their planting cycles: what crops work at what time of year. At least 1,870 students have benefited from this project – and still counting. As the gardens grow, more and more classes participate. Science, math, cooking/nutrition, language and art are the top subjects taught in the gardens.

In addition to the improved consumption numbers, we are happy to report the following:

- 25% increase in students who think that a healthy diet is very important
- 60% increase in students asking parents to purchase fruit and vegetables
- 18% decrease in students never asking parents to purchase fruits and vegetables

Lessons Learned

- "We could improve on the garden by making it an Ag Class that meets twice a month on a Saturday morning for two hours. There are enough students that really like gardening … the part that would be 'cool' to the kids is the cooking component."

As reported above, there was much improvement in the way students thought about fruits and vegetables and in eating them. In addition, the school reports were very positive:

- "Gardening has helped our students make better choices about nutrition and health which has benefited our students, schools and community."
- "Cooking from the garden produce is a big hit!"
- "Our garden is getting planted with our Arizona winter growing plants. We are expecting lettuce, spinach, and radishes soon! We have 135 students in our new Cerritos Garden Club this year and have many other whole classrooms participating. I would say we estimate that close to 300 students participate in our garden planting and maintenance as well as harvesting."

Sadly, there were a couple of students who reported eating no fruits and vegetables in their pre-tests or their post tests. This could be the result of a variety of issues – beyond a garden or school program, but when Western Growers Foundation visits the schools, it will be something to explore and better understand.

Garden enhanced nutrition education projects do have an impact on students' consumption of fruits and vegetables, with an average of 33% increase.

Because some of the schools didn't have the exact same students take pre- and post- tests, we were a bit limited in our comparison to only evaluating those students that took both. Otherwise, we wouldn't be comparing "apples to apples," so to speak.

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Food Safety for Youth in Yuma County

This project was completed on September 30, 2012

Project Summary

The purpose of the project is to educate youth of the recent Arizona Leafy Green Marketing Agreement and its implications in Yuma County. Main project is to create a web-based library for teachers, educators, youth development workers and other community members looking for activities and curriculums regarding agriculture and food safety. Additional project is to educate students of their role in food safety through classroom presentations, workshops and clinics.

What initially started the idea for the project was a recent issue involving Planning and Zoning with relation to residential areas near agriculture fields. There is an inherent danger with livestock in the same vicinity as a produce field and as a result of working through the City of Yuma; it was determined to be a lack of knowledge with the general public, especially youth, with regards to fresh produce practices. Youth continually cut across fields to get to school, residents walk their pets on canal banks and people throw trash out their window without thinking. The idea behind this project was to educate youth, who would in turn educate their parents.

Project Approach

Much effort was concentrated initially with the creation of a webpage at http://cals.arizona.edu/fps/. Once the webpage was "unveiled", we didn't notice an increase in web traffic and we began to ask educators if they found it helpful. Most indicated that they hadn't looked at the website and weren't inclined to unless they really needed something and had the time. After hearing that, we decided to focus more attention on hands-on experience to ensure that youth were still receiving the information. We visited schools, had displays at the Yuma County Fair twice and presented information on the project idea at multiple national meetings.

Goals and Outcomes Achieved

The original outcomes were through school assemblies and classroom presentations, to reduce the risk of field contamination to all crops, but especially lettuce and other leafy greens. We

exceeded our goal of 3,000 being educated about the importance of agriculture, but failed in ascertaining the adequate number of surveys. There were problems from the beginning with obtaining completed surveys from participating students.

We also wanted to ensure that 75% of the teachers in Yuma County would receive informational packets with the hands-on lessons in agriculture and how to access the information. We surpassed our number and had a great initial response with teachers. Several opted for us to come to their classrooms or attend field days.

And finally, our goal was to create a website that would be easy to use and navigate. A website was created with curriculums, activities and agricultural classroom supplements that could be useful for students, teachers and parents; however, teachers did not use the webpage. They would call or email for information or specific curriculum needs rather than checking the webpage and sorting through what they were looking for. They indicated multiple times that they were too busy to work through yet another resource.

Beneficiaries

The largest beneficiaries from the project were local youth who interacted with program related staff. School visits, farm field days and other hands on experiences proved to be the best lessons learned by students.

Lessons Learned

The idea of a webpage seemed to be the best use of time and funding, but it proved to be an education tool teachers weren't interested in or used. They were willing to allow staff to come and work with their students, but asking them to search through a page for an activity or check the updates proved to be ineffective. Teachers are already overburdened, and our project seemed to only add to their already full plate by asking them to search out yet another resource.

An additional lesson learned was to have a real partnership with teachers prior to requesting funding. While we work with schools on a very regular basis, we underestimated the amount of effort it would require to collect something as simple as a survey. It took time away from the class and proved to be another assignment for the teacher to add into their day. The lack of sufficient survey results prohibited any real measurable outcomes other than anecdotal information.

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Additional Information

Teachers and students are far more aware of the activities in and around their communities with regards to agriculture. Students use agriculturally based topics for science fair projects and are far savvier about the effects they have on their surroundings.

Agricultural Literacy – Online Course for Educators

This project was completed on September 30, 2012

Project Summary

The Agricultural Literacy online course was designed to allow Kindergarten through Twelfth grade classroom teachers to increase their knowledge about Arizona's Specialty Crop industry while meeting Arizona's Academic Standards in Mathematics, Language Arts, and Science which includes nutrition. The course content provides teachers with research-based strategies to implement agricultural concepts into their current curriculum. This increase in knowledge about the industry will help enhance the competitiveness of the industry since the teachers and their students will be more aware of the opportunity to purchase and consume Arizona specialty crop commodities.

The need to develop an online course is especially relevant in today's internet based world. Research demonstrates that many people choose to further their education through courses available on the internet and this allows working adults to achieve their educational goals.

This project is important and timely because there is a demand by teachers to implement lessons in their classrooms that are relevant to their students, which are aligned to the academic standards, and enhance the curriculum the teachers are required to use. Online courses allow teachers to participate in professional development activities at a time and place easily accessible by them. This course was designed so participants will utilize what they are learning in the course by teaching lessons in their classroom as part of the course completion requirement. This format has been implemented successfully in other state Agriculture in the Classroom programs. Research on the Utah State Ag in the Classroom online course has shown that even five years after completing the course, teachers are still utilizing what they learned in the online course.

Project Approach

Project workers met with The University of Arizona Outreach College and The University of Arizona Office of Instruction and Assessment. From these meetings, it was determined that the online course would be offered through the Outreach College utilizing the D2L platform.

Project workers developed an online survey to assess teachers' interest in an online professional development course on agriculture literacy and distributed it to 524 individuals who subscribe to our Ag Literacy ListServ. One question asked, "Given the following online course options, which would you choose?" Of the 68 who responded to the survey, 29.4% selected $165 for a certificate of completion, 50% selected $230 for forty-five continuing education units (CEUs), none selected $1,800 for three undergraduate credits towards a degree, and 20.6% selected $2,000 for three graduate credits towards a degree. Furthermore, of the 73 teachers who participated in the assessment, 23 expressed interest in participating as pilots. Ten were selected (seven completed) based upon criterion that allowed for a variety of grades, a broad range of teaching backgrounds, and various counties throughout the state.

Project workers met with Outreach College personnel on the development of a successful online course. A course syllabus and learning objectives were developed. An online pilot course was

developed and launched. Information from the ten participants was gathered on ways to improve the course. A reoccurring theme in their feedback was the sequential ease from which the course layout is designed. One of the participants stated, "I am taking another course online and the ease of your course is amazing. The link to each section is wonderful. Everything has been very clear. The other course is very confusing, [I] spend lots of time clicking back and forth to find out where I have been and where I need to go. Not so with this course." Suggestions for improvement were integrated and a consistent structure for each of the modules was developed. Participants were given a stipend of $200 for their participation.

The online pilot course was expanded into the full online course, entitled *Incorporating Agriculture Education into Your Classroom*, and launched. The course was heavily advertised for four months which resulted in expressed interest, but no one enrolled in the course. It was hypothesized that this was due to there not being a significant enough number of teachers who could attest to the benefits of the course through their own personal experience. Therefore, budgeted funds were shifted which allowed for 21 teachers to be reimbursed for taking the full online course and promoting it within their school and district.

Currently, these 21 teachers are taking the course which is scheduled from March 1, 2012 to March 1, 2013. It is anticipated that the promotional efforts of these teachers will result in the enrollment of other teachers who will take the one-year course beginning October 1.

To enhance the promotional efforts of the course and to provide additional resources to teachers enrolled in the course, participating teachers in Maricopa County were given the opportunity to have them videotaped while teaching a course lesson to their students.

Goals and Outcomes Achieved

Twenty-one teachers who cumulatively teach 1,023 students signed-up for the full online course. These teachers have been given access to numerous classroom materials including lesson plans on a variety of topics, such as soils, seeds, plants, animals, geography, and nutrition. Each of these lessons has a specific focus on specialty crops grown in Arizona, such as apples, potatoes, eggs, pecans, and lettuce. The well-defined objectives on these lessons have enhanced instructional strategies and content knowledge concerning science, mathematics, writing and reading, and healthy lifestyles.

To date, six teachers have actively participated in the course and reported teaching a total of eighteen lessons to their 366 cumulative students. The classroom instruction time for implementing these lessons equates to 29.5 hours. Teachers' lesson selection has shown a preference towards teaching lessons on apples, eggs, potatoes, lettuce, and bees. Teachers report students enjoying these lessons, and the measurements they use show an increased knowledge of Arizona's specialty crops. For example, a 9th and 10th grade high school science teacher reported her students discussed the consumer's desire for fresh apples and participated in a lab experiment documenting why cut apples turn brown when exposed to oxygen and ways to prevent browning. Students learned that placing cut apples into a container of orange juice is a convenient way to keep apple slices fresh while providing a healthy snack and drink.

Participants were also required to provide feedback to other teachers regarding the lessons that other teachers had taught. One teacher taught a lesson about lettuce and had the students compare and contrast differences between two varieties. Another teacher read this teacher's lesson and subsequent report and provided feedback on teaching strategies. She suggested that this teacher may want to consider growing the different varieties with her students for future lessons instead of purchasing only a couple from the store, this way the planting and growing process can be utilized in other lessons. She also reinforced the teacher for having her students include taste in their comparison of the lettuce varieties. Her feedback took it a step further by suggesting that nutritional content could be included in their comparisons, such as the greater amount of Vitamin A in red versus green leaf lettuce.

Teachers have until March 1, 2013 to complete their course final. To date, one teacher has completed this requirement. She is an elementary school physical education teacher to 208 students. The course final requires teachers to develop a new Arizona specialty crop lesson on a crop for which a lesson has not already been created. This PE teacher taught her students about Arizona's chili crops. She reports that her students were excited to learn that a crop which is so well known in their Hispanic culture and regularly consumed in their families was included as a specialty crop. During the PE portion of the lesson, students were paired into two different teams. One team was within an enclosed area (the "walls" were low enough for the students to see over) and the other team was on the outside of the enclosed area. Colored balls (representing the different colors of the variety of chilies discussed in the lesson) were thrown by one team of students into the enclosed area. The students within the enclosed area would toss the balls out for the other students to randomly grab. When the colored balls were grabbed, the students on the outside of the enclosed area would run to a matching colored placemat and yell the corresponding chili while throwing it into the enclosed area. Throughout the course, this teacher has been extremely creative in modifying lessons to fit her physical education teaching requirements while increasing student's understanding of Arizona specialty crops.

Of the four participating teachers who reside in Maricopa County, only one felt that she was far enough along in the course and proficient with course materials to feel comfortable enough to have her videotaped while teaching a course lesson to her students. This video is in the process of being edited to be developed into both a resource video for participating teachers and a promotional video for the course.

Beneficiaries

The beneficiaries of this project include the pilot teachers and their students. The seven pilot teachers included four elementary teachers and two high-school agriculture teachers and one high-school English teacher, and their cumulative 263 students. Beneficiaries also include the twenty-one, currently-enrolled teachers and their cumulative 1,023 students. Those enrolled in the full online course are K-12 teachers, some of which includes a special education teacher, agriculture teachers, a physical education teacher, an art teacher, and middle-school and high-school math and science teachers.

Each of the teachers have benefited by enhancing their professional development through the means of an online course. Teachers were given access to numerous classroom materials

including Arizona Specialty Crop Lessons, and an array of supportive specialty crop education materials, such as videos and articles available through the internet. Through these lessons, teachers and their students have increased their understanding of Arizona's specialty crop industry and the health benefits of consuming Arizona specialty crops.

Since the funds for this project were used to design, develop, and implement the first term of the online course, future teachers who enroll in the course and their respective students will also benefit from this project. Furthermore, as the teachers listed above continue in their educational profession, they will continue to draw upon these specialty crop lessons to teach their future students, thus increasing their understanding of Arizona's specialty crop industry and increase their consumption of Arizona's specialty crops.

The videotaping of a participating teacher presenting a course lesson to her students will help other educators see the fun and ease in teaching students about Arizona's specialty crops while meeting teaching standards and fulfilling their professional development requirements.

Lessons Learned

The most surprising aspect of this project was the high number of teachers who expressed interest in taking the course compared to the low number of teachers who enrolled (specifically zero enrollments until the reimbursement process was adopted). The teacher's schedule seems to be so busy that it proved difficult to catch those who were interested in the course at a time when they were able to actually take the steps to enroll. Also, with the new implementation of the Common Core Standards into the Arizona education system, many teachers felt overwhelmed with requirements to adjust their present teaching materials in order to meet these standards. Therefore, they were less inclined to put their focus into a professional development course. Although the initial launch of the course may have come at a time when teachers have been consumed with Common Core Standards, the course has included this component from the onset; therefore, having this base will be an attractive feature in the years to come. It is also believed that the difficulties of transitioning into Arizona's Common Core Standards not only inhibited teachers from enrolling but also hindered enrolled teachers from being more active in the course. The only teacher to make it through to the course final at this point is a physical education teacher who is not as impacted by the Common Core changes as are the classroom teachers.

Marketing also proved difficult. We learned that it is the school district and not the state that has the authority to accept or reject the course in which a teacher participates in order to fulfill state requirements for teachers to receive continuing education towards their degrees. Compounding the issue is that there are hundreds of school districts within Arizona in addition to the popularly expanding charter schools. As such, there is not a central advertising location or website where all of the continuing education courses can be posted to which teachers can enroll. Therefore, it stands to reason that in order for continuing education courses to be successful in reaching massive numbers, the course must be promoted within the district. Coordinating with a district's Professional Development Coordinator would seem essential. However, it may prove difficult to gain this person's support without having one advocating the benefits of the course. For these reasons we have pursued reimbursing teachers for taking the course, gaining personal experience with it, and promoting the course from within their school and district.

Related to marketing is the title of the course. It seems that the term agriculture comes with certain stigmas that reduce educators' interest in participating. Perhaps a name change to include gardening or locally grown food may bring about more investigation of what the course entails which would lead to greater enrollment.

The time investment for the instructor of the course has also proven to be greater than anticipated. In addition to the regular communication with enrolled teachers and following up with their requests, there are constant changes that need to be made to a newly developed course. No matter how clear it is believed that instructions are communicated, a question arises or a procedure isn't followed that requires modifications in hopes of preventing further misunderstandings and mistakes. However, regular communication with the participating teachers has led to significant changes for the October 1, 2012 term. Making these changes from term to term will improve the ease and implementation of the course, thus decreasing the time investment over time.

One of the changes that need to be made is to better communicate to the participants the requirement to incorporate in their course final an evaluative measurement of students' consumption of Arizona's specialty crops. Throughout the course, participants used lessons from the current Arizona Specialty Crop Lessons as a framework from which to teach their students. These lessons do not currently include evaluation measurements for consumption of specialty crops. Having taught these lessons throughout the course, it is understandable how one could forget to include that additive feature in the new lesson that they create. As such, the one submitted course final does not include any data regarding students' consumption of specialty crops. The course instructor will need to be more vigilant in communicating this requirement to future participants and ensuring its inclusion.

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Additional Information

See **Appendix C** for a list of content information accessible by those teachers enrolled in the course.

Arizona Grown Landscape Plant Marketing Program

This project was completed on November 30, 2011

Project Summary

The Arizona Nursery Association (ANA) applied for this grant to promote and encourage the production, sale and use of Arizona grown regionally adapted landscape plants and trees. Educating both producers and consumers of the commercial and aesthetic value of these landscape plants has been at the core of ANA's service to its members and the public for the past two decades. As the overall markets and economic conditions improve, the need for such marketing efforts was critical to the recovery of the industry. Educating the public on the value

of locally produced landscape plants had a significant impact on the long term success of the Arizona nursery industry.

This project was a multi-level marketing effort for current and potential future producers. Project components included promotion to the public, education to retail nurseries, promotion of the environmental benefits of trees, hosting of an educational forum for municipalities and other governments as well as outreach to other agricultural producers. All these components worked toward the goal of the project which was to increase the competitiveness and long term sustainability of the Arizona nursery industry.

Since 1959 the ANA has served as the public, political and professional face for a membership that includes Arizona's leading wholesale and retail nurseries. ANA was uniquely positioned to promote and encourage the use of Arizona grown landscape plants. Educating the general public to the use of locally produced landscape plants is critical to the long term success as an Arizona industry.

Project Approach

As a multi-level marketing effort for the Arizona nursery industry, this project proposal included funding for:

1) **Promotion to the public** – ANA worked with retail members and industry partners such as the Arizona Municipal Water Users Association (AMWUA) and the Water-Use It Wisely campaign which resulted in developing a marketing program targeted to homeowners promoting the benefits of purchasing and planting Arizona grown, desert adapted plant material. The marketing campaign, Plant Something, is very broad based and included a public relations campaign, media events and placing of paid advertisement and use of on-line media. Specific items developed include a brochure, posters, advertising copy, small and large plant stakes as well as retail nursery kits.
2) **Education to retail nurseries** – ANA worked with their member growers and other industry experts to host educational programs for the industry including retail nursery employees. These programs such as the New Farmer Summit, the Sonoran Horticulture Annual Day of Education (SHADE) and the Tree and Shade summit familiarized the plants offered by Arizona growers as well as answer questions and provide additional information about the current plant palate available from Arizona growers.
3) **Promotion of the environmental benefits of trees** – The Plant Something campaign also featured information on the specific environmental benefits which trees and plants offer in the landscape and surrounding community. These environmental benefits include water conservation utilizing Arizona grown plants and shade provided by mature trees which can lower your cooling bills.
4) **Hosting an educational forum for municipalities and other governments** – Trees and plants have the potential to enhance Arizona communities by not only providing the environmental benefits referenced above but also by improving the aesthetic qualities to the community. Cities and other municipalities were invited to a Tree & Shade Summit in April of 2011 to be educated on this subject. The Plant Something materials, as well as the new publication developed from this grant, Container Grown Tree Guide, were available at this summit as well as speakers from ANA. Attendance at the Tree & Shade

summit was 400 and an estimated 12 producers, growers and other related associations who participated as exhibitors. About 65% of the attendees are active in the green industry. This event was educational in nature only, as detailed by the primary sponsor of Arizona State University and did not involve any type of lobbying activities.

5) **Outreach to other agricultural producers** – In May of 2011, a seminar was held to encourage new farmers to get into the agricultural arena. ANA presented a session detailing the benefits of getting into the nursery industry. This session was intended for those interested in becoming a producer. Approximately 60 people attended the session. It is undetermined at this point how many entered the industry due to this presentation.

All components worked toward the central goal of the project which was to increase the competitiveness and long term sustainability of the Arizona nursery industry.

Goals and Outcomes Achieved

The central goal of this grant project was to increase the competitiveness and long term sustainability of the Arizona nursery industry through promoting Arizona grown low water use plants in retail nurseries and to the communities. All of the components of the program which were completed are listed in the above section.

ANA targeted two measurable goals.

1) **Arizona grown low water use plant sales will increase during the promotional period.** ANA sent surveys to its member retail nurseries to report plants sales during April and October in 2009 and 2010 to measure the effectiveness of the promotion. This same survey information was requested for 2010 compared to 2011 as marketing effects generally take longer than just a first impression to make an impact.

   Reported results were as follows:
   Comparing ANA member retail nursery sales in 2009 to 2010, an average increase of 11% was reported.
   Comparing ANA member retail nursery sales in 2010 to 2011, an average increase of 20% was reported.

   Although ANA would like to take credit for this entire increase being due to our Plant Something campaign, we should note that the Arizona market was recovering at this same time.

2) **City professionals will discontinue tree selection only by caliper size.**
   ANA was able to move the city professional's educational level on this subject by attendance at the educational forum. Also, since ANA is in control of the caliper size document on their website, by the development of the new ANA Container Grown tree guide with this grant, it was developed on a range system; therefore the tree selection only by caliper size has been discontinued. This should positively impact the longevity and structural integrity of trees as they mature in the landscape. With this new information, competitiveness of the nursery

grower industry will be increased as buyers are better educated they become more comfortable with making appropriate tree selections and the investment.

Beneficiaries

This project benefited the entire Arizona nursery crop industry. This industry, according to the latest survey, has total sales of $644 million. These sales reflect 60% to low water use plants and trees which were the items specifically targeted by the Plant Something campaign. The Plant Something campaign benefited the retail nursery industry, the grower industry as well as the general public.

Lessons Learned

Since this was the first Specialty Crop received by the Arizona Nursery Association, several lessons were learned. The first lesson is that the grant process and making decisions by committee take far longer than you anticipate. Secondly, the research and development work to establish a marketing campaign for an industry requires a lot of pre-work and set-up time and therefore, several components of the grant were performed at a later date than anticipated. Thirdly, ANA learned getting the message out to your members and keeping momentum on a project is a huge task and takes a lot of staff time to continue.

A positive lesson learned is that when you have a good project, many partners who you didn't anticipate in the beginning come forward. Our partner with Arizona State University on the Tree and Shade Summit was not anticipated when we wrote this grant.

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Additional Information

We believe the Plant Something promotional campaign has increased the competitiveness and the consumption of ornamental plants in Arizona because of the awareness it has provided. Most of the public and media portions of promoting the project will be detailed in our next grant. Without this grant to develop the campaign, there would have been nothing to continue and the nursery industry would still be without a campaign it can rally around.

Copies of any and all promotional materials are available upon request.

Arizona Pesticide Use Reporting Database

This project was completed on July 31, 2011

Project Summary

Protecting the security and safety of domestically produced food crops, while identifying opportunities for economic growth and expansion into new markets, is vital to the future of the specialty crops industry. The purpose of this project is for the University of Arizona, Arizona Pest Management Center (APMC) to build, in collaboration with specialty crop stakeholders and the Arizona Department of Agriculture, a database and information infrastructure that will support the pesticide and pest management information needs of the Arizona specialty crops industry. The outcome of this project will be an Arizona Specialty Crops Pest Management Database, built on 19 years worth of state pesticide use data, with the objective of serving and benefiting the Arizona specialty crops industry, making it more competitive, more profitable and more responsive to consumer needs and food consumption trends, while addressing environmental, food safety and food security issues.

Project Approach

The purpose of this project was for the University of Arizona, Arizona Pest Management Center (APMC) to build, in collaboration with specialty crop stakeholders and the Arizona Department of Agriculture (ADA), a database and information infrastructure to support the pesticide and pest management information needs of the Arizona specialty crops industry. This was a large undertaking that required integration of diverse data from several different entities (ADA, Arizona Office of USDA National Agricultural Statistics Service (NASS), U.S. EPA and others); rigorous error checking and data verification and correction; coordination with ADA partners to ensure ongoing data entry and currency of our APMC pesticide use data; and input and feedback from a broad stakeholder advisory committee which has guided product development and how the data will be used. The end result is a 20-year repository of Arizona pesticide use data and concomitant information with a research interface that allows us to mine the data to respond to data queries from the specialty crops industry; to develop data to respond to federal pesticide information requests on behalf of the industry; and to develop educational information and presentations that highlight the progress and environmental stewardship of the specialty crops industry in Arizona.

The APMC pesticide use database spans over 20 years of Arizona pesticide use records (1991 - 2011) and includes over 867,000 applications submitted on over 516,800 L-1080 forms. Over 2,100 distinct products are represented on 153 unique crops (119 specialty crops), including seed crops. Qualitatively, the data are cleaner and more accurate than the ADA source data and are organized and integrated with other data sources to facilitate efficient and precise responses to diverse queries.

Funds for this project were expended to solely enhance the competitiveness of specialty crops. We routinely isolate, query and develop data outputs focusing on the needs and practices of the specialty crops industry (see many examples provided in the Outcomes sections of this report). While nearly 52% of field applications in the database represent specialty crop uses, funding for this project represents a much smaller fraction of the overall investment we have made in

database development. So the benefits to the specialty crop industry described in this report are achieved in part through effective leveraging of other resources. Availability of accurate pesticide use data enhances the competitiveness of specialty crops industry. For example, our analyses clearly demonstrate a dramatic decrease over time in the use of most broadly toxic insecticides for leafy vegetable crops, and can be used to market the outstanding environmental stewardship demonstrated by the industry. We have responded to many data requests from Dr. John Palumbo of University of Arizona, who has used these data to understand pesticide use trends, to plan research that is targeted to specialty crops and making them more competitive through adoption of new technology (e.g., reduced-risk insecticides) and to combating new pest threats (e.g., bagrada bug in cole crops), and for resistance management planning and development of pest management recommendations for the specialty crops industry. He has frequently presented data to educate pest managers (PCAs) working directly with specialty crops producers, and has also presented it to research colleagues in national forums (e.g., Entomological Society of America, Insecticide Resistance Action Committee (IRAC) symposium) to promote the safe and progressive practices of this specialty crops industry.

Brief Summary of Activities Performed:

- Assembled an advisory committee which has provided input and feedback on the development of the APMC Pesticide Use Database, the products to be developed, and addressed issue of privacy protection and data access. The Committee met 5 times since it was formed.
- Coordinated with the Environmental Services Division of ADA to enter a backlog of 1080 forms and to get up-to-date with data entry. Also collaborated with them to gain access to ADA 1080 data in real time by setting up a link to a secure server at the Maricopa Agricultural Center.
- Created a “research interface” program in beta-testing phase that allows us to access, query and identify potential problems with the data.
- ***The pesticide use data are available to the public and to specialty crop producers by requests made to the Arizona Pest Management Center and also through publications and presentations developed and delivered through our cooperative extension programs.***
- Conducted numerous data queries and analyzed data on specialty crops pesticide use. These data have been used mainly for educational purposes and have been presented on numerous occasions to diverse audiences.

Significant Contributions and Roles of Project Partners:

- **Dr. Al Fournier**, lead PI for this project, has supervised the development of the APMC Pesticide Use Database, including supervision of employees and contracted personnel; coordinated activities with ADA partners; convened the advisory committee and documented meeting discussions; interacted with persons requesting data and supervised development of data outputs; and has presented information about this project, including aggregated data that highlight pesticide use trends of the vegetable industry.
- **Richard Farmer** served as Database Specialist for the APMC from the beginning of this project through June 18, 2010, and developed much of the foundation for the database

and the interface between UA Maricopa Ag Center and ADA servers. Mr. Farmer resigned from ADA prior to the completion of this project. From early September 2010 through the end of this project, we employed 2 different contracted personnel through Robert Half International with expertise in database development, computer programming and networking: **Don Lewis** and **Wayne Dixon**. These personnel have further developed and refined the APMC pesticide use database, evaluated and corrected data, responded to data queries, developed the research interface and presented progress reports to the advisory committee.

- **ADA Personnel.** Our collaborators at Arizona Department of Agriculture, Environmental Services Division, include Jack Peterson, Associate Director of ESD, who has served in a consulting role and interacted as a member of our advisory committee; Gary Christian, who supervises 1080 data entry personnel and provides data for reports; and David Hall, database and networking specialist, who has served as our technical contact for database interactions.
- **APMC Pesticide Use Database Advisory Committee.** The committee members have provided input and feedback throughout this project on a number of development and data use issues.

Goals and Outcomes Achieved

Outcome 1: *An Advisory Committee of specialty crops stakeholders, researchers, ADA and UA personnel will provide input on database development, ensuring that concerns of the specialty crops industry are met. Outcome measures will be the diversity and extent of specialty crop industry participation in the effort.*

- The Advisory Committee was formed and has convened face-to-face 5 times (3 times during the course of this grant); meeting minutes were documented and input provided has shaped database development and procedures for securing personal data and sharing of data. Individual members have also provided input via phone discussions, email and other informal interactions. The committee includes 23 (non-UA) members of the agricultural sector, including growers, PCAs, custom applicators, chemical manufacturers, state regulatory officials, representatives of Western Growers Association, Yuma Fresh Vegetable Association, Arizona Cotton Growers, Arizona Farm Bureau and Arizona Crop Protection Association.
- **Outcomes:** This outcome has been met. We have been pleased with the level of interest and participation from key stakeholder groups, who represent nearly all interested parties that participate in various aspects of the 1080 process. Their input and buy-in has been vital to the development of this project.

Outcome 2: *A backlog of 1080 data from 2007-2009 will be entered by ADA personnel and integrated into the APMC 1080 database. The outcome measure will be the availability of up-to-date data to the specialty crops industry.*

- ADA partners caught up on a backlog of un-entered 1080 forms, bringing the data up to date by the end of the first quarter, becoming current with incoming data. Over the first 12 months, an ADA temporary services employee (paid 50% through this grant), worked about 2,000 hours and entered over 23,680 L-1080 forms into the ADA database, verified

and corrected data, and filed 1080s. In addition to data entry, ADA personnel have also worked on the harmonization of the ADA 1080 data with the EPA pesticide information such as active ingredient, common name and chemical codes. In addition, David Hall, ADA database and networking specialist, developed database enhancements that allow direct loading of electronic 1080 data from clientele into the ADA database. (David's work is not expensed against this grant.) Richard Farmer set up server space at UA and a process to transfer data from ADA to UA. Don Lewis later developed procedures to verify and clean data as part of the importing process. This technology allows us to keep the APMC pesticide use database up to date with the latest ADA information. Our partnership with ADA Environmental Services Division has helped us to identify and address potential problems with the data and improve data access and integrity.

- **Outcomes:** This outcome has been met. By the third quarter of this project, up-to-date pesticide use data have been available by request to support the interests of the Arizona specialty crops industry.

Outcome 3: *The specialty crops industry will have access to reliable, verified 1080 pesticide use data for Arizona (1991 to date). The outcome measure for this will be the existence of a functional database and infrastructure to support specialty crops information requests submitted to the APMC. All information requests will be logged and tracked for response time.*

- A historical database was created using SQL Server, combining electronic records of 1080s from 1991 to date with important tables from EPA and other sources.
- Extensive data evaluations and corrections have been performed to improve the quality and accuracy of the data.
- A research interface program, developed by Wayne Dixon and now in beta-testing stage, provides ready access to all data tables and cross-sections of data. This facilitates data mining and also data checking and verification. The program is accessible only on site at the Maricopa Ag Center and is password protected and encrypted for security, and is only accessed by project personnel. This was not a defined objective of this project, but has greatly facilitated our ability to develop data outputs and respond to information requests.
- ***The APMC pesticide use data are available to the public and to specialty crop producers by requests made to the Arizona Pest Management Center and also through publications and presentations developed and delivered through our cooperative extension programs.*** While this outcome has not been achieved in exactly the way we envisioned it prior to project initiation, it has been achieved in accordance with specific direction of our stakeholder advisory committee. Committee members have expressed security concerns about providing access to the database over a public web interface. This lack of a public interface does not limit our ability to assist and inform specialty crop producers, but instead represents a critical element of "trust" required in any ongoing educational programs that impact stakeholders.
- We have developed, communicated and presented data from the 1080 database, for the benefit of the specialty crops industry. Examples include:
    - The APMC has responded to federal information requests related to specialty crops production, to the benefit of the specialty crops industry. These

communications included an APMC database query and report on thiodicarb use, and regular updates on spirotetramat cancellation and rules for using remaining stocks. These communications and reports are posted to the Arid Southwest IPM Network website at http://ag.arizona.edu/apmc/Arid_SWPMC_Info_Requests.html, and are also communicated to the agricultural community through the Arizona Crop Information Site (ACIS) email update list. (Currently, we have about 300 subscribers.) We have also continued a long-standing effort to defend the use of endosulfan in Arizona. Dr. Peter Ellsworth, Director of the Arizona Pest Management Center, invested considerable time attending EPA and MANA conference calls, calling and querying specialty crops PCAs about endosulfan importance, and helping MANA formulate a rational phase out plan. Without our input, including our analysis of 1080 data, phase out of endosulfan usage on celery, cabbage and melons of all types (all specialty crops) may well have been much sooner if not immediate (2010). In addition, it was brought to MANA's attention that Arizona is a potato producing state that uses endosulfan for pysllid control; potatoes were already under consideration for a 6-yr phase out. Finally, it was also brought to their attention that highly valued, yet very small acreages of vegetable seed were produced in AZ where endosulfan might play an important role in some years. ***One reason why more extended phase-outs were considered was because of our specific knowledge of use patterns in these crops in Arizona, in part derived from the 1080 database.*** Our use of these data to advocate for the needs of the Arizona specialty crops industry has affected the dialog about continued availability of important pest management tools for producers of leafy vegetables, celery, cabbage and other cole crops, other vegetables, melons, potatoes and ornamentals, affecting about 360 specialty crop producers statewide.

- Al Fournier presented to about 90 agricultural stakeholders, including many specialty crops growers, PCAs and industry representatives at the Southwest Ag Summit on March 10, 2011, on the topic of the 1080 database. The presentation included charts and graphs showing strong trends for reduced use of broad-spectrum insecticides in vegetable crops and cotton. He spoke with several people, including advisory board members, who were impressed by the value of these data for the vegetable crops industry.
- At the request of John Palumbo, we developed data on pest targets and pesticide uses in cole crops from 2008 through 2010; results of this analysis were integrated his presentation at Desert Agriculture Conference (DAC) on May 4, 2011, "The Bagrada Bug: A New Invasive Stink Bug in Arizona Crops". About 40 PCAs and other stakeholders attended. Two additional presentations at DAC made use of information developed from the APMC database: by Peter Ellsworth and Paul Jepson (Oregon State University).
- William McCloskey and Lydia Brown produced a one page Extension publication on the available glyphosate products on the market, in part based on a query of the APMC database. This piece was posted on the Arizona Crop Information Site (http://ag.arizona.edu/crops/cotton/files/GlyphosatevF.pdf) and was sent out via county Extension advisory email lists. The piece was picked up by Western Farm

Press and featured on their website as "must read". We estimate it reached tens of thousands of readers with an interest in Southwest agriculture.

- **Outcomes:** As a result of this project, we now have in place the core information (historical pesticide use database) and information infrastructure to respond to the pesticide data needs of the specialty crops industry. These data have been used to inform research, to educate specialty crop producers, pest control advisors and federal pesticide policy makers about pest management needs and trends that affect the specialty crop industry, and to defend important chemical registrations under threat.
    - **Data Requests.** From April 2010 through June 2011, we logged 16 data requests, one of which was later withdrawn. In all, we filled 15 data requests. 11 of these were filled within 24 hours. The remaining 4 ranged from 3 to 112 days. Our average response time was 12 days. Two data requests were from external stakeholders, and 14 were "internal" requests from UA and Cooperative Extension personnel for information usually related to developing and presenting educational information to growers and other clientele. The external requests were not from specialty crop producers. Because of the highly technical nature of the source data, it is unlikely that a producer would make individual requests or use of these data. However, these data have been amply used to educate specialty crop producers, pest control advisors and other specialty crop industry stakeholders about the practices and needs of the Arizona specialty crop industry, and to advocate for those needs via our responses to federal information, and research and educator requests. For example, the 14 internal data requests included five requests for information targeting specialty crops producers and pest managers. Counted as "one" of these requests has been a complex ongoing iterative historical analysis, in dialog with Dr. John Palumbo of University of Arizona, of lettuce, melon and other vegetable insecticide use patterns and how they have changed over the 20 year span of data. We have met every request that Dr. Palumbo has made on behalf of the specialty crops industry for data on pesticide use practices in leafy vegetables, cole crops and melons.
    - **Impacts.** 361 distinct licensed specialty crop growers were impacted through the synthesis and usage of APMC Pesticide Use Database information by specialty crop researchers, educators, and policy makers. This accomplished better focused research targeting rapid adoption of new technology (e.g., reduced-risk chemistry) and research to combat significant new pest threats (e.g., the invasive bagrada bug in cole crops). It also led to better-informed extension education programs for growers and PCAs on topics such as optimal deployment of new and old chemistry, preventing resistance in whiteflies and other insect pests, and more effective and economical control of Bagrada bug. Development of this "real-world" data has informed more efficient and more appropriate pesticide regulation and policy and thus reduced uncertainty in the marketplace for specialty crop producers (e.g., by providing for an orderly phase-out of critical crop protection chemicals such as endosulfan). Based on our database records, we estimate more than 319 lettuce producers, 138 broccoli producers, 94 cauliflower producers, 68 other cole crop producers and 130 melon producers are beneficiaries of this information.

Outcome 4: *We will conduct an analysis and develop a report that will support the promotion of Arizona specialty crops as safe and sustainable. For example, based on preliminary data (Palumbo, unpublished) we expect to see a 45% reduction in broad-spectrum insecticide use in some specialty crops in recent years.*

- Data were extracted from the database and analyzed to examine trends in insecticide use on lettuce, cole crops, melons, other crops; this was done over several iterations throughout the project term, as 1080 data issues were identified and corrected. The resulting data set has served as the basis for charts and graphs presented as part of cooperative extension presentations by Al Fournier, Peter Ellsworth, John Palumbo and others. Some of these data will serve as the foundation of achieving Objective 4. Our preliminary data analysis indicates reduced use of broad-spectrum insecticides by the Arizona vegetable industry and increased adoption of reduced-risk chemistries that preserve beneficial insects and provide environmental and human health benefits.
- At 2011 May and June meetings, we sought further input from our stakeholder advisory committee on the content and approach for development and promotion of the synthesis report. A number of excellent suggestions were made. "The industry needs to be better at defending the value of what it does and the progressiveness of its practices," one stakeholder said. The analysis may focus on how classes of pesticides used have changed over time; how the industry has reduced the use of broad spectrum products in favor of more selective options; and an analysis of use by IRAC numbers, to show the increased diversity in modes of action used by the industry. It was suggested that in addition to the report, that we get info out to the broader press to promote the industry. A subcommittee was formed to provide further input and to review and edit the draft report.
- **Outcomes:** As indicated in our Sixth Quarterly Report in April, we have deferred completion of the synthesis report (objective 4) to our related continuation grant (SCBGP-FB10-04). The decision to defer was based on the need to implement improvements to the database and to address data integrity issues we have identified. Many of these have been addressed, though a few remaining improvements are still in progress. Data quality and integrity were key issues of concern raised in previous meetings of the database advisory committee, so we have seen this as an important improvement well worth the delay. We have increased our capacity to develop a high quality "synthesis report" that will support the promotion of the Arizona specialty crops industry as safe and sustainable. We will complete additional work on this synthesis report as part of our 2010 Specialty Crop Block Grant.

Beneficiaries

Beneficiaries of this project have included growers including specialty crop producers (175), PCAs (204), applicators (866 private and commercial) in Arizona as well as registrants who have been affected by the outcomes of our responses to federal pesticide information requests, including those developed for spirotetromat (Movento), thiodicarb and endosulfan (detailed under Objective 3 above). In addition, we estimate that information developed from this project, including data on pesticide use trends, has reached many thousands of agricultural stakeholders through cooperative extension presentations and publications described above.

Lessons Learned

- At the outset of this project, we believed the primary challenges in developing a database and making information available would lie on the technical side. In truth, the technical aspects of database development posed minor challenges and time investment compare to data verification and data integrity issues, which dominated our development time after the first six months of the project.
- Through the course of this project, we have seen an increased interest among agricultural stakeholders in the potential value of the pesticide use database. This has been apparent to us in the increased level of participation by significant stakeholder representatives in the database advisory committee.
- An unanticipated outcome of this project has been the development of the research interface program. This program has facilitated the handling of data requests and had also helped us to identify and isolate errant data, much of which has been corrected. While this is not a "product" that end users will see, it has been an important tool that has improved our data processing and outputs.
- We have been very pleased with our collaboration with ADA-ESD. They have become true partners and have dedicated time and effort on this project well beyond their original commitment.
- Our data analyses so far have supported our assumptions at the beginning of this project that there has been a steady trend in reduction of pesticide use on Arizona specialty crops, particularly a reduction in broad-spectrum insecticides.

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Additional Information

This project has helped to enhance competitiveness of the specialty crops industry through education of specialty crops growers, PCAs and applicators and through our responses to federal pesticide information requests, which we believe has helped to secure an extend phase out of endosulfan for some specialty crop uses.

Automated Lettuce Thinning Machine Development

This project was completed on September 30, 2012

Project Summary

Approximately 35,000 of Iceberg and 15,000 of Romaine lettuce are raised in Arizona each year. One of the major challenges facing this $500 million industry is a shortage of hand labor as up to four manual operations are required to raise a crop. One of these is thinning which is required since lettuce seeds are sown at high rates higher than necessary to ensure adequate stand establishment. Following germination, workers equipped with hand hoes thin the stand to the desired plant spacing for optimum head size and quality. Hand thinning is a labor intensive

operation requiring roughly 8 man hours/acre for Iceberg and 11 man hours/acre for Romaine lettuce to complete. Finding workers to perform the task has become difficult due to increased immigration enforcement and the reluctance of laborers to work for the low wages offered. Using manual labor to thin lettuce crops is also a fairly significant expense for the industry. The cost for thinning Iceberg and Romaine lettuce is roughly $100/acre and $137/acre respectively. Based on these cost estimates and acreages, Arizona producers spend about $5.5 million for thinning each year.

To date, there are no commercially viable automated lettuce thinners in the marketplace. The goal of this project was to develop an automated machine for thinning lettuce to 1) reduce labor requirements for lettuce production and 2) lower production costs. Once the machine had been developed, a further objective was to identify and work with companies interested in manufacturing the device so that the technology would be available to growers.

Project Approach

The principal tasks for an automated lettuce thinning machine are to 1) identify crop seedlings and their location, 2) determine which seedlings to selectively thin, 3) control machine operations such that plants are selectively thinned and 4) kill seedlings without injuring "saved" crop plants. Several approaches were explored simultaneously to accomplish these tasks. First, to facilitate testing, a two bed, test frame was fabricated and mounted to a tractor via a three point hitch. An electronic control system was then developed and mounted on the test frame. The control system was principally comprised of a computer for adjusting the machine's settings and a circuit board for monitoring inputs and controlling outputs. This system allowed for the development and evaluation of various methods for identifying and killing seedlings in situ.

One of the methods considered for detecting young lettuce plants was use of optical sensors. These systems were found to work reasonably well, but they were unable to accurately locate the exact position of lettuce seedlings due to the unpredictable growth of the plants. As a consequence, their precision was limited and considered unacceptable for use on an automated thinning machine. The other method evaluated was a camera based machine vision system. This system was developed by first capturing thousands of images using a camera mounted on the test frame. Computer algorithms were then developed to identify crop plants in the images and determine which seedlings should be selectively thinned. Once successful algorithms had been developed, programs were written to interact with the control system and provide a user interface. These systems were integrated with other hardware components and installed on the test frame. When field tested, this system worked very well. As a consequence, the machine vision system was selected over the optical sensor based system for evaluation in formal field trials.

Various methods for killing lettuce seedlings were iteratively developed and tested until an acceptable system was found. These included high pressure water, mechanical knives and herbicidal spray. Systems were mounted on the test frame and evaluated in the field. Single and dual nozzle high pressure water systems were tried at various system pressures. When properly aligned with the seed row, these systems effectively removed plants and induced minimal soil disturbance near the saved plant. Keeping the system properly aligned however proved to be

very difficult. Another problem was the water flow rate required to effectively remove plants was excessively high for viable use in commercial production. As a consequence, this system was abandoned for further development and testing.

Two mechanical knife systems were developed and tested. One of these utilized a knife blade that was inserted beneath the plants from one side of the crop row. A linear pneumatic actuator was used to insert and withdraw the knife blade from the soil. The other system utilized a horizontally oriented blade positioned directly above the crop row. The knife was lowered and raised vertically with a linear pneumatic actuator to selectively thin plants. After making several design improvements, both systems were found to be capable of thinning plants to within a 1 ¼ inch radius of the plant to be saved when properly aligned with the crop row. When not aligned, the performance of the device where the knife was inserted from the side was not acceptable as lateral movement of the blade caused either the plants to be saved to be killed or plants to be selectively thinned to remain unharmed. The horizontally oriented blade was not affected by misalignment since it was positioned above the crop row and was wide enough to account for the amount of lateral movement that occurred. This system was selected for formal evaluation trials.

The development of an herbicidal spray system involved two technical challenges. These were 1) finding a nozzle and solenoid valve spray assembly that could deliver herbicidal materials in a wide band (> 4 inches) with the precision and accuracy required for lettuce thinning (within a 1 ½ inch radius of the plant to be saved) and do so on a vehicle traveling at a speed that would be commercially viable (> 1mph) and 2) identifying a cost effective herbicidal spray solution for lettuce. Initially, over twelve types of spray nozzles and three types of solenoid valves were tried. No combination of spray nozzle and solenoid valve was found to be acceptable. Problems with these systems were that either particle drift of herbicidal materials onto the saved crop plant was too high, the spray pattern produced was unacceptable, the material flow rate was too high to be commercially viable or droplets of material would form on the nozzle tip after the solenoid valve had been closed and drop on the saved crop plant.

As a consequence, a nozzle of our own design was fabricated and tested. This design utilized a series small, 0.008 inch inner diameter capillary tubes mounted in a nozzle body. This system was found to work very well, however tube plugging was problematic. Also, construction of the device was very time consuming which would limit the commercial viability of the design. A spray nozzle that had not been tried before was then purchased and attached to solenoid valve using an unconventional, yet simple mount of our own design. This system worked extremely well and met all the established spray nozzle solenoid valve assembly design criteria.

Efforts were made to identify liquid chemicals that could be cost effectively sprayed to kill lettuce seedlings. Currently, there are no herbicides registered for lettuce that kill lettuce. As a consequence, various concentrations and application rates of several compounds that are not regulated herbicides but are known to kill lettuce and are commonly applied in agriculture were investigated. These included fertilizers (AN 20 and UAN 32) and acids (sulfuric acid, N-phuric acid and acetic acid). Both AN20 and UAN 32 at concentrations above 50% and application rates of 30 gallons/acre were effective and have acceptable application costs of $22 and $25/acre respectively. Sulfuric acid at a concentration of 10% and application rate of 30 gallons per acre

was highly effective and could be applied at a very cost effective rate of less than $5/acre. N-phuric acid was effective at concentrations above 30% and application rates of 30 gallons/acre, but was more costly at $14/acre to apply than sulfuric acid. Acetic acid at concentrations above 30% and flow rates of 30 gallons per acre was effective, but would be very costly at $48/acre to apply. Based on these findings, UAN 32, AN 20 and sulfuric acid were selected for evaluation in formal trials. Because acetic acid at concentrations of 20% is commercially sold as an organic herbicide it was also chosen for further study. Application costs for this material at 30 gallons/acre is roughly $32/acre.

The components selected for formal study were integrated to form an automated machine for thinning lettuce. The machine was principally comprised of a machine vision system for detecting plants, a computer based system for controlling machine operation and a method for killing plants (Fig. 1). In the spring of 2011, a field trial was conducted to evaluate the performance of the automated thinning machine as compared to conventional hand thinning. The machine was tested at a travel speed of 1.5 mph using herbicidal spray and mechanical blade methods for killing plants. Herbicidal materials included AN 20 (50% v/v), UAN 32 (50% v/v), sulfuric acid (10% v/v) and herbicidal vinegar (20% v/v acetic acid).

Automated machine thinning performance in terms of plant spacing, coefficient of variation (COV) in plant spacing, plant stand after thinning and time required for a hand laborer to intra-row weed and remove plants missed during the thinning operation was not significantly different from hand thinning when plants were selectively thinned using sulfuric acid or concentrated vinegar ($P = 0.05$) (Siemens et al., 2012; Fig. 2). Significantly lower plant spacing and higher plant stands were found when the fertilizers UAN32 and AN20 were applied because the material was not highly effective at killing lettuce seedlings at the 30 gallon/ acre, 50% v/v concentration rates used. Significantly lower plant spacing and higher plant stands were also found when the mechanical knife was used to kill plants. This was a consequence of the system's inability to consistently position the blade at the proper depth in the varying soil conditions encountered. These results are reflected in the fact that the time required for hand weeding after thinning was also significantly higher for these treatments as compared to hand thinning or treatments where sulfuric acid was sprayed. Automated machine thinning performance after hand weeding was also not significantly different from hand thinning in terms of plant spacing, COV in plant spacing and plant stand when plants were sprayed with any of the chemicals tested. These results indicate that the automated machine was able to reliably control intermittent spray of herbicidal materials such plants were selectively thinned to the desired final plant spacing. It was also concluded that the machine was able to accurately deliver highly toxic herbicidal sprays without significant injury to seedlings since yield of hand thinned lettuce was not significantly different from machine thinned lettuce. The study was repeated in the spring of 2012 and similar results were found.

Having deemed that a successful prototype automated thinning machine had been developed, a 77 page invention disclosure was written and submitted to the University of Arizona's Office of Technology Transfer (OTT). A law firm was hired to write and file U.S. and international patents on the machine vision aspects of the invention. This was completed in December, 2011

(Siemens et al., 2011). A separate provisional patent application on the new novel spray assembly technology developed was filed in January, 2012.

The prototype machine developed worked well for developing and testing technologies, but was not a design that would be suitable for commercial use. Consequently, a two bed production style machine was designed and fabricated (Fig. 3). Hardware components of the two bed machine were successfully tested in field trials in Salinas, CA (Fig. 4).

Goals and Outcomes Achieved

The goals of this project were to 1) develop an automated machine for thinning lettuce to reduce labor requirements for lettuce production 2) low production costs and 3) identify and work with companies interested in manufacturing the device so that the machine will be available to growers. Activities listed to achieve goals 1 and 2 are described in the previous section. To achieve goal 3, several activities were performed. At extensive outreach effort was made to inform growers, industry and equipment manufacturers about the automated thinner technology developed. Twelve invited and one volunteered presentations were given at grower, industry and professional meetings. Attendance at these meetings was approximately 650 individuals. Demonstrations of the machine in operation were given at three field day events to a combined audience of about 450. A technical paper about the development and performance of the machine was written and presented at the 2012 American Society of Agricultural and Biosystems Engineering Annual International Meeting (Siemens et al., 2012). We also worked with journalist to publish 10 popular press articles about the automated thinning technology developed.

These efforts results in significant interest in the device from growers and industry. We had private meetings with 9 different companies interested in manufacturing the device for retail sale or for their own proprietary use. Five of these companies expressed serious interest and were given private field demonstrations and additional information under signed confidentiality agreements. Three companies made offers to license the technology from the University of Arizona; however a licensing agreement that was acceptable to both parties could not be reached. One of the companies, Agmechtronix, Silver City, NM, commenced manufacturing an automated thinning machine for commercial sale based on the technologies developed in this project. They were hired as a consultant on the project and are a co- assignee on the patent application filed. Consequently, they are not required to license patent rights from the university in order to commercialize the technology. Growers were made aware of the device's availability through personal communication, making two invited presentations at grower/industry meetings and by cooperating with journalist to publish two popular press articles. Attendance at the meetings was approximately 150 individuals. Agmechtronix demonstrated their commercial style unit in Yuma, AZ in September, 2012 (Fig. 5). Reception of the device was very good. It is expected that several machines will be sold to growers in the next several months. If this happens, the project's goal of providing a commercially viable automated lettuce thinner to growers will have been met. Another option for achieving this goal is that the University of Arizona is currently working with a company that is interested in manufacturing an automated thinning machine based on the technologies developed in this project. We will continue to work

with them and other companies until the goal of having a commercially viable automated thinner available to growers is met.

The long term outcomes of this product include the number of units sold and the device's impact on production practices. Although to date, no units based on this work have been sold, it is expected that several machines will be purchased soon. Once this occurs, the number units sold will be obtained from the manufacturer. Impact on production practices will be measured using a survey that solicits information on the number of growers who have purchased automated thinners, the number of acres the thinners are used on and the estimated savings in labor, time and cost. The surveys will be repeated 1, 3, 5 and 10 years after the first unit has been sold.

Beneficiaries

Development of an automated lettuce thinner benefits the majority if not all of the more than 100 lettuce growers in Arizona. Agmechtronix quoted a sale price of $125,000 and work rate 2 acres/hour for a 4 bed automated thinner. Based on these figures, it is reasonable to assume that such a machine would reduce thinning costs by about 50% ($50 - $68 per acre savings) and labor requirements by roughly 95% (7.5 – 10.5 man hours/acre reduction). Implementation of such a device on the 50,000 of Iceberg and Romaine lettuce raised in Arizona would save growers approximately $2.25 million and 425,000 man hours of labor annually.

Lessons Learned

Due to the unpredictable growth of lettuce seedlings, conventional optical sensors cannot be used to reliably detect the location of lettuce seedlings with the accuracy required for an automated thinning machine. Lettuce seedlings can accurately be located with a camera based machine vision system that is programmed to use hue, saturation and luminance threshold limits to differentiate lettuce seedlings from weeds and soil in captured images. Because implements can only be guided to within about ± 2 inches of the seed row, systems whose position must be maintained precisely to kill plants are not suitable for use with automated thinning machines. Also, because lettuce seedlings are spaced so closely together (typically < 2 inches apart), selective thinning of plants using a mechanical system is difficult if not impossible without causing injury to the saved plant. The reason for this is that in order to kill plants, these systems must disturb soil and soil conditions are too variable to reliably kill one plant and leave an adjacent plant near to it uninjured. Utilization of fast acting solenoids in combination with nozzles assemblies that deliver herbicidal sprays in wide bands without particle drift or dripping is a well suited technology for selective lettuce thinning.

Identifying a manufacturer for the automated thinner developed was difficult. We found that large manufacturing companies such as John Deere and Case New Holland are not highly interested in developing and supporting products for small markets like automated lettuce thinners. We also found that small companies don't have the capital to take on the risk of developing new product lines and/or don't have the expertise in all the technological areas necessary to manufacture the product. Furthermore, because there is a market demand for automated thinners, several potential manufacturing companies were developing machines independently during the course of this project. As a consequence, they preferred to keep their technologies proprietary and were hesitant to collaborate with us and share returns on their

investment. Commercializing University of Arizona intellectual property shouldn't be as difficult in the future since the university has a new technology transfer structure in place that is much more conducive to working with businesses.

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Additional Information

Development and commercialization of an automated machine will significantly enhance the competiveness of Arizona specialty crops. As mentioned previously, implementation of the device on the 50,000 of Iceberg and Romaine lettuce raised in Arizona would save growers approximately $2.25 million and 425,000 man hours of labor annually. Through these reductions, this project has the potential to significantly impact the profitability and price competiveness of Arizona grown lettuce and the sustainability of the industry by reducing its dependence on a manual labor for viable production.

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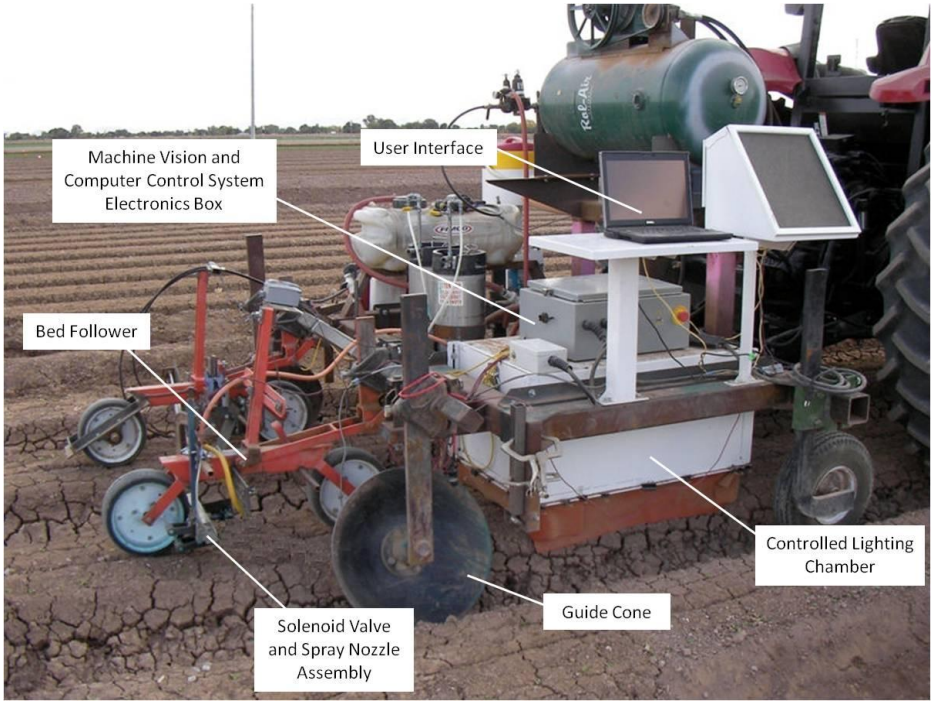

Figure 1. Prototype automated thinning machine that utilizes a machine vision system to detect plants and their location and an herbicidal spray to thin plants to the desired spacing.

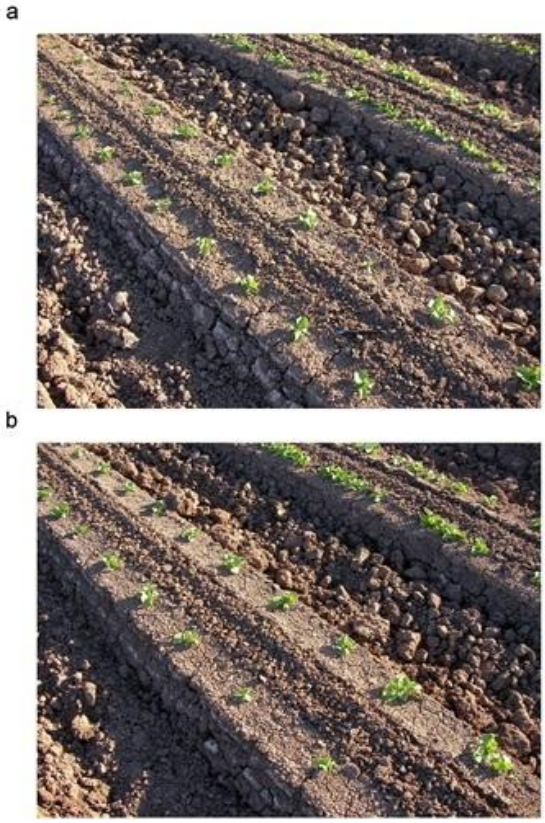

Figure 2. Lettuce stand 12 days after thinning by (a) hand and by an automated thinning machine that sprayed (b) sulfuric acid and on seedlings nominally spaced 1.1 inches apart.

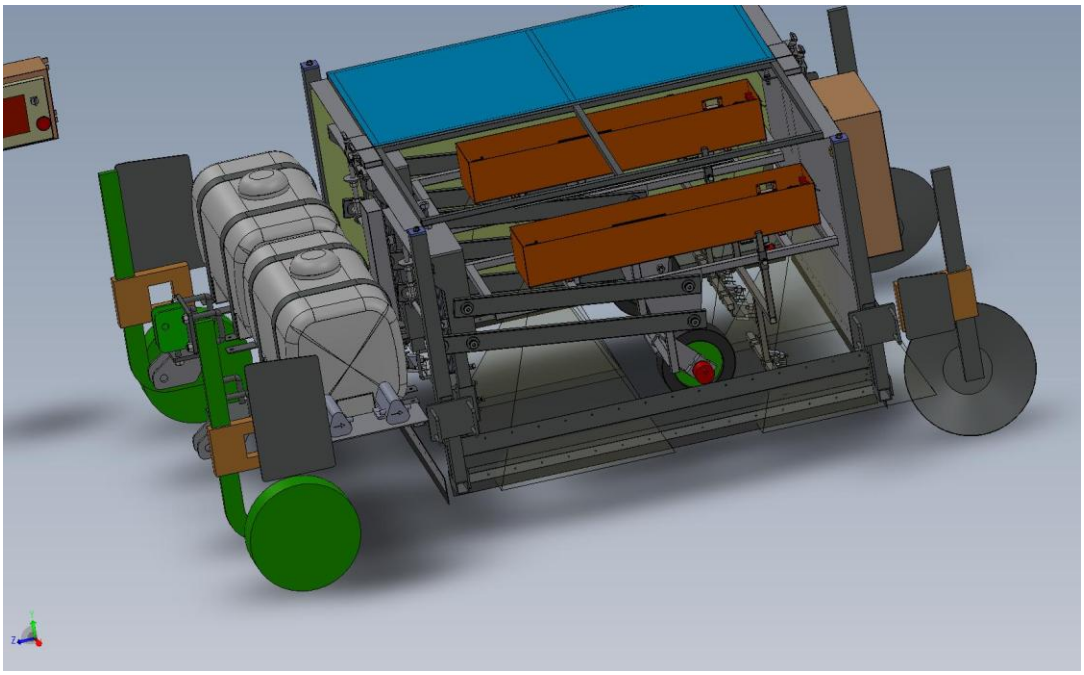

Figure 3. Schematic of prototype commercial style automated thinning machine for lettuce.

Figure 4. Prototype commercial style automated thinning machine for lettuce operating in the field.

Figure 5. Agmechtronix two bed, commercial automated lettuce thinner demo unit.

Breeding Lettuce Cultivars with High Quality and Disease Resistance

This project was completed on September 30, 2012

Project Summary

Winter production of lettuce is centered in the low desert region of Arizona and California, and is critical to maintaining a year round supply of high quality lettuce. Lettuce production is continually faced with pre-existing and new challenges. In Arizona, premature bolting reduces yield, while the physiological defect tipburn can result in entire fields being discarded. The soil-borne diseases big-vein and Fusarium wilt reduce yield and quality, and currently have no feasible cultural control options. Fungicides are currently used to control powdery mildew on lettuce, which increases production costs. Our goal is to develop landmark cultivars and breeding lines with resistance to these production constraints. Seed of new cultivars are disseminated to the lettuce industry for crop production and to develop additional cultivars.

Project Approach

We used conventional and molecular breeding methods to select genetically improved lines of lettuce. Lettuce is an inbred crop species that produces seed through self-pollination, and new cultivars are developed by selecting plants or inbred lines with improved characters from genetically variable families created through artificial hand cross-pollinations. The selected plants are allowed to self-pollinate to create the next generation in order to repeat the selection process. A breeding project can last five to10 years, although molecular breeding can accelerate the process in some cases. The breeding process can be divided into four phases: 1) development of populations for selection through artificial hand cross-pollination, 2) selection for improved plants and families in early breeding generations (F_2-F_4), 3) selection for improved inbred breeding lines in late generations (F_5-F_9), and 4) advanced testing of genetically stable lines over multiple locations and years to determine suitability for release.

Field Experiments: Field experiments were conducted at the University of Arizona, Yuma Valley Agricultural Research Center and in commercial lettuce fields. Planting dates and location are selected to insure that environmental conditions are suitable for expression of genetic variation of priority traits (resistance, head type, etc.). This allows the identification and selection of plants, families, or inbred lines with the appropriate combination of traits. Premature bolting, powdery mildew, and tipburn occur most frequently in Sep., Nov., and Dec. plantings, respectively, and field experiments were planted at those times to select for resistance. Tests for resistance to the soil-borne diseases big-vein and Fusarium wilt were planted in infested fields, when available, in addition to being planted at specific times (big-vein October; Fusarium September) for disease symptoms to occur. For each project, every plant, family or breeding line was assessed for resistance and the crop was grown to maturity using typical methods for the Yuma Valley. Seeds of selected plants were produced in the field or the plants were transplanted to a Salinas greenhouse for seed production. Seeds of selected plants were cleaned and stored in Salinas until needed for planting the following season.

Molecular Marker Analysis: The USDA has developed the capacity to select for genes conferring resistance to *Lettuce mosaic virus*, the bacterial disease corky root, and the soil borne

viral disease dieback (*Tombusvirus*) through the use of molecular markers. All of these diseases are known in Arizona. We used these molecular markers to select multiple disease-resistant lines, i.e. tipburn, bolting, big-vein, powdery mildew, or Fusarium wilt resistant cultivars that additionally have resistance to *Lettuce mosaic virus*, corky root, and/or dieback.

Contributions by project partners: Tipburn resistance breeding for romaine used 13 F_8 inbred lines from (Valmaine x Salinas 88) x Salinas. These lines were part of a larger recombinant inbred line populations developed by the University of California, Davis.

Goals and Outcomes Achieved

In 13 field experiments conducted between 2009 and 2011 in Yuma, AZ, over 1460 accessions, lines, or families were evaluated and 385 plants or lines were selected based on a superior combination of horticultural characteristics and resistance to biotic or abiotic stress. Seed from selected plants or inbred lines were cataloged and placed in -20°F storage for planting in future experiments, additional seed increase, or distribution to the public in the case of inbred lines approved for public release by the Agricultural Research Service. Molecular marker genotypes that can indicate or predict resistance to corky root, dieback, or *lettuce mosaic virus* were determined for 110 lettuce accessions. Details and comparisons of actual accomplishments compared to initial goals are supplied below for specific breeding objectives.

Bolting-resistant icebergs and tipburn resistant icebergs. One goal was to develop a novel type iceberg adapted to Fall season plantings with resistance to premature bolting and *Lettuce mosaic virus*. A second goal was to develop a novel type iceberg adapted to spring harvests that had resistance to tipburn and *Lettuce mosaic virus*. Inbred lines developed by Dr. Ed Ryder were already available for these objectives, but they needed to be fully characterized, which we succeeded in completing (Figures 1 and 2). The release statements are in preparation. To our knowledge, there were no commercially available cultivars adapted to these planting slots with the same combination of characters at the time of this report. These iceberg cultivars are unique and the first of their kind.

Figure 1. General characteristics and picture of iceberg germplasm with bolting resistance. Information originally presented in a handout for the SW Ag Summit field demonstration on March 9, 2011. Image of lettuce heads taken by M. Chawner.

Bolting resistant iceberg lettuce

RH07-0667, RH07-0668, RH07-0669

Selected from 84-718 x Autumn Gold
Adapted to fall plantings
Yields similar to Autumn Gold, but with larger heads
Core length similar to Empire
Unique appearance
Low head coverage

Figure 2. General characteristics and picture of iceberg germplasm with tipburn resistance. Information originally presented in a handout for the SW Ag Summit field demonstration on March 9, 2011. Image of lettuce heads taken by M. Chawner.

Tipburn resistant iceberg lettuce

RH09-1698, RH09-1699, RH09-1700

Selected from Salinas x Vanguard 75
Adapted to spring plantings
Yield, size, and appearance similar to Tiber
Less tipburn than Tiber or Gabilan
Low head coverage
Resistant to *Lettuce mosaic virus*

Fusarium resistant iceberg: In a Yuma, AZ commercial lettuce field experiment approximately 100 F_3 families using multiple sources of resistance were evaluated for resistance and resistant families were identified. Thirty iceberg type plants with resistance were taken, although none survived to produce seed. The study will be repeated. At this time there are no commercially available iceberg cultivars with Fusarium wilt resistance that are adapted to Arizona. This project identified resistant families, and if new cultivars are developed from these families they would be the first of their kind.

Powdery mildew and big-vein-resistant iceberg. Evaluations were made for iceberg type plants with reduced disease incidence or disease severity. To develop big-vein-resistant icebergs, three distinct populations each with a different source of resistance (cultivars Pacific, Pavane, and Margarita) in the F_4 through F_9 generation were used in field experiments. For the powdery mildew resistance project, F_2 through F_4 populations incorporating resistance from the Butterhead cultivars Big Boston and Soraya were used. In both projects, inbred lines and early generation families with resistance were identified, but never in combination with good iceberg horticultural characteristics. Resistance to big-vein and powdery mildew in this germplasm may be related to plant horticultural characteristics. F_2 populations with powdery mildew resistance from the wild species *L. saligna* were developed for future research. The *L. saligna* accession used in these crosses was identified as immune to AZ isolates of the fungus causing powdery mildew.

Bolting resistant romaine. We made progress toward the development of bolting-resistant romaine. We developed 30 F_3 families with bolting resistance from the heirloom cultivar Blonde Lente a Monter. These families have the potential to be resistant to the diseases corky root, dieback, and *Lettuce mosaic virus*; the evaluation of these families for corky root, dieback, and *Lettuce mosaic virus* resistance through field testing, greenhouse testing, or molecular markers has not been completed. At the time of this report, there were no romaine cultivars adapted to this planting slot with this combination of characters. Therefore, if material is released from this population it would be the first of its kind. Release of bolting-resistant romaine germplasm is targeted for 2018 in the event that good performing inbred lines are selected from this germplasm.

We developed five inbred lines from crosses between Eruption and Siskiyou, or Valmaine. Some lines are additionally resistant to corky root and *Lettuce mosaic virus*; all lines need further characterization in multi-location trials to determine their suitability for release. Release of this bolting resistant romaine germplasm is targeted for 2016.

Tipburn-resistant romaine. The project began with 218 F_2, F_3 and F_4 families from crosses of numerous tipburn-resistant iceberg cultivars with adapted and commercially acceptable romaine cultivars, and 13 F_8 romaine type inbred lines from (Valmaine x Salinas 88) x Salinas. The goal of this project was to breed tipburn resistance from the iceberg cultivar into a hearting type romaine. At the time of this report, there were no hearting type romaine cultivars adapted to this planting slot with this combination of characters. Therefore, if material is released by this project it would be the first of its kind.

The F_8 breeding lines, which were targeted for release in 2011, were initially identified in project FB07-09 'Spring Harvested Lettuce Tipburn Resistance Research.' With additional field testing, the tipburn resistance in the F_8 lines was determined to be inadequate to warrant additional testing or release. Significant progress towards the research goal was made in families derived from the cross Green Towers x Salinas. From this cross we bred five F_5 closed-top, hearting-type romaine breeding lines (RH09-1513, -1526, -1562, -1565, and -1566; shown in Figure 3) that had significantly less tipburn than Green Towers in four field experiments. Molecular marker genotyping and field testing of parents or breeding lines indicates that these lines are not resistant to corky root, dieback, or *Lettuce mosaic virus*. These lines need further characterization in field experiments to determine if they are suitable for release, which is targeted for 2016.

Eleven F_3 families from crosses between the romaine cultivars Clemente, Darkland, or Green Towers to the iceberg cultivars Hallmark W, Tiber, or Sniper were developed by selecting tipburn-free romaine type plants. Molecular marker analyses indicate that these families also carry the genetic marker for dieback resistance and/or corky root resistance.

Figure 3. Five F_5 romaine breeding lines from the cross Green Towers x Salinas and the cultivar Green Towers in a Yuma, AZ field experiment. Planted December 15 images taken on April 6 by M. Chawner.

Conferences where research findings were presented.

Information, tools, and methods generated from this research project were disseminated to lettuce breeding programs and lettuce growers at the following research/industry conferences:
The SW Ag Summit in Yuma, AZ (March, 2010 and March, 2012). Each year had about 150 participants.

The Soil Fungus Congress (Davis, CA March, 21, 2011). There were about 100 participants.
The biennial meetings of the California Leafy Greens Research Program (Seaside, CA on Oct., 2009, Oct., 2010, Oct., 2011and Coalinga, CA on March, 2010, March, 2011, March, 2012). Each meeting had greater than 100 participants.

Promotion of released breeding lines.

Breeding lines developed by this project have not been officially released. The breeding research has not been completed or the release statements have not been finalized. Therefore, we have not begun monitoring of seed sales or distributing release statements to seed companies by mail or online.

Beneficiaries

Lettuce is the most valuable specialty crop grown in Arizona, grossing as much as 500 million dollars annually. Releasing improved cultivars that possess the combination of characters described in this report will lower production costs, which will increase the profitability of Arizona's agricultural economy. The beneficiaries of this research include lettuce growers, handlers, packers, shippers, seed producers, and consumers. Collection and reporting of quantitative data concerning beneficiaries is beyond the time frame of this project. However, our lines may be used by up to 400 growers on up to 10,000 acres resulting in seed sales of approximately three billion seeds. We will monitor seed sales using existing seed industry contacts and will report data as it accumulates. At the time of this report the lines discussed in this research had not been released and no benefits to lettuce growers, handlers, packers, shippers, seed producers and consumers have occurred. This project developed and provided information, tools, and methods that increase the rate at which new cultivars are developed for Arizona by public and private seed companies outside of the USDA. Information, tools, and methods generated from this research project was disseminated to lettuce breeding programs through the following research/industry conferences: biennial meetings of the California Leafy Greens Research Program (Seaside, CA on Oct., 2009, Oct., 2010, Oct., 2011and Coalinga, CA on March, 2010, March, 2011, March, 2012), The SW Ag Summit in Yuma, AZ (March, 2010 and March, 2012), and the Soil Fungus Congress (Davis, CA March, 21, 2011). Up to 30 institutions conducting lettuce breeding in Arizona may have benefited from receiving this information.

Lessons Learned

We utilized selected Yuma, AZ testing environments to expose genetic variation for priority traits in progenies from crosses between various parents identified as possessing one or more specific traits of interest. This was done in order to select genetically recombinant progeny with

new trait combinations. In general, the selected testing environments were successful at exposing genetic differences among plants, families, or lines. Recombinant progeny were selected with resistance to tipburn, premature bolting, Fusarium wilt and improved horticultural quality. The big-vein and powdery mildew projects failed to identify recombinant progeny with the desired combination of traits. The desired recombinants may not exist in the crosses used for these projects, and highlights the need to identify new sources of resistance, attempt breeding with genetically distinct populations, and to determine the genetic and biological basis of big-vein and powdery mildew resistance.

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Controlling Lettuce Drop Disease by Increasing Post-Application Survival of the Biocontrol Agent Coniothyrium Minitans

This project was completed on September 30, 2011

Project Summary

Disease management in lettuce production is a principal activity for all growers as viral, bacterial, and most importantly, fungal diseases can seriously impact yield. Of the four fungal diseases ranked as highest priority concerns among lettuce growers in the 2003 CA/AZ Lettuce Industry Strategic Plan, only lettuce drop seriously impacts all production regions. Lettuce drop is caused by two closely related soilborne fungi, *Sclerotinia sclerotiorum* and *S. minor*. Both fungi produce durable structures known as sclerotia, which function as survival structures and as disease inoculum in subsequent crops. A notable difference between these fungi is that *S. sclerotiorum* produces large irregular shaped sclerotia in low numbers whereas *S. minor* produces small spherical sclerotia in far greater numbers. Both fungi are present in the lettuce-growing areas of Arizona but the occurrence of *S. minor* has been increasing in recent years and is considered an emerging challenge to desert lettuce production.

There currently are no commercial lettuce cultivars with significant resistance to either *Sclerotinia* spp. and most management strategies rely on chemical control. However, chemical control is not complete and improvements in disease management are strongly needed. Considerable research has been devoted to evaluating biological control strategies for the management of *Sclerotinia* diseases in different cropping systems. Field trials conducted by Pryor in Yuma in 2001-2002 revealed only limited disease suppression in lettuce with most commercially available products. However, one product, *Coniothyrium minitans* distributed as Contans™, performed very well and superior to other chemical products tested. Studies by Pryor from 2002-2005 revealed that Contans was capable of reducing the incidence of lettuce drop due to *S. sclerotiorum* by over 95% even under high disease pressure. Interestingly, in the same trials, *C. minitans* had only a limited effect against lettuce drop caused by *S. minor*.

The reasons for reduced effectiveness of *C. minitans* against *S. minor* are not known. Our previous work revealed that the sclerotial exudates that stimulate *C. minitans* parasitism are similar between the two *Sclerotinia* spp. and the biocontrol agent parasitizes both pathogens equally in the lab. However, it is suspected that the large numbers of sclerotia produced by *S. minor* in the may impact the ability of *C. minitans* to effectively parasitize all. Moreover, our work has shown that post-application survival of *C. minitans* in Arizona soils is low, which may further impact complete parasitism by *C. minitans* using standard application rates.

The results from our recent lettuce field trials, 2006-2008, revealed that high application rates of Contans (5X) completely controlled lettuce drop caused by *S. minor* even under high disease pressure. This level of disease suppression has never been achieved previously with any other biocontrol or chemical agents against *S. minor*. However, the high application rate is not economically viable option for commercial production. Therefore, additional studies are needed to examine environmental factors that impact survival of *C. minitans* in soil, and to optimize application methods for Contans to increase survival rates in the field following application.

Project Approach

The specific objectives were: 1) to conduct laboratory-based studies to determine the specific impact of several environmental parameters on the survival of *Coniothyrium minitans* spores (the form present in commercial formulations) on soil surfaces; and 2) to conduct field-based trials to optimize Contans application techniques to reduce post-application mortality of the biocontrol agent under field conditions.

Objective 1: Experiments were conducted to test the survival of *C. minitans* spores when exposed for varying times to 1) varying temperatures, 2) desiccation, 3) UV irradiation, and 4) native soil microbial communities. Suspensions of fresh *C. minitans* spores were applied to the surface of sterile or non-sterile soil held at varied temperatures (20-40C), varied water conditions (wet vs dry), or varied UV exposure (UVA, UVB, UVC). Soil used for these experiments was collected from agricultural fields in Yuma, AZ. The inoculated soil was held for 48 hr under each condition and sampled periodically at specific hour times (t=0, 1, 6, 12, 24, 48). Sampled soil was plated on *C. minitans* semi-selective medium and incubated for 5 days. The experiments were replicated 3X and resulting *C. minitans* colonies were enumerated. Data was analyzed using PROC GLM (SAS Institute) to perform ANOVA.

Objective 2: In order to evaluate the efficacy of application of Contans through overhead irrigation, trials were conducted at Yuma Agricultural Research Station, Yuma, AZ. Trial were set up in a RCBD with 3 blocks. Prior to planting, sclerotia of *S. minor*, produced in the lab, were broadcast on the tops of each bed at high and low inoculum levels to allow the examination of Contans performance under both high and low disease pressure. The head lettuce 'Winterhaven' was then be planted with using standard planting equipment and seed densities, and trials maintained using standard agricultural practices for lettuce. Contans was prepared as per manufacturer's recommendation and applied two times: one at planting and one at immediately after lettuce thinning. One application was through overhead sprinkler lines during irrigation. All other applications were applied over-the-top using standard back-pack sprayers. After each over-the-top application, sprinkler irrigation was initiated following varying delays from 1 hr, 6 hrs, 12, hrs, 24 hrs, and 48 hrs to test the impact of post-application drying on

product viability. Additional treatments consisted of a control and the fungicide Endura™ for comparison with a standard chemical product. At harvest, disease incidence, average head weight, yield, and survival of *C. minitans* were recorded from each plot. Data were analyzed using PROC GLM (SAS Institute) to perform ANOVA.

The proposed project began in October 2009 and continued for two years. Each field trial began with lettuce planting in mid-November and continue until early March. The lab-based studies began in December following the field trial set up, and were continued for the duration of the project. Data analysis is ongoing and will finish up in March 2012. Manuscript preparation for both studies will follow data analyses. A graduate student conducted all lab and field studies with the help of undergraduate lab assistants. The field based studies were conducted in coordination with the Yuma Agricultural Center. The PI oversaw all lab and field work and budget issues, and initiate and supervise manuscript preparation.

Goals and Outcomes Achieved

Laboratory-based studies. *C. minitans* spore sensitivity to heat in soil and water was determined by exposing spore suspension (CONTANS™ and strain 0959) in sterile soil (autoclaved 4 h at 121°C) and spore suspension in water, incubated in chambers at 10, 20, 30, 40 and 50°C, during 24 h. Three replications were used per temperature. Plating dilution method in a fixed volume of 0.2% Water Agar and APDA media every 8 h, was used to determine number of colony forming units (CFU) after 5 days to calculate percent spore survival. For UV radiation sensitivity 15 ml of spore suspension kept in open petri-dishes were placed within a closed chamber under UVA and UVC sources for different periods of time. Three replications were used for each exposure time. The source of UVA were two 40W GE UVA light bulbs (368 nm), irradiance set at 6.0 W/m^2, and for UVC, five 15W light bulbs (254-nm) in a UV Crosslinker (Stratalinker® 2400) irradiance set at 40 W/m^2. After irradiation, plating dilution method in a fixed volume of 0.2% Water Agar and APDA media was used to determine the number of CFU after 5 days.

Field-based studies were conducted at the Yuma Research Agricultural Center, in Yuma AZ. Sclerotia of *S.minor* were prepared in the laboratory. Sclerotia were placed at the top of each bed at two inoculum levels (6.6g/120ft and 13g/120ft), to evaluate CONTANS™ performance at high and low disease pressure. Experimental design consisted of a randomized complete block design (RCBD). Treatments were applied after planting and included: one over-the-top CONTANS™ application, one application through the sprinkler system, applications delaying irrigation initiation at 24 and 48h to evaluate the impact on product efficacy, one application of Fungicide Endura™ (after thinning) and control plots. Diseased lettuce crops were scored at the end of the growing season to determine disease incidence. Results were analyzed by Two-way Analysis of Variance (ANOVA) to determine significant differences between treatments. Statistical significance between means of different treatments was calculated using Tukey HSD comparison test (SSPS). Field trials have been conducted during two years: 2009-2010 and 2010-2011. A third year field trial (2011-2012) is underway.

Outreach. Following completion of our field and lab based studies in March 2012, a peer review manuscript will be written for publication in a scientific journal. The target journal will be Plant

Disease, which reaches international audiences in both academic and industry circles (academic impact factors of 2.4). The annual distribution of this journal is not known, however, after 6 months in press, all manuscript in Plant Disease are open access on the web. Preliminary writing has begun with completion and submission expected in Oct 2012. We have high hopes for this manuscript and do not expect problems during the review process. Without problems, final publication is expected in Dec 2012.

Progress on the development of the project website has been slow due to difficulty in getting qualified personnel on the project. Currently the website is being revised and is under password protection until the revision is complete. We have recently lost the second student employed to work on the website and are looking for a final employee to add the finishing touches. Additional input to the website from other University extension personnel has been proposed but to date most faculty have stated they haven't the resources/time to contribute at the moment. We are hopeful that future contributions will be forthcoming. No tracking of website visits has been conducted to date.

Other proposed outreach was presentations at the SW Agricultural Summit held each year in Yuma. Each year we have proposed our participation and each year the speaker itinerary is filled by other presenters, presumably due to specific agenda objectives. And finally, our proposed bulletin highlighting the results of our project has not yet been developed. This effort was to be developed along with our web development and as we have had difficulty in that activity, the information bulletin did not advance. Moreover, our distribution of the information bulletin was supposed to be promoted at the SW Agricultural Summit. As our participation in that summit was never accommodated by event organizers, our primary outlet for distribution did not emerge. Perhaps we needed to work these activities in reverse and first distribute the bulletins. In this manner, perhaps then our presence at the Ag Summit would be sought out rather than our group having to request the opportunity to present. In any event, as our website develops we will develop content for the bulletin as planned and target distribution before the beginning of the next cropping season in 2013.

Laboratory based studies proved environmental factors such as heat, desiccation and UVA and UVB radiation have a negative impact on the ability of CONTANS^{TM} spores to germinate, reducing the product efficacy. Optimal temperatures for *C. minitans* spore survival remained at 20 and 30°C in water and in soil during first 8 hours after application. Field-based studies revealed that one application of CONTANS^{TM} through the sprinkler system ("biogation") resulted in a 25% decrease in the incidence of disease, compared to either 8lb/acre CONTANS^{TM} or fungicide (Endura) treatments. Results suggest that application of product via biogation may be a novel strategy for enhanced performance of *C. minitans* in the biocontrol of lettuce drop caused by *S.minor*.

For laboratory-based studies, all planned studies were completed by March 2012. For field-based studies, an additional third year (2011-2012) field trial was initiated in November 2011 at the Yuma Agricultural Research Station. Special irrigation equipment required from the previous field trials was still available and no additional procurement was necessary. Results of third year field trial were obtained by March of 2012. An MS thesis written by the project graduate student

has been submitted to the College of Agriculture and Life Sciences, University of Arizona, and details all studies conducted. A peer-reviewed manuscript, consisting of a combination of laboratory and field based studies has been prepared and is ready for submission to the journal Plant Disease.

Results from laboratory base studies concluded that exposure of *C. minitans* spores (from CONTANS™ and the pure strain 0959) to heat revealed a rapid decline in spore germination after 8h exposure to high water or soil temperatures. Less than 30% spore germination was observed after 8 hours in all temperatures and rapidly declined below 20% after 24 hours. Percent survival below 15% was observed at 40 and 50°C after 24 hours. Survival rates of spores in CONTANS™ and from the pure strain 0959 in water were higher than in soil, which remained above 35% after 8 hours. Exposure of *C. minitans* CONTANS™ spores and strain 0959 to UVA, UVB, and UVC radiation also revealed a negative impact on percent survival. UVC radiation had an adverse effect on *C. minitans* spore survival; less than 20% spore germination was observed in CONTANS™ spores after 10 minutes, whereas in strain 0959 spore germination was reduced to nearly 0% after 2 minutes. UVA radiation had the most pronounced negative effect on strain 0959 spores than CONTANS™; percent survival in CONTANS™ spores remained above 25% and declined below 10% in strain 0959 after 20 minutes. ALL UV radiation treatments caused a significant reduction in spore viability after 2 minutes of exposure, compared to its control.

In field-based experiments, increased application rates of commercial formulation of *C. minitans* – CONTANS™ improved control of lettuce drop caused by *S. minor*. Disease incidence in the control plot under high disease pressure was 37.36%. Field studies revealed that one application of CONTANS™ through the sprinkler system (biogation) resulted in a decrease of disease incidence at 26.24% compared to 28.94% with fungicide (Endura) treatment. Irrigation delay after 24h and 48h of planting caused a decrease in CONTANS™ efficiency, resulting in disease incidence of 31.48% and 39.32% respectively. A 48h delay in irrigation resulted in a disease incidence higher than the control plot, revealing the importance of proper irrigation practices after application of the bio-control product. Similarly, under low disease pressure conditions, disease incidence was lowest at 11.95% with one application of CONTANS™ through biogation method, compared to 27.37% in the control plot; and also revealed to be more efficient than Endura fungicide treatment at 13.14% or 8lb/acre CONTANS™ treatments at 14.21%. Irrigation delays of 24h and 48h proved to have a negative impact on bio-control product efficiency, even under low disease pressure conditions.

During second and third year field trials, similar results were observed and the data averaged. Disease incidence in the control plots were higher than the first year (up to 52.5% under high disease pressure). Two applications of CONTANS™ through the sprinkler system (biogation) resulted in a decrease of disease incidence at 40.4% compared to 39.3% with fungicide (Endura) treatment. Irrigation delay after 24h and 48h of planting caused a decrease in CONTANS™ efficiency, resulting in disease incidence of 45% and 44.4% respectively. A 48h delay in irrigation resulted in a disease incidence higher than the control plot, revealing the importance of proper irrigation practices after application of the bio-control product. Similarly, under low disease pressure conditions, disease incidence was lowest at 20.4% with two applications of

CONTANS™ through biogation method, compared to 50.5% in the control plot; and also revealed to be more efficient than Endura fungicide treatment at 29.8% or 8lb/acre CONTANS™ treatments at 24.8%. Irrigation delays of 24h and 48h proved to have a negative impact on bio-control product efficiency, even under low disease pressure conditions.

Beneficiaries

The beneficiaries of this activity are primarily the growers, although findings from this study have not yet been shared directly with this group. Rather, the findings have been shared, to date, with the University of Arizona Extension Specialist in Plant Pathology, Dr. Mike Matheron, who is based at the UA Yuma Agricultural Center. Through interaction and discussion with the Extension Specialist or the PI, area growers have access to research findings in advance of formal presentation in Plant Pathology and Biocontrol journals. No data has been collected as to the number of these discussions to date, and it has not been calculated how many growers have increased yields and less crop loss as a result of this project. Secondly, the consumers benefit by increased availability of lettuce and lower pesticide residues. However, it was not calculated how much of an increase in availability has resulted from increased yields, nor has it been calculated how much less pesticide has been used as a result of increased knowledge of biocontrol options. And thirdly, the citizens of rural Arizona and Arizona in general benefited from a more robust and profitable lettuce industry. The actual economic impact of this activity was not calculated.

The quantitative data derived from this project includes rates and methods of application of Contans to more effectively control lettuce drop caused by *Sclerotinia minor*. Growers can access this data immediately through informal discussion with the PI or with the University of Arizona Extension Specialist on how to improve disease management and increase yield for their lettuce growing operations. No data has been collected as to the exact number or dates of these discussions. Following final publication of these data in 2013 (manuscript is in preparation and drafts circulating among authors), the data will be easily available to all interested parties.

Lessons Learned

The primary lesson learned in this study is not so much a new lesson as it is an old lesson learned time and time again in applied research. That lesson is that field trials have inherent factors that are not absolutely controlled by the researcher. If a project plans for a single or two years of field trials, variability in each year may necessitate and additional year or two to statistically validate the findings. Often times these additional studies don't overlap neatly with the funding cycles, which can lead to delays in deliverables. These delays may result in final outcomes several years following the cessation of project funding.

There were no unexpected outcomes of this project. The need for additional field trials is not unexpected, but it is less than optimal.

Although the predicted goals have not been obtained to date, we are confident that they will be met following this final year of trials. These delays were not something that expedited problem solving could have prevented. They are simply the nature of field-based experimental trials.

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Additional Information

This project will insure the continued competitiveness of Arizona's winter lettuce industry by reducing losses to lettuce drop, and will insure the health-promoting aspects of the Arizona crop by reducing the amount of fungicides needed to maintain high yields. Although not specifically calculated in this project, it is reasonable to conclude that if Arizona's lettuce crop economically competitiveness has increased AND there are less fungicides applied resulting in a healthier product, THEN consumption will increase providing that the marketing side of the industry is performing appropriately and effectively.

Publications from this project are forthcoming. It is anticipated that this final year of research will result in a very comprehensive publication in the journal Plant Disease, which is the premier journal for presenting studies in applied plant pathology.

Developing RNA Vaccines to Manage Pepino Mosaic Virus

This project was completed on May 31, 2012

Project summary

Pepino mosaic virus (PepMV), an emerging tomato virus, presents a serious threat to sustainable tomato production in Arizona. PepMV infections during flowering and fruit setting severely affect tomato fruit quality and yield, leading to economic losses. Despite its significance, there are currently no effective means to control the viral disease. It has been observed that tomato plants can naturally recover from an early PepMV infection, and subsequently display little or no viral symptoms. This observation suggests that PepMV resistance in tomatoes can be induced by PepMV infection, and that the immunization of tomato plants may be a viable approach to control PepMV. This project proposes to explore the mechanisms of the induced resistance and to develop novel immunization approaches to induce the resistance. If the resistance is mediated by RNA interference, as suggested by previous research, tomato plants may be immunized against PepMV by a vaccine consisting of either a short fragment of the viral sequence or an attenuated PepMV strain. Both strategies are aimed at protecting tomato plants from PepMV infections with minimum or no risks. Completion of this project will provide an effective tool for growers to manage PepMV.

Project Approach

This project was proposed to develop novel approaches to immunize tomato plants against PepMV. Specific objectives were to determine if the naturally induced resistance in tomatoes is mediated by RNA-based immunity, and to develop two alternate vaccines that can effectively induce the resistance, protect tomato plants from PepMV, and eliminate the risk of late PepMV outbreaks.

To accomplish these objectives, we performed studies to determine if PepMV-induced resistance operated in PepMV-infected tomatoes and to ascertain if RNAi drives this resistance; constructed

infectious cDNA clones of PepMV, mutagenized the clones to create an attenuated strain that is less virulent and does not move well in the inoculated plants, and tested the possibility of using the attenuated viral strain as a PepMV vaccine. Our approaches for the project are summarized below:

Biological characterization of PepMV and the naturally induced resistance in tomato plants. To understand the biology of PepMV, we initiated experiments to determine the nature and the diversity of PepMV found in the Eurofresh Farms. Diseased samples were inoculated to Roma tomato, Mariachi tomato, and two additional experimental hosts, *Nicotiana benthamiana* and *N. clevelandii*. We tracked both the visual symptoms and the presence of PepMV in infected plants by RT-PCR over a period of 3 months to see if PepMV-infected tomatoes recovered from infection naturally. Although the severity of symptoms fluctuated over time from being apparent to being difficult to discern, PepMV was easily detected all the time. The symptom variations were apparently a consequence of tomato developmental stages and environmental factors, particularly light intensity, rather than a fundamental change in the amount of viruses in the infected tomato plants. PepMV-infected plants in greenhouse with high light intensity developed very light or no apparent symptoms while PepMV-infected tomatoes kept in the lab or in growth chambers with low light conditions developed pronounced mosaic and leaf bleaching symptoms. The biological characterization of PepMV was repeated twice and the results from both experiments were consistent. We concluded with certainty that PepMV-infected tomatoes do not naturally recover from the infection, contrary to what was believed.

To understand what PepMV strains are prevalent in Arizona, we designed two sets of universal primers that are capable of amplifying regions of any PepMV strains, and conducted experiments to determine the 5' and 3' terminal sequences of PepMV isolates collected from the Eurofresh Farms in Arizona. These experiments are crucial to the construction of the infectious PepMV cDNA clone and the engineering of a vaccine strain with attenuated virulence. In this project we cloned and sequenced 96 clones of the 5' terminal region and a region near the 3' terminus of PepMV genomes. Sequence analyses showed that PepMV in Arizona consists of a mixture of 2 strains: one strain similar to several isolates found in Europe with sequence identities of ~99% (European strain), and another strain similar to the US1 isolate with a sequence identity of 99% (US1 strain). The sequences of the two strains only share a sequence identity of only 85%. Only one of the 96 clones sequenced was found to be a recombinant between the two strains, indicating a very low frequency of recombination in PepMV. Within each strain, there is a small degree of sequence variations, indicating that the population of each strain is homogeneous and that the PepMV strains may have been in the tomato plants for some time. We subsequently developed specific primers that can distinguish both strains and used them to test 24 samples collected from the Eurofresh Farms. All the samples apparently contained both strains, indicating that the mixed infection by the two strains is quite common.

Develop an attenuated, movement-deficient PepMV strain and test its usability as an RNA vaccine to cross-protect health tomato plants. In order to develop infectious cDNA clones, we used the 5' and 3' RACE (random amplification of cDNA ends) technology to determine the terminal sequences of PepMV strains. Sixteen RACE clones, eight from each strain, were sequenced. Two pairs of oligonucleotide primers were designed according to the newly obtained sequence for amplification of the entire genomes of the US1 and European strains using Phusion

DNA polymerase. The 5' terminal primers contain the T7 promoter sequence and the correct 5' terminal sequences of each PepMV strain. Two additional guanosine nucleotides have also been inserted between the T7 promoter sequence and the PepMV 5' terminal sequence to increase transcriptional activity of T7 promoter. The 3' primers contain stretch of 40 oilgo (dT) and a BamHI restriction site at the end. Each primer was tested in combination with another internal primer and was shown to bind to and amplify viral cDNA. The optimum annealing temperature for each of the primer was subsequently determined by temperature gradient PCR. We experimented with regular RT-PCR to amplify the full-length cDNA of approximately 5.4 kb in length; however the yields of the full-length cDNA of PepMV were very low.

We subsequently developed a novel technique and used it to clone successfully the full-length infectious cDNA. This technique consisted of two steps: initial reverse transcription of the full-length cDNA from viral RNA and then synthesis of the secondary strand DNA by the high fidelity Phusion DNA polymerase. The double-stranded DNA was then cloned directly into SmaI-linearized pUC18. A total of 23 PepMV infectious cDNA clones, 17 representing the US1 isolate and 6 representing the European isolates have been obtained with this technique. Infectious clones were linearized with BamHI enzyme and used as template for in vitro transcription by T7 RNA polymerase. Transcripts were inoculated to plants and symptom development on the plants was observed. A major finding was that the capping of the transcripts with a modified guanosine, methyl-7-guanosine, was a critical factor in the infectivity of the transcripts. We had contributed our previous troubles in getting highly infectious transcript to primer designs and potential mutations during cloning, but this turned out not to be the case. Capped transcripts were much more infectious than non-capped transcripts. Among the 23 clones tested, more than half are highly infectious.

Experiments with the infectious cDNA clones revealed an important observation: the variability in pathogenicity among individual PepMV clones. In general, the US1 clones were more pathogenic than the European clones. Even among the US1 strains, some clones produced more severe symptoms than others. Using clones of less virulence, we mutagenized 2 clones each of the US1 and the European strains, and obtained one attenuated clone from each strain that showed no apparent symptoms on infected plants. We also inserted a green fluorescent protein (GFP) gene into one of the attenuated strain in order to track visually its infection under UV light microscope. RT-PCR tests confirmed that the plants were fully infected with these mutants. In order to find out if the attenuated strains can act as an RNA vaccine and cross-protect tomato plants from the wild type PepMV strains, tomato plants were inoculated with the attenuated strains, and then challenged with strains of full virulence 7 days later. Two weeks later, inoculated plants were harvested to test for the presence of the protecting and the challenging PepMV strains. Experimental data showed that the attenuated strains were able to protect the tomato plants when the induction viral strain and the challenge viral strain were inoculated to the same leaf. When the challenge strain was inoculated to younger leaves, however, only about 50% of the inoculated plants were free of the challenging strain. These results together indicate that the attenuated strains of PepMV have potentials to act as an RNA vaccine and protecting healthy tomato plants from infections by more severe PepMV strains. Additional research is needed to optimize the use of these attenuated PepMV strains as RNA vaccines.

Goals and Outcomes Achieved

Goal 1: Determine if RNAi is involved in the naturally induced resistance in tomato plants. At the start of the project, it was unknown what strains of PepMV infect tomatoes in Arizona and it was thought that PepMV-infected tomatoes recover naturally from the viral infection via possibly an RNAi-mediated resistance. Through the analysis of 96 clones of PepMV, we identified two PepMV strains, the US1 and the European strains, that co-infected tomatoes in Arizona greenhouses. We also found that is a certain level of genetic diversity of these two strains, indicating that they have been in existence in greenhouse tomatoes for some period of time. The biological characterization of PepMV infected tomatoes has indicated that the infected plants **do not recover** from virus infection as previously reported, although the symptoms fluctuate as a function of growth stages and light intensity. PepMV-infected tomatoes display little or no obvious symptoms most the times of the year in Arizona. Therefore RNAi-mediated resistance does not occur in the PepMV-infected tomato plants as previously believed. Experiments performed in this project fully completed the objectives in Goal 1.

Goal 2. Construct immunization vectors that deliver a PepMV sequence fragment and induce PepMV resistance in tomato plants. Experimental results from Goal 1 indicated that PepMV-infected tomato plants do not naturally recover from PepMV infection, suggesting that RNAi-mediated resistance against PepMV does not operate naturally in tomato. For this reason, experiments planned for this goal were not performed as they were formulated on the premise that RNAi-mediated resistance against PepMV occurs naturally.

Goal 3. Develop an attenuated, movement-deficient PepMV strain and test its usability as an RNA vaccine to cross-protect health tomato plants. At the onset of the project, there were no infectious clones for the European and US1 strains of PepMV, and there was no research indicating that attenuated strains of PepMV could provide protection to tomato plants again infection by wild type PepMV strains. Through this project, we constructed 23 infectious clones of the two PepMV strains that occur naturally in Arizona. Biological characterization of these clones showed variations in pathogenicity of individual infectious clones. We mutagenized two least virulent clones and made them incapable of moving systemically in the infected plants. Inoculation of tomato plants with the attenuated strains followed by challenges with the wild type PepMV indicated partial protection of the tomato plants by the attenuated strains. The successful construction of infectious cDNA clones has enabled us to molecularly separate two PepMV strains, which is impossible by biological or physical means. This has allowed us to determine that each strain can independently contribute to the tomato disease with different degree of severity. Attenuated strains of PepMV that cannot move from infected cells to neighboring cells has been shown to provide a limited degree of local protection as a vaccine in the inoculated leaves, but only partial protection in the entire plant. Objectives set in Goal 3 were mostly met. However, the protection provided by the attenuated PepMV strains was less than desirable. This may be caused by the constraints of the biological system, or by the less than ideal attenuated strain used in the protection experiments. Either way, additional research is required to answer these questions. We plan to engineer other attenuated strains of PepMV that can spread more widely in the inoculated plants and to test their efficacy in systemic protection as PepMV vaccines. This additional research will continue as a part of on-going project on engineering PepMV as a vector to deliver vaccines against *Tomato chlorotic dwarf viroid*.

Partial results from this project were presented as a poster in the American Phytopathological Society 2011 Annual Meeting. The meeting was attended by more than 1600 scientists, educators, and industrial representatives including tomato growers. The poster described the analysis of sequence diversity of the PepMV in Arizona and the progress in the cloning of the full-length infectious cDNA of the two strains of PepMV. More than 500 people were present at the poster presentation. A portion of the project results was also presented in the 2012 Undergraduate Poster session at the University of Arizona. Over 100 students and faculty members viewed the posters. The research results were also presented in the 2011 SCBGP Oral Presentations in Phoenix, and attendants included tomato industry representatives. However, the planned presentation of this research project was not made in the 2010 annual Maricopa Agricultural Center Field Day, due to a scheduling conflict.

Through these presentations, we informed tomato growers that PepMV did not cause noticeable disease on tomatoes in Arizona, due to the high light intensity here. This is contrary to what have been reported in Europe where PepMV is a significant disease. Therefore, less attention should be paid to this viral disease, and more management resource should be allocated to more damaging diseases in tomato. This will enhance efficiency of tomato production in Arizona.
Additionally, growers have learned that PepMV infectious cDNA clones developed in this project will have many potential uses. They can be used as an expression vectors to deliver vaccines against other diseases of tomatoes, such as *Tomato chlorotic dwarf viroid*. They can also be used to express vitamins, human edible vaccines, and antioxidant that will further enhanced the nutritional and economic values of tomatoes in Arizona.

Beneficiaries

The primary beneficiaries are tomato growers in Arizona, particularly greenhouse tomato growers. Tomatoes are ranked as one of the top ten Arizonan commodities with an output of 3,789,748 cartons in 2010. The tomato industry contributes to the economy of the state and provides job opportunities to many Arizonans. For example, the Eurofresh Farms, the largest tomato grower in Arizona with 318 acres of greenhouses, has over 1,000 employees on its payroll and estimated annual revenues of over of $160 million.

Lessons Learned

The completion of this project allows us to fully understand the biology and the impact of PepMV in tomato production in Arizona. While the disease causes considerable yield losses in Europe, it is not major factor in tomato production in Arizona, due to plenty of sunshine. While it was thought that tomato can naturally recover from PepMV infection, our experimental data indicated that this was not the case. The symptom remission was due to high light intensity, rather to a natural resistance. Through many failed experiments, we also learned the value of adding methyl-7-guanosine cap in the production of infectious cDNA transcripts of PepMV and related viruses. The availability of infectious cDNA clones of the mild strains of PepMV will prove to be valuable tools in research and in tomato production.

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Additional Information

Publications:

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Enhancing Arizona Vegetable IPM

This project was completed on September 30, 2010

Project Summary

Continual maintenance of existing Integrated Pest Management (IPM) programs and implementation of new reduced-risk technologies will be essential for sustaining economically and environmentally sound production of high value vegetable crops in Arizona. Because "all IPM is local" the knowledge base necessary for training young Pest Control Advisors (PCA) and implementing new IPM approaches must be developed specifically for desert growing conditions. Although the University of Arizona Cooperative Extension is recognized as a leader in outreach education for desert vegetable crops, resources to sufficiently support IPM educational programs are scarce. The objective of this project is to install a new Extension educator. This person will assist the Vegetable IPM team in the production of educational materials, workshops, meetings and grower demonstrations to: increase awareness and technical knowledge of IPM among target audiences, increase use of IPM tactics and reduce pest levels and reliance on routine pesticide use among adopting growers, resulting in human health and environmental benefits.

Project Approach

The objective of this project was to synergize the University of Arizona's outreach efforts in Vegetable IPM by strategically investing in an extension educator to assist team members in delivering and demonstrating IPM in local high value, vegetable production systems. The extension educator, Mr. Marco Pena, was hired in late November 2009 at a 1.0 FTE, half of

which was funded by this project. The extension educator initiated and participated in a number of project activities in association with the core team members. The Vegetable IPM team members, who are responsible for the majority of the educational materials and activities, include Dr. John Palumbo, Extension Entomologist; Dr. Mike Matheron, Extension Plant Pathologist; Mr. Barry Tickes, Area Weed Specialist, and Dr. Kurt Nolte, Area Vegetables Specialist.

The most significant activity in which the educator has been engaged was in the development and implementation of a new outreach system for delivering timely and relevant information to our varied stakeholders through our Vegetable IPM Updates. During this project the Vegetable IPM Team delivered 25 updates that provided new and timely information to vegetable growers and PCAs with the assistance of our extension educator. These email messages contained information on insect, weeds, diseases and market activities that are presently occurring in Arizona. Each update contained at least one electronic .pdf document available on our website that contains recently developed research information addressing a local pest problem. These updates have been sent to PCAs, growers and other agribusinesses every two weeks since early January 2010. The updates can be found at http://ag.arizona.edu/crops /vegetables /advisories /advisories.html.

The extension educator has worked with the Arizona Vegetable IPM team members on setting up and participating in field translational research and on-farm demonstrations with cooperating vegetable growers in the Yuma county area. Several projects that were completed during this project included four herbicide demo trials for melons and broccoli, and two large translational research projects which focused on aphid control and monitoring the use of reduced-risk insecticides .

The Vegetable Team, with the assistance of the extension educator, participated in the development and publications of miscellaneous extension publications that have been provided on-line via our Arizona Crop Information internet site http://ag.arizona.edu/crop/. The team also successfully organized and participated in numerous educational meetings including the Lettuce Insect, Disease and Weed Workshop held in April, the Melon Insect, Disease and Weed Workshop held in July and the Desert Vegetable Workshop held in Aug which had a stakeholder attendance of over 150.

The extension educator has also produced a number of video demonstrations on herbicide mode of action, pesticide application through drip irrigation for inclusion, insect sampling and is currently working on another for foliar pesticide applications. These videos and other can be found on our Vegetable IPM Video Archive page which contains a collection of educational videos from current research work in vegetable crops by University of Arizona Researchers. http: //ag.arizona.edu/crop/vegetables/videos.html. Finally the extension educator has been engaged with numerous stakeholders soliciting input for identifying their IPM needs/priorities as well as feedback on the relevance of our deliverables.

Goals and Outcomes Achieved

Our primary expected outcome for this project was to increase awareness and technical knowledge of IPM among target audiences. Based on the activities described above, the Vegetable IPM Team and the extension educator achieved these goals by producing and delivering numerous educational materials, workshops, meetings, and grower demonstrations. A total of 23 continuing education units (CEUs) were provided by the team during this project with attendance at these meeting ranging from 30 to over 250 attendees, which is a significant increase to the usual meeting attendance which rarely exceeded 100 participants.

An increase of awareness has also been demonstrated by the number of subscribers to our VegIPM Updates over the course of the last 12 months. When we initiated the project in January 2010, our list serve contained 172 emails addresses. At the completion of the project in December 2010, the email list serve contained 385 addresses who receive our bi-weekly update. This list continues to grow weekly. In addition, upon request from 2 popular regional publications, our IPM Veg updates are published bi-weekly on their websites which cater to stakeholders throughout the west: the Western Farm Press, http://westernfarmpress.com, and the Western Agri-Radio Network, http://www.westernagri-radio.net/index.htm. These publications reach well over a 1000 subscribers. In addition, we receive positive feedback on the information we provide via these updates. Most of the comments are very complimentary and inform us that the information is constructive to the daily activities of the growers and PCAs who view the updates.

Our long term expected outcome was to increase the use of IPM tactics. We have begun to measure this outcome though the Insect, Disease, and Weed Losses Workshops described above. To date we have collected baseline data on sampling, pesticide usage, threshold usage and profitability that will allow us to measure changes in grower behaviors in the IPM tactics they adopt. We have collected data on sampling, IPM tactics and pesticide usage. We will continue to run this program for the next 3 years using funding form SCBGP and USDA-NIFA funding received in 2010. At the completion of those programs we will have adequate data to measure the success of this outcome.

Beneficiaries

The stakeholders who directly benefitted from this project include vegetable growers, PCAs, vegetable seed representative, Agri-chemical Industry representatives, and miscellaneous agribusinesses. The impact of this project on the beneficiaries is easiest measures by the significant increase in attendance at educational meetings and the rapid growth in our list serve for our VEG IPM updates, which increase 2-fold during the project. The number of positive comments by our stakeholders concerning the updates is also a positive measurement of the relevancy of our activities. The fact that 2 large regional agricultural publications also requested to use our updates indicates the value in the outcomes of this project. The economic impacts of this project are difficult to measure at this time, but will be clearly quantified once we have collected additional data over the next 3 years through our Insect, Disease, and Weed Losses Workshops.

Lessons Learned

The most helpful lesson learned from this project was that it pays to be creative. Prior to this project we were searching for a new mechanism to deliver timely and relevant information to our stakeholders. We knew that smart-phone and laptop computer technology was being employed by growers and PCAs in the field, so we went with the idea that rather than have them come to us for information, we would go directly to them via email updates. This was popular in the past via USPS mailings, but was slow and information was often outdated by the time it was received. We had no idea that this concept would be so easily implemented, so well received and so highly appreciated by our clientele.

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Additional Information

It is not clear if this project has directly enhanced the competitiveness and/or increased consumption of Arizona specialty crops. However, given the feedback we have received from our stakeholders via conversations, emails, texts and phone calls, we are confident that this project has had a significant positive impact on the vegetable industry in Arizona.

For a complete access to the Veg IPM Updates and associated publications/videos, please go to:
http://ag.arizona.edu/crops /vegetables/advisories/advisories.html

Identification and Distribution of Beet Curly Top Related Viruses

This project was completed on September 30, 2010

Project Summary

Leafhopper-transmitted *Beet curly top virus* and related viruses known as curtoviruses can cause significant losses to vegetable growers in Arizona. *Beet curly top virus*, has over 300 known hosts including common beets, peppers, tomato, watermelon, cucurbits as well as many weeds. In spring 2009, a new curtovirus, *Beet severe curly top virus*, was identified in spinach fields in central Arizona with losses greater than 25%. Little is known about the identity, distribution, host range, symptom expression, disease severity and over-seasoning hosts of curtoviruses in Arizona. The objectives of this project are to identify *Beet curly top virus*, determine its distribution across Arizona, determine disease incidence, and distribute the results of this project to producers in Arizona. Weeds are ideal hosts for both viruses and beet leafhoppers, but very few weed hosts have been identified. Surveys to determine curtovirus incidence in spinach growing areas in Arizona and to identify their alternate hosts would allow growers to implement appropriate weed and insect control strategies to minimize the potential for a severe outbreak of curtoviruses that may significantly reduce yields in spinach and other vegetables.

Project Approach

From October 2009 to April 2010 spinach, beet and chard leaf samples with and without viral symptoms were collected from sites in Phoenix, Eloy and Yuma where leafy greens and spinach are routinely grown. A total of 170 samples were collected for testing and included 64 alfalfa samples and 41 weeds in three leafy green growing regions. DNA was extracted from all samples and was tested for the presence of curtoviruses using specific primers. The amplified PCR products were sequenced at The University of Arizona's sequencing core facility in Tucson, AZ and the sequences were run in a BLAST search in GenBank database to compare with other curtovirus sequences.

The samples collected from Yuma, AZ had the fewest virus infected samples with only 14% of the spinach samples and one chard testing positive. None of the tested alfalfa was positive. There were no weeds to test in the vicinity of the fields.

The Phoenix location had the highest rate of infection with 94% of the red and golden beets, 70% of the chards and 93% of the spinach. The beets had severe symptoms consistent with curtovirus infection that resulted in severe yield losses, the chards had mild symptoms and the spinach had no symptoms. The viruses were identified as Beet severe curly top virus and in one beet as a recombinant of Pepper curly top virus, Beet mild curly top virus and Pepper yellow dwarf virus. The Beet severe curly top virus was detected in the curtovirus-positive alfalfa (57% of the samples) samples tested from two fields within five miles to the northwest of the beet field and in weeds (50% of the samples) surrounding the beet field. Alfalfa was included in the sampling as an alternate host in addition to weeds surrounding the fields when numerous beet leaf hoppers were found in an alfalfa field in Phoenix near the field with beets and spinach. A final survey was conducted in early September 2010 of weeds near newly planted or ready to plant leafy green fields, but no curtoviruses were detected. No beet leafhoppers were observed at this time.
The Eloy location had 12% of the spinach, 50% of the weeds and 15% of the alfalfa testing positive for curtoviruses. Tests of weeds from Eloy and Phoenix revealed four new hosts in addition to the well known hosts, London rocket (*Sisymbrium irio*) and *Chenopodium* and *Amaranthus* species. The new records are *Fumaria capreolata*, *Tidestromia lanuginosa*, *Melilotus indicus* and *Funastrum hirtellum*. None of these weeds have been known as curtovirus hosts previously according to the literature.

The low incidence of curtovirus in Yuma may be due to the lack of weeds surrounding the fields and insecticide application in the alfalfa fields. No leafhoppers were found in the Yuma fields, but numerous leafhoppers were found in the alfalfa fields in fall 2009 in Phoenix. The reduced curtovirus incidence in Eloy could be the result of the delayed 2009 seeding and improved weed control. The seeding was delayed by six weeks compared to 2008 which may have allowed the spinach to escape a major infestation with beet leafhoppers. In addition, the virus found this year in Eloy was different from the one last year. It is currently unknown if different curtoviruses affect spinach varieties differently.

Both partners in this project were active in collecting samples from the field and in writing publications about the results of the project. Dr. Olsen added the results to information available on the Extension Plant Pathology website. Dr. Nischwitz performed all of the DNA analyses and

identified the curtoviruses in samples. She is credited with finding new host species for the viruses.

Goals and Outcomes Achieved

The activities of this project included the collection of suspect and symptomatic plants and the characterization of the curtoviruses found, or not found, in those plants according to location. These results have been reported on the internet on the Extension Plant Pathology website on the page for spinach diseases:
http://ag.arizona.edu/PLP/plpext/diseases/vegetables/spinach/spinbctv.html

Results were also published a first report on curtoviruses in Arizona in Plant Health Progress (doi:10.1094/PHP-2010-0216-01-BR). This publication is directed at both lay and scientific audiences, and thus has the potential to reach interested growers, industry representatives and scientists throughout the world. Descriptions of the viruses found and images showing symptoms in the field are available in both the publication and on the web site.

An up-to-date extension bulletin on beet curly top virus and its variants in Arizona is in preparation. Because of the lag time for the results from peer review of Extension bulletins and from a backlog of information to be added to the CALS Publication web site due to reduced staffing, the web page was updated first. Once completed, the bulletin will be directly distributed to 10 commercial producers and 10 pest control advisors in the vegetable industry and in small farm or garden production. In addition, Horticulture Extension Agents will have the bulletin available for homeowners and small growers who historically have had the most inquiries about "curly top"; a readily available bulletin (hard and electronic versions) will be a welcome addition for their distribution from county offices. The time line for bulletin publication has been necessarily moved from the end of 2010 to summer 2011.

Survey of pest control advisors. Ten pest control advisors in Arizona will be surveyed one year after the bulletin has been published (or in fall 2011) to determine how often they used the bulletin, passed information from the bulletin or the bulletin itself on to commercial growers and small farms. It has been the experience of the PI (Olsen) that most pest control advisors and growers do not use the internet for this kind of information, and this will be a test of that viewpoint. Many USDA Specialty Crop grants rely on using web sites for the extension component of the project, and there is little evidence that this avenue is effective at all. We have made an effort to meet with pest control advisors in the field or at meetings and talk to them directly – this communication has had an impact. At least three major growers have changed planting dates, sites, and/or weed control strategies, as well beginning variety selections, as a result of the face-to face interaction.

Diagnoses of Curtovirus by commercial lab(s). Availability of diagnosis of BCTV variants in spinach and other leafy greens for all growers in Arizona is necessary to make the information we present useful. At least 5 BCTV symptomatic samples will be sent to commercial lab(s) in spring 2011 and/or fall 2011 and successful detection recorded. The goal is to detect curly top related viruses in infected samples 100% of the time; if not, we know we must work with

scientist at the commercial labs and/or make recommendations to clientele on where successful sampling has been reported.

Beneficiaries

The beneficiaries of this research are indirectly all the growers in the three sampling areas that grow leafy greens and spinach. Key personnel, including three pest control advisors that deal with the curly top disease in leafy greens in central Arizona, have been kept up to date about the disease. Changes in planting date and weed control are a result of this research and a direct benefit to growers.

Lessons Learned

An unexpected outcome was the discovery of several new variants of the Curtovirus group in the leafy greens and of new host plants that are important in the ecology of the disease. The most outstanding of these is the presence of the curtovirus in alfalfa. This discovery alone is an important contribution of this project to management of crops to avoid disease.

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Additional information

Competitiveness of production of spinach and leafy greens has been enhanced by application of findings of seasonal disease incidence of different curtoviruses and new alternate hosts. Growers have changed cultural practices to avoid disease, resulting in a more profitable crop in Arizona that out-competes the same crop in another state.

Results of this project were presented to the Curtovirus Working Group, funded by USDA that meets every year to discuss new and continuing research on this disease problem. This interaction is a valuable tool for coordinating regional information. Both partners attended the 2009 meeting, interacting with scientists from the western states.

Improved Phosphorus Fertilization Practices for Desert Cool Season Vegetables

This project was completed on September 30, 2012

Project Summary

Cool season vegetables produced in the desert receive large annual applications of phosphorus (P) fertilizer. Amounts of P applied to vegetable production systems often approach and exceed 200 kg P/ha and crop recoveries of P fertilizers are generally less than 25%. While much of the added P is converted to insoluble forms in the calcareous soils of the region (Porter and Sanchez 1992; Sanchez, 2007), some of it is carried in runoff and drainage water into receiving surface waters having adverse ecological effects (Izuno et al., 1991; 1995).

Over the past two decades, desert vegetable growers have been disinclined to reduce P inputs in agricultural systems due to large crop yield and quality responses and low fertilizer costs. However, erratic fertilizer pricing over the past three years has created incentives for improved efficiency. Approximately one year ago, the costs of mono-ammonium phosphate (MAP), a formulation widely used for desert vegetable production, exceeded $1,200.0 per ton. Although costs have since declined, rapid increases are anticipated as the world economy recovers and resource demand in the developing world regains momentum. World P reserves are rapidly declining and there is concern that a shortage of P fertilizers will ultimately compromise world food production (Vaccari, 2009).

In addition, P fertilizers are a major source of cadmium (Cd) and uranium (U) input to agricultural systems. Recently, maximum levels of Cd in food crops are regulated in the European Union and regulations elsewhere are likely. The contents of Cd and U in P fertilizers used in the desert approach 150 mg/kg and 200 mg/kg, respectively, and a reduction in P fertilizer inputs may be required to reduce Cd and U exposure through food.

Research conducted in areas outside the southwestern desert has shown that a number of fertilizer management practices can be used to reduce P fertilization rates required for optimal crop yield and quality (Sanchez, 1990; Sanchez and Hanlon, 1990; Sanchez et al., 1990; 1991, 1995). These practices include soil test based fertilizer recommendations and exploitation of innovative placement technologies. Thus, abundant opportunities exist for improving P fertilizer use efficiency of cool season vegetables in desert crop production systems. The objective of this project was to evaluate a number of P fertilization practices that reduce fertilizer costs to growers without compromising production. These studies have generated the data to improve P utilization efficiency in lettuce, broccoli, and cauliflower by 40%.

Project Approach

These studies involved field experiments which evaluated and demonstrated soil testing based fertilizer recommendations, directed placement methodologies, and alternative P formulations aimed for greater efficiency and reduced costs. We will initiated field experiments in fall 2009 and complete them in spring 2011. Experiments performed at the agricultural center were randomized complete block with four replications. Experiments were also performed in grower fields. Treatments included alternative P fertilizer management practices based on soil tests and modified by placement methods. Crops were harvested at maturity by cutting and weighing all marketable portions from 20 ft of double row beds. Plant tissue and soil test were performed as needed throughout the season. Marketable yields were determined after grading using standard practices. Data were evaluated using appropriate statistical models.

Goals and Outcomes Achieved

We have generated data in this project to revise soil test P fertilizer recommendation for lettuce, broccoli, and cauliflower. We have shown that there is approximately a 40% improvement in P use efficiency when fertilizers are applied band applied versus broadcast application. We have demonstrated benefits to starter P application. When soil tests approach or exceed 30 ppm, only a starter P application is required. These data are being disseminated to producers in an ancillary outreach program. Many producers have reduced P inputs based on the findings in this project.

As outreach activities continue we anticipate we will achieve our goal of an overall improvement of 40% in P use efficiency by the industry at large.

A subset of the data is shown. Overall, we found that crops response to P can be accurately predicted by pre-plant soil tests (Figure 1). Relative yields of lettuce were as low as 20% where soil test P levels were close to 20 ppm but approached 90% to 100% as soil test P levels increase above 30 ppm. The common practice of applying 600 kg/ha MAP, regardless of soil test P level, cannot be justified in light of the effectiveness of soil tests in assessing plant available soil P and the erratic costs of P fertilizer. We revised P fertilizer recommendations based on these results (Table 1). The examples shown are for lettuce but we have similar data for broccoli and cauliflower. Further, from studies on our research farm, and experiment-demonstrations conducted in grower fields, we found that when soil tests are high maximum yields can be obtained by a starter fertilizer alone (Figures 2 to 4).

Based on these studies, as well as others funded from other sources, we found, however, a composite soil test does always capture in-field soil test variability (Figure 5). Developing variable rate P placement technologies was beyond the scope of this study but we have obtained funding from another source (CDFA-FREP) to pursue these objectives.

As part of these studies we also evaluated technologies aimed to improve P use efficiencies. In grower-demonstrations we validated the efficacy of band placement confirming what the authors reported previously (Sanchez et al., 1990).

A number of polymers have been reported to improve P fertilizer using efficiency. While we have found some of these technologies show promise under greenhouse conditions (Figure 2), we did not observe any improvements under field conditions (data not shown).

We also looked at alternative P sources. In these studies we found a P fertilizer (Struvite) derived from municipal waste streams was equal to or better to conventional sources manufactured from mined P rock (Table 3). We funding from other sources (Ostara) we are continuing this work.

Finally, this project opened up the door to evaluating genetics as a means of improving fertilizer use efficacy. Preliminary data with genetically modified lettuce show a possible genetic path to improved P use efficiency (Figure 6). We funding from a follow up project (SCBG 11-29) we are pursuing this possibility in follow up research.

The outreach component of this project has also been also successful. However, we wish to stress that outreach activities are on-going using data generated as part of this project, and data we are generating with follow up projects. Through grower workshop presentations and on farm experiment-demonstrations we believe that we have directly impacted the 700 to 800 growers and crops advisors anticipated. Growers have shown interest in these results and have begun to evaluate these technologies themselves (outside the demonstrations we organized or are organizing). I estimate we have reduced P inputs by a least 20% and should achieve the 40% goals as outreach activities continue. We wish to stress that in a follow up project (SCBG 12-14) we will further develop the delivery of this and other material through grower friendly venues such as mobile APPs.

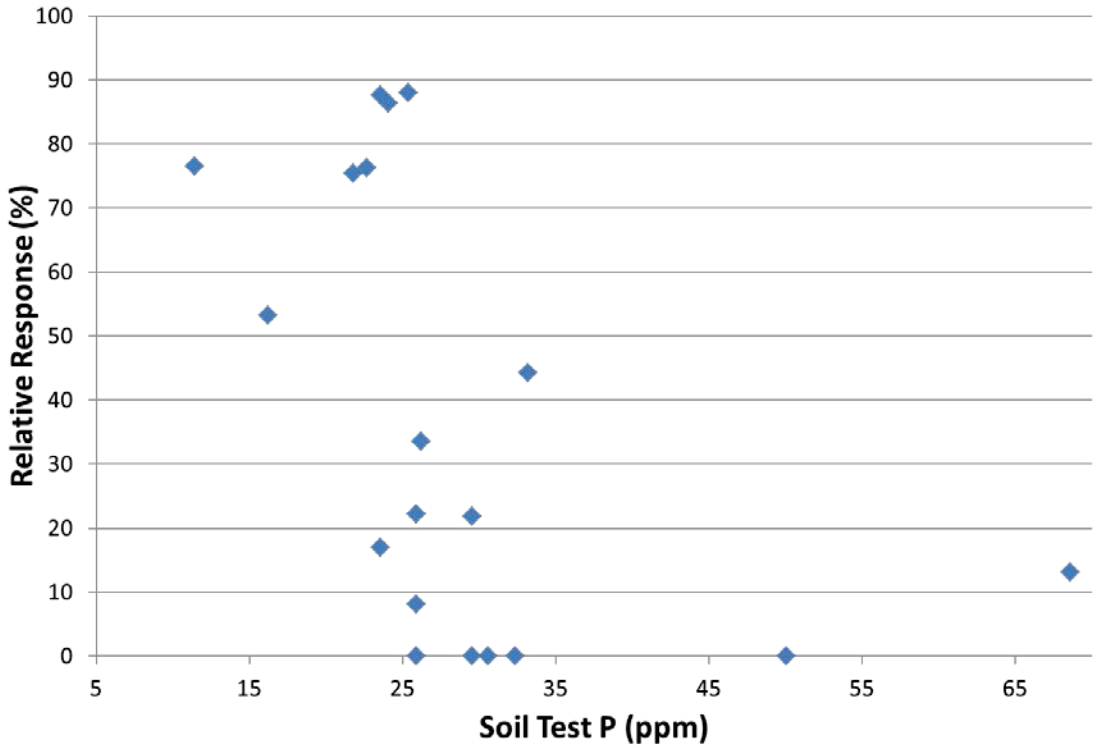

Figure 1. Data showing relationship between lettuce yield and pre-plant soil test P. Similar data was generated for broccoli and cauliflower. These data were used to revise soil test based fertilizer recommendations. However, with funding from other sources these studies are being continued on low P testing soils in central Arizona.

Table 1. Revised P fertilizer recommendations for desert lettuce. Similar revisions were made for broccoli and cauliflower.

Soil Test P	**Broadcast Fertilizer Recommendation[a]**
< 10 mg/kg	550 lbs MAP/acre
10 to 15 mg/kg	500 lbs MAP/acre
15 to 20 mg/kg	450 lbs MAP/acre
20 to 25 mg/kg	400 lbs MAP/acre
25 to 30 mg/kg	350 lbs MAP/acre
30 to 35 mg/kg	300 lbs MAP/acre
>35 mg/kg	Starter only

[a]We have and band application credit results in a recommendation 60% that for broadcast application.

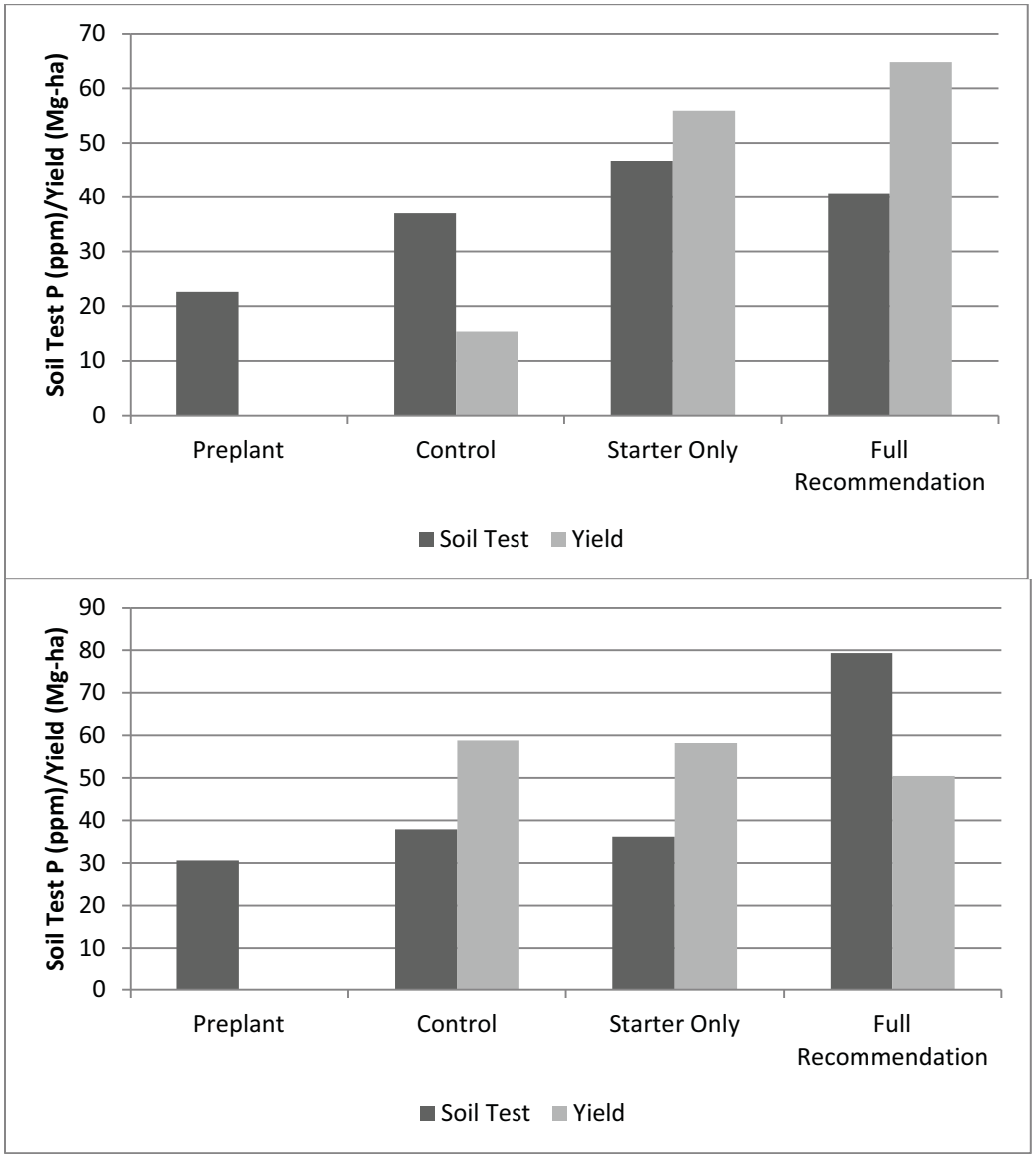

Figure 2. Response of lettuce to starter P and full rate of grower applied P in the field. This is a small subset of experiment demonstrations conducted in grower fields. Note in the first case (soil test P <20 ppm) response was to full P rate but in case two (soil test P >30) yields only responded to starter. A similar but more complex study was conducted at the University Research Farm.

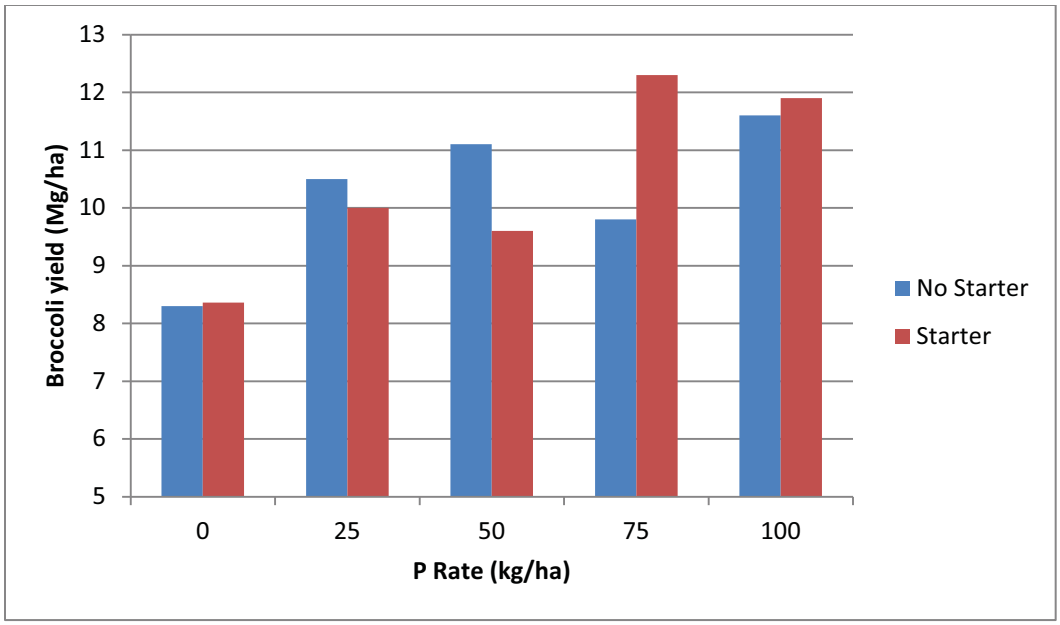

Figure 3. Yield response of broccoli to P rate and starter fertilizer. This study was conducted at the University Research Farm but similar but simpler experiment-demonstrations were conducted at multiple sites in grower fields.

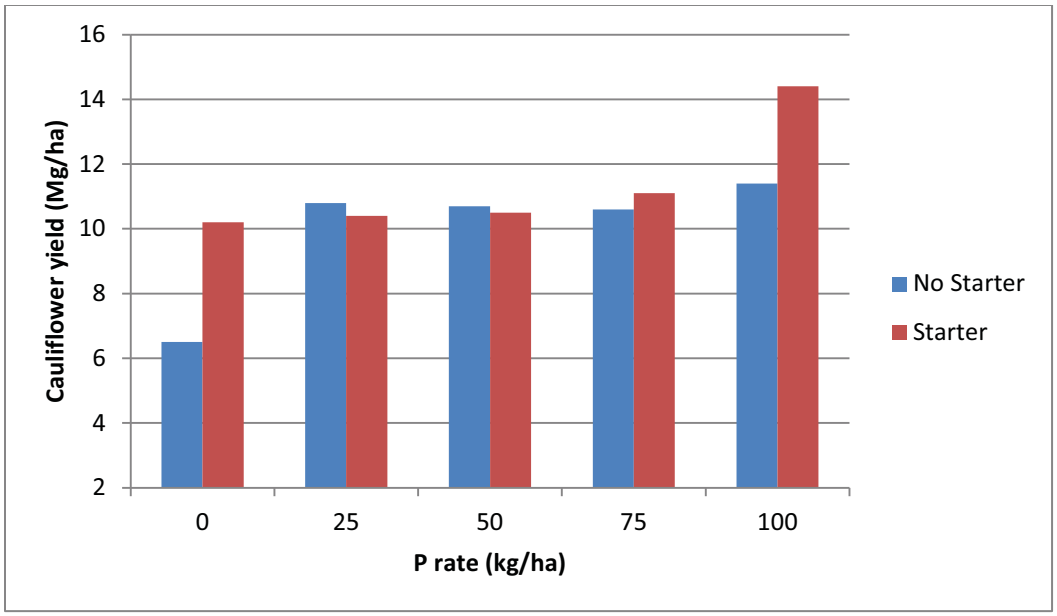

Figure 4. Yield response of cauliflower to P rate and starter fertilizer. This study was conducted at the University Research Farm but similar but simpler experiment-demonstrations were conducted at multiple sites in grower fields.

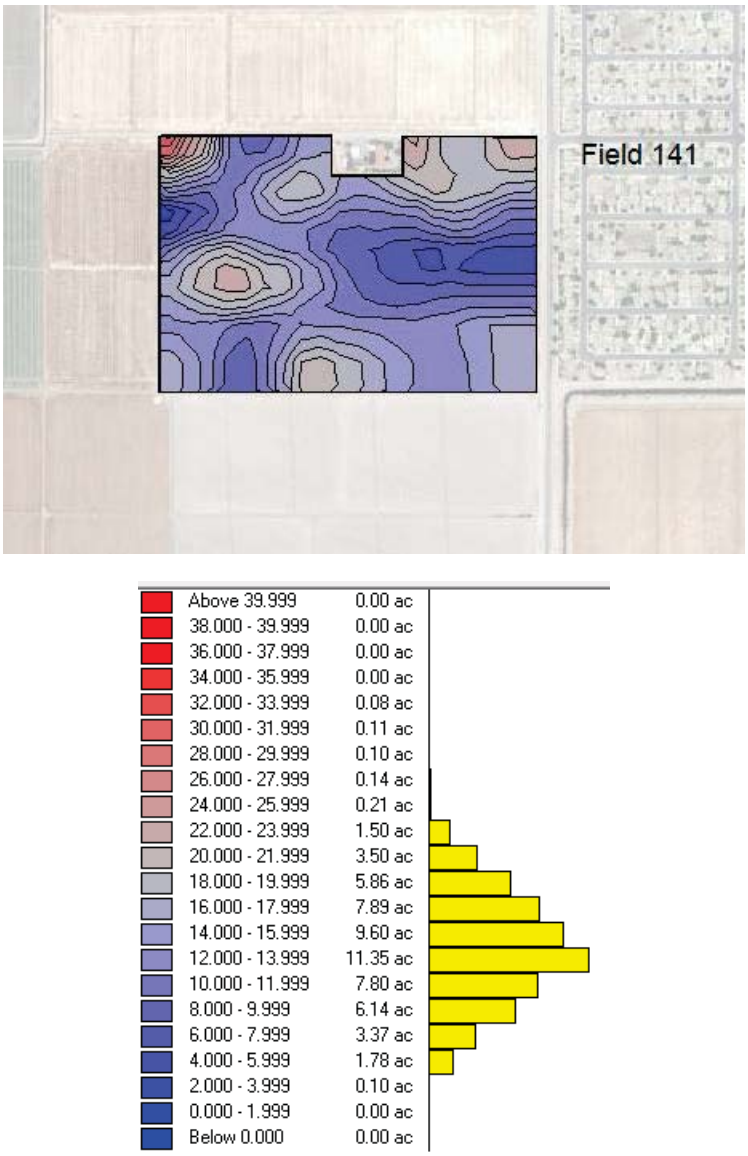

Figure 5. These studies, as well as some funded by other sources, show variation in soil test P across fields can complicate recommendations. Using these data as a basis, we have obtained funding from other sources to develop variable rate placement technologies.

Table 2. Responses of Lettuce to P rate and polymer.

P Fertilizer (g/pot)	Polymer (mL/pot)	Soil Test P (mg/kg)	Dry Weight (g/pot)	Tissue P (%)	P Uptake (mg/pot)
0	0	6.2	0.22	0.04	0.08
0.17	0	50.5	0.23	0.16	0.40
0	3.6	46.5	0.15	0.13	0.15
0.17	0.36	55.7	0.35	0.21	0.74
0.17	3.6	63.8	0.40	0.20	0.97
0.08	0.36	48.8	0.37	0.20	0.72
0.08	3.6	36.7	0.38	0.16	0.69
0.04	0.36	33.0	0.39	0.21	0.71
0.04	3.6	25.7	0.40	0.13	0.53
LSD		33.5	0.08	0.15	0.54

Table. 3. Marketable yield and residual soil test P after harvest of iceberg lettuce to P rate and source.

P Rate (kg/ha)	P Source	Lettuce Yield (MT/ha)	Soil Test P mg/kg
0	--	5.2	<1
25	Triple Superphosphate	13.4	<1
50	Triple Superphosphate	17.7	1.8
100	Triple Superphosphate	15.3	1.6
25	Crystal Green	18.0	<1
50	Crystal Green	25.7	<1
100	Crystal Green	24.6	<1
Stat.			
P Rate		L**Q*	NS
P Source		*	NS

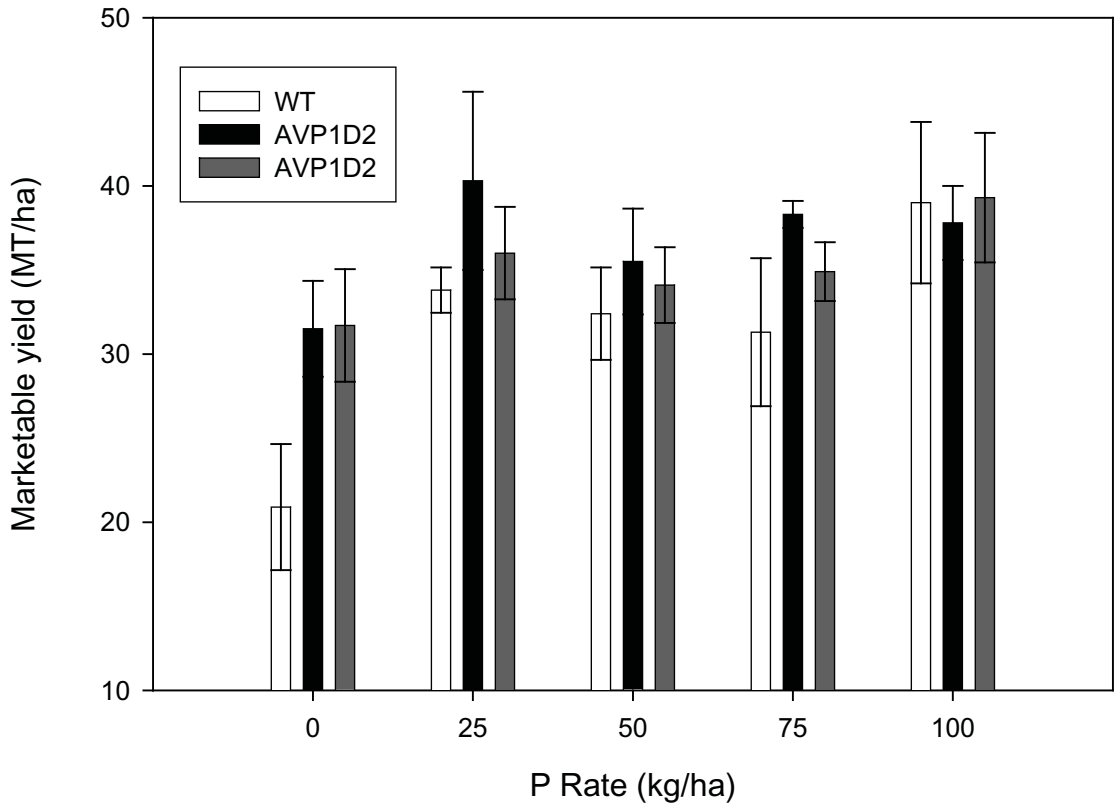

Figure 6. Marketable yield of conventional and two selections (AVP1D2 and AVP1D6) of modified romaine lettuce to P fertilizer in field experiment 1.

Beneficiaries

The beneficiaries are principally vegetable producers in the low desert. However, society at large benefits from improved P use efficiency due to less pollution and conservation of finite resources.

Lessons Learned

Because of years of vegetable production and continued P fertilizer application, it is increasingly difficult to find field sites in Yuma that test low in P. Thus we have recently moved much of our on-going P fertility research to central Arizona to generate meaningful response curves.

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Additional Information

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Improving Management of Phytophthora Root and Crown Rot in Arizona Chile Peppers

This project was completed on September 30, 2012

Project summary

Phytophthora blight of peppers, caused by the oomycete pathogen *Phytophthora capsici*, can cause extensive losses for chile pepper growers in southeastern Arizona. Management strategies at the time this project was initiated relied predominantly on the use of two fungicides, Ridomil Gold (mefenoxam) and Forum (dimethomorph); however, significant crop losses continued to occur. Clearly, new and innovative disease management tools were needed. This research project focused on four areas to develop these new management tools: 1) evaluating new fungicides, including biofungicides, and use rates within application programs to optimize disease control when these tools are used; 2) assessing potential efficacy of cultural disease management tools, such as cultivar resistance and soil solarization; 3) examining the role of weeds as potential hosts for *P. capsici* in pepper fields, which may contribute to survival of this pathogen in the absence of a pepper crop; and 4) characterizing pathogen isolates collected from pepper fields throughout southeastern Arizona with respect to virulence, mating type, and sensitivity to registered fungicides. The objective of this project was to generate knowledge that will facilitate incorporation of effective cultural disease management tactics with judicious use of fungicide inputs to create a truly integrated system for management of *P. capsici* induced losses in Arizona chile pepper fields.

Project Approach

Phytophthora blight of peppers, caused by the oomycete pathogen *Phytophthora capsici*, occurs in virtually all states where peppers are grown. Pepper production in Arizona, which is concentrated in the southeastern part of the state, can sustain extensive losses due to the destructive effects of this pathogen. In Arizona, the root and crown rot phase of the disease appears on plants early in the growing season in areas where soil remains saturated after irrigation. Subsequent irrigations as well as significant summer rainfall from July to September encourage further development of root and crown rot, as well as initiation of the stem, fruit, and foliar infection phase of the disease. The final result: plant and pepper fruit damage and death, and significant economic losses.

Phytophthora capsici was first described as a pathogen on pepper plants in Las Cruces, New Mexico in 1922. In southeastern Arizona, watermelon and pumpkin plantings have sustained losses due to this pathogen in addition to chile peppers. As with all species of *Phytophthora*, water is a crucial factor in pathogen reproduction and subsequent disease development. Excessive soil moisture, either from irrigation or rainfall, stimulates production of sporangia and release of zoospores, the infective propagule of *P. capsici*. *Phytophthora* goes where water

flows and can be carried by surface irrigation water or dispersed aerially by rainfall. If both mating types of the pathogen are present, the oospores that can form in plants as they are dying may produce progeny that could be more virulent on plants or less susceptible to a fungicide than their parents. These oospores will remain in the soil after the host plant decays, lying dormant until another crop of peppers or other susceptible host is planted.

Disease management strategies at the onset of this research project relied predominantly on use of a few fungicides; however; significant crop losses continued to occur. Clearly, new and innovative disease management tools were needed to reduce losses due to this pathogen.

This research project focused on issues that could significantly impact disease severity and control; namely, examination of pathogen characteristics and means of survival in the field as well as development of new disease management tools. The four specific performance goals of this research project are listed below.

1. Evaluate new fungicides, including biofungicides, and use rates within application programs to optimize disease control when these tools are used.
2. Assess potential efficacy of cultural disease management tools, such as cultivar resistance and soil solarization.
3. Examine the role of weeds as potential hosts for *P. capsici* in pepper fields, which may contribute to survival of this pathogen in the absence of a pepper crop.
4. Characterize pathogen isolates collected from pepper fields throughout southeastern Arizona with respect to virulence, mating type, and sensitivity to registered fungicides.

Research goal #1 (Fungicide efficacy studies). Fungicides are an important component of a *Phytophthora* disease management program for peppers and other susceptible hosts; however, the number of fungicides available for use on peppers at the beginning of this research project was limited primarily to Ridomil Gold (mefenoxam) and Forum (dimethomorph). Furthermore, in many pepper-growing regions, *P. capsici* was resistant to Ridomil Gold. A number of new compounds recently under development have activity on oomycete pathogens, including *Phytophthora*. Research trials were conducted in the greenhouse and in the field to evaluate these products for their ability to reduce pepper plant losses due to infection by *P. capsici.* Chile pepper transplants were grown in soil artificially infested with the pepper pathogen. In the greenhouse trials, plants were grown in containers and soil was irrigated daily to promote disease development. In field trials, pepper plants growing on raised beds were irrigated heavily every week, again to provide conditions highly favorable for disease development. Results from three greenhouse and two field trials are shown in Table 1.

Table 1. Efficacy of fungicides applied to soil to reduce death rate of chile pepper plants grown in soil infested with *Phytophthora capsici*.

Fungicide Brand Name [1]	Active ingredient	Percent reduction in dead plants [2]	
		Greenhouse trials	Field trials
Ridomil Gold	Mefenoxam	90	38
Revus	Mandipropamid	87	13
Omega	Fluazinam	73	33
Experimental	(Not yet available)	73	33
V-10208	(Not yet available)	69	34
Forum	Dimethomorph	64	31
Presidio	Fluopicolide	62	40
Zampro	Ametoctradin+dimethomorph	59	25
Ranman	Cyazofamid	50	52

1. The amount of each product applied was either the highest amount stated on the label or the highest rate recommended for testing on nonregistered materials.

2. Percent reduction in dead plants compared to those that were not treated. The average percentage of nontreated plants that died in greenhouse and field trials was 93 and 72%, respectively. Each value is derived from three greenhouse or two field trials.

These data show the average percent reduction in dead pepper plants compared to nontreated plants. There are large differences in the effectiveness of tested products within the greenhouse and field trials. Also apparent is that product efficacy in field trials was usually much less than that observed in greenhouse trials. This difference in efficacy in field compared to greenhouse trials may be explained by the efficiency of fungicide delivery to plant roots in each case. In the greenhouse, soil drench application of materials thoroughly treated plant roots. One the other hand, directed spray applications to the base of the plant and surrounding soil, as directed by the labels for most registered products, likely did not reach and treat the entire plant root zone. Data presented in the table were derived from plants treated on a 2-week interval. In some trials, product application every 2 weeks was compared to monthly application intervals. No significant difference in disease control was observed in monthly compared to 2-week fungicide application intervals. Tenet and Soilgard, two products containing biological active ingredients, were tested in some of these trials and did not provide meaningful reductions in disease.

Another series of trials were conducted to evaluate potential differences in soil compared to stem and foliar application of products on subsequent development of stem cankers. Chile pepper transplants were treated with various disease control products either by immersion of roots or of foliage and stems of plants into a solution containing the test material. Seven days after treatment, plant stems were wounded and inoculated with mycelium of *P. capsici*. The length of resultant stem cankers was recorded one week later. The results from two runs of this trial are presented in Table 2.

Table 2. Effect of fungicide application site on subsequent development of stem cankers on chile pepper transplants inoculated with *Phytophthora capsici* one week after treatment.

Product [1]	Stem canker length in mm [2]	
	Stem & foliage treated	Roots treated
Zampro	0	1.8
Ridomil Gold	0.6	0
V-10208	1.0	8.8
Presidio	1.1	1.6
Forum	1.2	5.3
Experimental	1.4	19.2
Revus	2.0	21.8
Actigard	7.0	8.8
Aliette	13.4	19.4
HM0736	13.6	39.0
Ranman	18.2	46.2
Reason	20.4	24.0
Previcur Flex	26.9	19.6
Omega	40.5	45.0

1. The amount of each product applied was either the highest amount stated on the label or the highest rate recommended for testing on nonregistered materials.

2. Mean length of stem canker on nontreated plants was 59.0. Values differing by more than the Least Significant Difference (LSD, $P = 0.05$) of 11.0 are significantly different.

The results of these trials demonstrate the relative efficacy of tested products in another manner than that presented in Table 1. In these studies, eight different products (Actigard, an experimental, Forum, Presidio, Revus, Ridomil Gold, V-10218, and Zampro) were highly and equally effective in reducing disease development when applied to foliage and stems of pepper plants. Furthermore, six of the materials (Actigard, Forum, Presidio, Ridomil Gold, V-10218, and Zampro) provided the highest level of disease reduction on inoculated stems when applied to plant roots. Most tested materials contained one or more active ingredients that directly affect the viability of the pathogen. In contrast, the products Actigard and HM0736 affect disease development by activating defense mechanisms within the plant. Since the root and crown rot phase of Phytophthora blight of peppers develops before the onset of the foliar phase of the disease, appropriate timing and site of application, as shown by the data, will yield maximum control of both phases of Phytophthora blight of peppers.

Research goal #2 (Disease management tools other than fungicides). Different genetic selections of plants may be resistant or tolerant to certain disease-causing microbes. Four chile pepper selections used in a pepper breeding program were tested for their ability to resist development of Phytophthora blight when plant stems were inoculated with *P. capsici* in the greenhouse. These pepper selections were compared to a standard chile pepper variety, AZ 20, grown in southeastern Arizona. This experiment was conducted twice. The mean length of resulting cankers 7 days after inoculation for AZ 20 and pepper selections 1, 2, 3, and 4 were 76, 64, 91, 72, and 37 mm, respectively. Significant differences in stem canker development in the

presence of *P. capsici* were noted; however, even the pepper selection with the smallest mean canker length did not exhibit a useful level of resistance to disease development on stem tissue.

The occurrence and severity of Phytophthora blight on peppers is greatly affected by the amount of inoculum carried over from one season to the next. Soil solarization entails covering moist soil with plastic and allowing the sun to heat soil to levels sufficient to kill plant pathogens. Research in Florida demonstrated that soil solarization reduced but did not eliminate *P. capsici* from soil. A soil solarization trial was conducted in southeastern Arizona in a pepper-production farm to determine if soil temperatures could be raised to and maintained at sufficiently high levels to destroy *P. capsici* in soil. In the Florida study, soil was solarized for 28 days. At a soil depth of 5 cm, 289 and 433 hours at a temperature above 40°C were recorded, respectively, during the first and second year of the study. At these soil temperatures, the Florida researcher was still able to routinely recover *P. capsici* from soil. At the Arizona farm site in 2011, only 41 hours above 40°C were recorded at a soil depth of 5 cm during a 28 day solarization period. Therefore, soil solarization in this region of Arizona, where extensive cloud cover and rainfall during the summer monsoon period greatly impede soil heating, will not be a useful tool for management of Phytophthora blight.

Research goal #3 (Weeds as hosts for *P. capsici*). Researchers in Illinois and Florida documented the role of some weed species as alternate hosts and asymptomatic carriers of *P. capsici*. In southeastern Arizona, roots from several different kinds of weeds found growing in pepper fields affected by this pathogen were tested for the presence of *P. capsici*. The pathogen was recovered from a sampled morning glory plant. The plant and roots appeared healthy; however, *P. capsici* was recovered from root tissue after rinsing in a 70% ethanol solution to kill root-surface contaminants. If this preliminary evidence of a possible weed host is substantiated by further research, then minimizing the presence of this weed in pepper fields could be an important disease management tool.

Another trial was focused on assessing the ability of *P. capsici* to grow and sporulate on roots of weed plants and crops alternated with chile peppers. Roots from 1 to 3 mm in diameter were collected from the following plants: alfalfa, corn, cotton, cowpea, morning glory, mustard, chile pepper, pigweed, Sudan grass, and Wright's ground cherry. Four root segments 5 cm in length from each kind of plant were placed in petri dishes containing two mycelial disks of *P. capsici* that had incubated in 20 ml of water for 2 days. Sporangia of the pathogen that formed on the mycelial disk were induced to release zoospores by a brief chilling followed by a return to room temperature. Three days after incubation of plant roots with zoospores of *P. capsici*, root segments were observed with a microscope. Sporangia of the pathogen had developed on the roots of all tested plants, indicating colonization and growth of *P. capsici* on these tissues. Root segments then were placed in 70% ethanol to kill the *P. capsici* and other organisms on the root surface, then placed on an agar medium that supports growth of *P. capsici*. The pathogen emerged from root segments of all plants tested, further demonstrating that *P. capsici* could colonize root tissue from a diverse group of plants either grown as crops or existing as weeds on a farm where chile peppers were grown. This ability of the pathogen to subsist on roots of other crop plants and weeds may help explain why Phytophthora blight on peppers can appear in a

field that has been out of pepper production for several years following a disease outbreak on a former pepper planting.

Research goal #4 (Diversity among pathogen populations). As mentioned earlier, populations of *P. capsici* in many pepper production regions have become resistant to the fungicide Ridomil Gold, which was used often to control Phytophthora blight on peppers. Populations of *P. capsici* can change, as in this case through selection pressure brought about through extensive use of a particular fungicide. Isolates of *P. capsici* used in all fungicide trials reported on here were sensitive to Ridomil Gold, which means that this fungicide can still be used effectively in a disease management program within the chile pepper production region in southeastern Arizona.

Phytophthora capsici exists as two separate mating types, designated A_1 and A_2. In regions where both mating types exist, then sexual reproduction is possible. The significance of sexual reproduction is that this facilitates the transfer of genes between individuals within a pathogen population, which can accelerate the development of undesirable qualities such as enhanced virulence or resistance to fungicides. Also, the sexual spores which are known as oospores have thick walls and can remain viable in soil for several years. To determine if both pathogen mating types were present in southeastern Arizona pepper fields, 13 isolates of *P. capsici* were recovered from soil or pepper plants throughout the area. In petri dishes containing an agar medium that supported growth of *P. capsici*, a mycelial disk 5 mm in diameter of a pathogen isolate from Arizona was placed near the edge of a petri dish and an isolate known to be either A_1 or A_2 was placed at the opposite edge. If the two isolates were compatible (of opposite mating type), then sexual oospores would be produced when they grew and came into contact with each other. In this way, the mating type of all the Arizona isolates could be determined. Of the 13 isolates tested, four were A_1 and nine were A_2. The ratio of A_1 to A_2 in this small sample of isolates is not as important as the fact that both mating types are present, which makes sexual reproduction possible and calls attention to the concerns of oospore production stated above.

Two trials were conducted to evaluate the virulence or aggressiveness of 12 different isolates of *P. capsici* from chile pepper fields in southeastern Arizona. In each trial, 10 chile pepper transplants were grown individually in pots containing soil infested with one of the 12 pathogen isolates. Plants were maintained in the greenhouse for 2 months and soil was kept wet to encourage disease development. The number of dead plants was recorded at the end of the 2-month trial. For both trials, the total number of dead pepper plants ranged from six to 20 out of 20 plants grown in the presence of each tested *P. capsici* isolate. Three isolates caused death on 6, 11, and 12 plants (30, 55, and 60% mortality), whereas the remaining nine isolates killed from 16 to 20 (80 to 100% mortality) tested pepper plants. Differences in isolate virulence were noted; however, nine of 12 isolates killed at least 80% of exposed pepper plants.

Goals and Outcomes Achieved

The performance (research) goals and measurable outcomes were achieved through the following activities.

Performance (research) goals

1. **Fungicide efficacy studies.** Three, two, and two research trials were conducted in the greenhouse, field, and laboratory, respectively, to evaluate disease control products with respect to their ability to reduce pepper plant losses due to infection by *P. capsici.*
2. **Evaluating disease management tools other than fungicides.** One greenhouse and one field trial were conducted to evaluate the potential of genetic resistance and soil solarization, respectively, for use as tools for management of Phytophthora blight on pepper in Arizona. No source of useful genetic resistance to Phytophthora blight was detected among the pepper plant breeding selections tested. Also, temperatures recorded in solarized soil were not high enough to significantly reduce the amount of *P. capsici* in soil. Therefore, this line of research was not continued further.
3. **Weeds as hosts for *P. capsici*.** Field sampling revealed that morning glory could be a possible nonsymptomatic host of *P. capsici* in pepper fields. Also, a laboratory inoculation trial of crop and weed plant roots demonstrated that the pepper pathogen *P. capsici* could colonize and sporulate on all plant roots tested. This finding was not expected and should be examined in more detail. The time and number of experiments required to study the potential role of crop and weed plants in sustaining *P. capsici* in the field between plantings of peppers would require an additional research effort beyond the scope and time commitment allocated to the planned activities of the current proposed work.
4. **Diversity among pathogen populations.** The existence of both mating types of *P. capsici* in the southeastern Arizona pepper production region was accomplished with one mating experiment conducted in the laboratory. Two greenhouse trials were conducted to evaluate the virulence or aggressiveness of 12 different isolates of *P. capsici* from chile pepper fields in southeastern Arizona. Results from these experiments demonstrate that the majority of tested isolates of the pathogen were highly pathogenic and aggressive.

Measurable outcomes

1. One aim of this project was to increase disease management efficiency by using data from project experiments to develop an integrated approach to maximize disease control and optimize cost efficiency **(Goal).** A survey of fungicides available for use on peppers at the beginning of this research project revealed that primarily Ridomil Gold (mefenoxam) and Forum (dimethomorph) could be used **(Benchmark)**. To achieve the goal stated above, several fungicides not yet registered for use on peppers were evaluated in several efficacy trials, which generated disease management efficacy data that supported eventual registration of at least four new fungicides for use by pepper growers by the end of this research project. Furthermore, additional chemistries tested could be available in the future **(Target and Performance Measure)**. Data generated by these efficacy studies also showed the relative effectiveness of tested products in reducing

Phytophthora root and crown rot, so that growers could select the most effective chemistries to maximize disease control. For example, the biofungicides Tenet and Soilgard were tested in the initial fungicide evaluation trials and did not provide meaningful reductions in disease. As the findings from this research are disseminated through meetings, field days, and publications, growers are now using products that have proven efficacy. Also, pepper growers are not needlessly applying the chemistries in excess, thus increasing the economic efficiency of disease management.

2. Another objective was to encourage growers to use fungicide application programs emphasizing alternation of chemistries with different modes of action to sustain fungicide effectiveness **(Goal).** Since Ridomil Gold and Forum initially were the primary fungicides available, and with Ridomil Gold being significantly more effective than Forum in reducing crop losses due to Phytophthora blight, Ridomil Gold was used more extensively and not often alternated with Forum **(Benchmark)**. Overuse of Ridomil Gold has led to the development of resistance within the pathogen (*P. capsici*) population in many states; however, tested populations in southeastern Arizona remain sensitive to this fungicide. Now, with the registration of at least four new fungicides for use by pepper growers since the beginning of this research project plus more products potentially becoming available in the future, the ability of growers to alternate among different fungicides and practice resistance management has been greatly enhanced. For example, in 2012 the major pepper producer in southeastern Arizona used a pepper treatment program alternating among fungicides with three different modes of action. Two of these fungicides were not available to him at the time this research project was initiated. Field isolates of *Phytophthora capsici* will be tested in the future to determine if fungicide sensitivity within the southeastern Arizona pathogen population is remaining stable **(Target and Performance Measure)**.

The measurable outcomes involving increased disease management efficiency and sustained fungicide effectiveness are long term in nature and will be achieved by continued educational efforts delivered by various methods, including verbal, written, and electronic means.

Of the four performance (research goals) outlined in the proposal, all were accomplished to the extent of the planned work outlined at the beginning of the proposal. The preliminary finding that roots of all tested crops grown in rotation with peppers as well as those from tested weeds could be colonized by *P. capsici* and serve as a substrate for spore production was not anticipated when the plan of work for this proposal was formulated. Therefore, the time and number of experiments required to study this phenomenon will require an additional research effort beyond the scope of this project.

When this project was initiated in 2009, approximately 3,000 acres of chile peppers where grown in Arizona. By 2012 that number had decreased to approximately 1,200 acres. Similar acreage reductions have occurred in New Mexico, a leading chile producing state. In 2009, the estimated

number of chile pepper growers in Arizona was approximately 15. That number has likely declined along with the acreage planted to this crop. Although the number of growers likely to grow chile in 2013 and beyond in Arizona is unknown, one grower has and is expected to continue to be the dominant chile pepper grower in the state. He is the same grower cited earlier in this report that implemented the use of a treatment program for managing Phytophthora root and crown rot that emphasized alternation among fungicides with different modes of action.

With respect to fungicide use and minimizing the presence of weeds in chile pepper fields, this major grower's early adoption of the principles of disease management resulting from this research will serve as model for the other smaller growers in Arizona.

At the recent 2013 Chile Pepper Conference held in Las Cruces, NM, I presented the fungicide research results from this project to growers not only from Arizona, but to attendees from New Mexico and other chile pepper production areas as well. Since this regional annual meeting brings together chile pepper growers from Arizona, New Mexico, and other production areas, the presentation to this group met my target of increasing grower awareness by at least 50% with respect to my goal of getting growers to use fungicide application programs emphasizing alternation of chemistries with different modes of action in order to sustain fungicide effectiveness. Similar educational efforts will occur in the future, with the overarching goal of improving the overall management of Phytophthora root and crown rot of chile peppers. The final results of this research project were not available until the 2012 growing season was essentially complete, and the first widespread exposure to the research findings did not occur until the Chile Pepper Conference in early February, 2013. Therefore, a survey of Arizona pepper growers with respect to adoption of research findings will not be possible until the end of the 2013 growing season.

Concerning the achievement of measurable outcomes, the major chile pepper producer in Arizona is adopting the use of new chemistries and inclusion of these products in disease management programs in such as way as to delay resistance management and prolong their effective lifespan. Moving forward, if disease severity in the region should increase as a result of changing weather conditions or changes in efficacy of one or more disease management tools, then ongoing educational and perhaps research efforts will address potential adjustments in disease management strategies to counteract these changes.

Beneficiaries

The completion of this project and the accomplishments described earlier will directly benefit pepper growers in Arizona. As noted earlier, the number of growers has likely declined along with the acreage reduction recorded from 2009 to present. However, due to dissemination of knowledge gained through vigorous and extensive educational efforts, including grower meetings, publications and other means of communication, pepper growers throughout the nation and the world will have access to this pepper disease management information as well.

The quantitative data that concerns the beneficiaries affected by this project's accomplishments can be found in earlier portions of this report. The potential economic impact of the project will derive from more effective management of Phytophthora blight on peppers in Arizona, which

will decrease crop losses, and reduction of disease management costs due to more judicious use of fungicides.

Lessons Learned

With respect to the goal of reducing the extent and severity of Phytophthora blight on pepper and resultant economic loss to growers, listed below are the positive and negative lessons learned that can be attributed to this project.

Positive lessons learned.

1. New fungicides were identified that significantly reduce the severity of Phytophthora blight on pepper caused by *P. capsici*.
2. Monthly application of tested fungicides was as effective as application at 2-week intervals.
3. Some fungicides applied only to stems and foliage and some applied only to roots as a soil drench provided effective control of disease development on the upper part of plants when inoculated with the pathogen.
4. Roots of tested weeds and crops grown in rotation between pepper plantings can support growth and sporulation of the pepper pathogen *P. capsici*. More research is needed to validate this preliminary finding.
5. The existence of both mating types of *P. capsici* in the pepper growing region of southeastern Arizona means that sexual recombination and rearrangement of genes can occur within this pathogen population, which could enhance the ability of the pathogen population to develop resistance to fungicides and possibly become more virulent.

Negative lessons learned.

1. A small sample of pepper selections tested revealed no sources of useful levels of genetic resistance to Phytophthora blight.
2. Soil solarization will not be a useful tool in southeast Arizona for management of Phytophthora blight.
3. The majority of tested isolates of *P. capsici* found in Arizona pepper fields were virulent and aggressive.

The one unexpected outcome of this research project was the finding that roots of all tested crops planted between crops of pepper with the purpose of lowering the population of *P. capsici* in soil because they are not known to be hosts of the pathogen may in fact be a means for the pathogen to carry over in soil between these pepper crops. Although this finding is very preliminary, further experiments should be planned and executed to examine this issue. Verification of this initial data would drastically alter our current view of crop rotation as an effective tool for management of Phytophthora blight of pepper.

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Temporal and Spatial Distribution of CYSDV and SLCV and the Whitefly Vector

This project was completed on October 31, 2011

Project Summary

Yield losses are on the rise due to new and emergent whitefly-transmitted viruses in melon crops in south-central Arizona. To manage whiteflies in desert crops most if not all field managers apply pesticides based on previous year's experiences, even though whitefly dispersal varies greatly with swings in rainfall and temperature. Therefore a system-wide management approach in which local knowledge is sought to learn about the dynamics and patterns of virus spread and whitefly dispersal locally has become essential. The objectives were: (1) identify and map (a) cultivated and (b) wild hosts of six virus species, and (c) the whitefly vector 0-5 miles from 'reference' cucurbit; (2) map whitefly trap counts, and whitefly and virus reservoir distribution using the project web-based *Whitefly Tracker* and email (smart-phone delivered) alert system as a strategic decision support tool. To this end we developed the capacity to identify whitefly borne viruses in specialty crops (melons and in alternate and wild hosts of the viruses), and integrated whitefly and virus data sets into the tracking tool to facilitate knowledge-based decision-making for timing and placement of insecticide and herbicide applications. This web-based tracking tool represents the beginning of a kind of model for a means of reporting such data that envisions proactive and pre-emptive approach to protecting our food, fiber, and ornamental/landscape plants in Arizona. It embodies a model, that if extended and expanded to embrace and address new vector borne pathogen disease problems as they arise, will be the first proactive monitoring and reporting system for commercial producers, nursery, and homeowners and gardeners in Arizona. Pesticides are best targeted and timed when decision-making is based on knowledge of temporal and spatial vector dispersal patterns and distribution of virus reservoirs. Regular monitoring of whitefly and virus sources in and near melon fields is advantageous because it accounts for vector-virus dynamics in local temporal and spatial arenas where control is needed. The aim was to provide producers and managers with a knowledge-based vector and host reservoir management to facilitate best practices for virus disease management. An added advantage is that lowered pesticide pressures reduce whitefly upsurgence, which further reduces selection of emergent, more damaging virus strains. Routine monitoring in the vicinity of melon and other vegetable fields, and at the cotton-vegetable interface, as well as in more remote areas, provides knowledge of temporal and spatial patterns that can be used to guide targeted control over the short and long terms.

Project Approach

We conducted virus analysis on all plant samples, assembled and edited DNA sequences for virus identification and provided the first summary of viral and whitefly host plants for south central Arizona melon crops and nearby wild or other cultivated hosts.

Sampling sites were as follows:

Area 1: Wendon, AZ located in La Paz County; Aguila, AZ located in Maricopa County. Reference field will be located in Wendon.

Area 2: Harquahala Valley, AZ, Tonopah, AZ and Buckeye, AZ located in Maricopa County. Reference field will b located in Harquahala Valley.

Area 3: Gila Bend, AZ and Cotton Center, AZ located in Maricopa County. Reference field will be located in Cotton Center. This field will be of a specialty crop not within the cucurbit family due to the lack of melon production in the area.

Area 4: Coolidge, AZ, Casa Grande, AZ, Sacaton, AZ and Eloy, AZ located in Pinal County. Reference field will be located near Coolidge.

General area in south central Arizona where sample sites were located.

Results of molecular detection for whitefly-transmitted and curtoviruses.

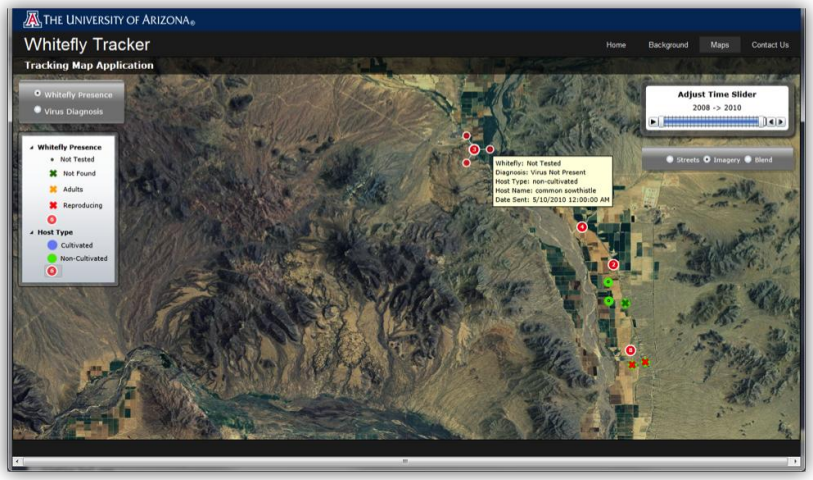
- During 2009 to 2011 a total of 296 plant samples were analyzed for the presence of virus.
- Cultivated species represented 130 samples and 166 represented uncultivated species. Of the 130 cultivated species, 34 were infected with virus (*Begomovirus*, *Curtovirus*, *Crinivirus* (CYSDV) or a combination) and 96 samples contained no detectable virus.
- Of the 166 non-cultivated species, 10 were infected with virus (*Begomovirus*, *Curtovirus*, *Crinivirus* (CYSDV) or a combination) and 156 samples contained no detectable virus.

Some highlights of the results of virus testing are provided below. Several samples were infected with more than one virus.

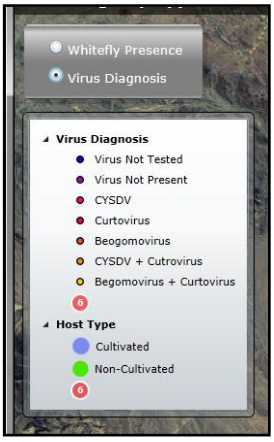
- *Cucurbit yellow stunting disorder virus*. The recently introduced CYSDV was identified in alfalfa, cucumber, mixed melons (cantaloupe, casaba, honeydew), horse purslane, canyon ragweed, papaya, and watermelon.

- Begomoviruses (*Squash leaf curl, Cucurbit leaf curl viruses*) were identified in mixed melons and watermelon, and possible positives were found for lablab and alfalfa.
- The begomovirus *Cotton leaf crumple (CLCrV) was identified in cotton, cowpea, Hibiscus tea, lablab bean, tepary bean, common mallow, cotton, wild tobacco.*
- *Tomato yellow leaf curl virus was identified in bean and tomato.*
- The curtovirus *Beet severe curly top* was identified in morning glory, ground cherry, wild tobacco; two new curtoviruses were found in spinach crops and wild tobacco.
- The newly identified wild host plants with detectable virus were: *Asteraceae*: canyon ragweed (*Ambrosia ambrosioides*), *Begomovirus* (CLCV); *Aizoaceae*: horse purslane (*Trianthema portulacastrum*), *Crinivirus* (CYSDV), skeleton buckwheat (Polygonaceae), desert starvine (Cucurbitaceae).
- Two extensive Appendices provide the list of archived plant (**Appendix D**) and whitefly collections/observations coded for 'Tracker' (**Appendix E** (available by request) and **Appendix F**)

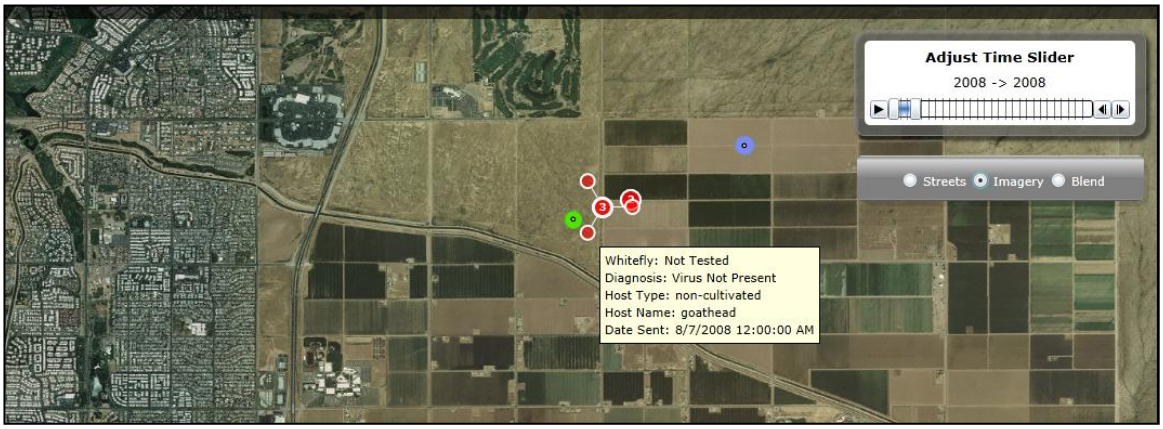
The virus and whitefly data sets have been mapped using the *Whitefly Tracker* website created during the project, and information can be accessed by year, host-virus, and host-whitefly presence. The *Whitefly Tracker* URL is: http://cals.arizona.edu/whiteflytracker. Examples of website utility are shown as screen captured windows to demonstrate the versatility and kinds of information that can be obtained for whitefly and virus data sets.



View data by "Whitefly Presence" or "Virus Diagnosis". Legend updates automatically.



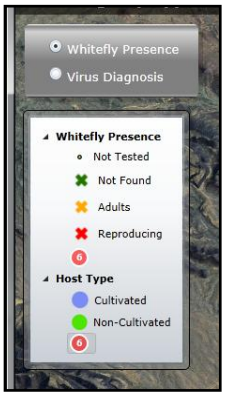
Mapping Main Window



Data show presence in cultivated croplands during summer months

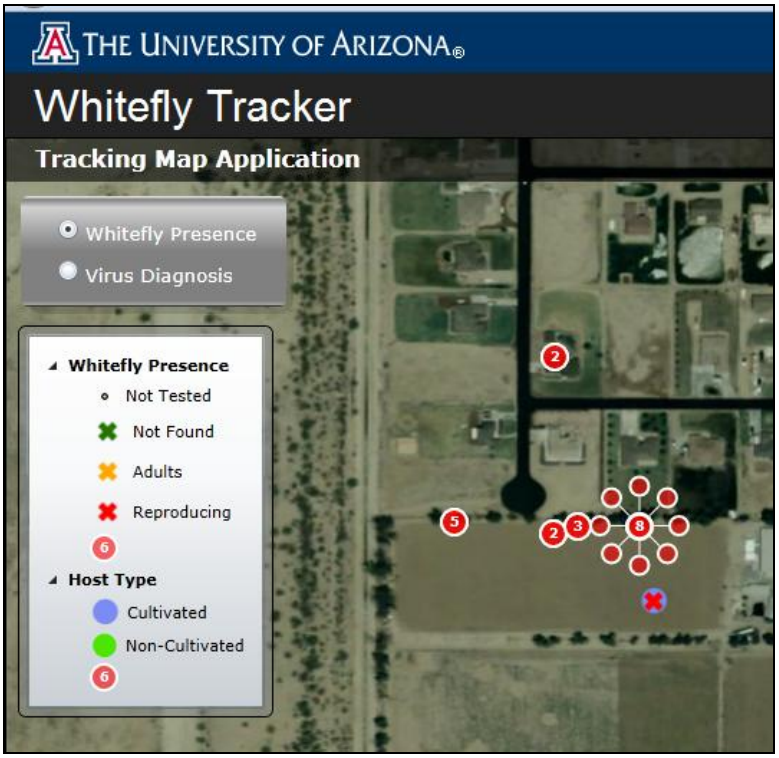
Adjust Time Slider

Example: 9/30/2008 – 12/30/2008: Salt River Pima-Maricopa Indian Community



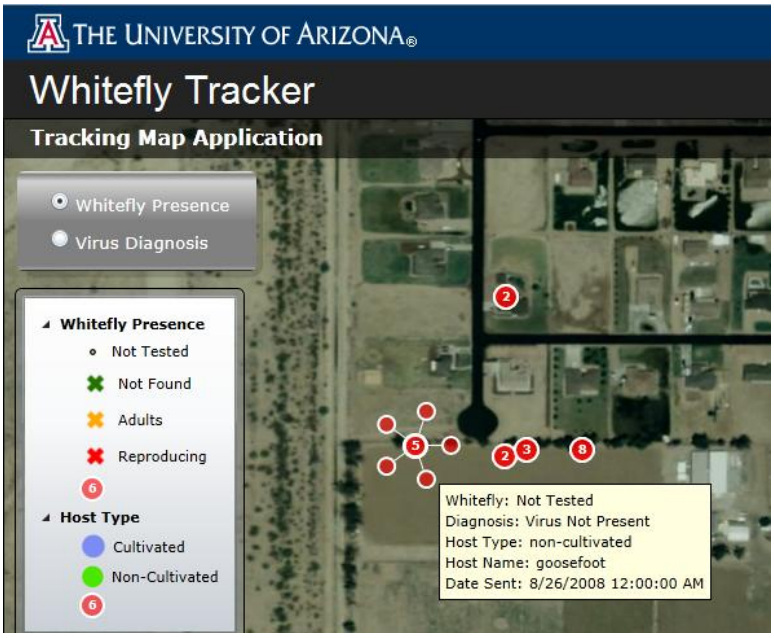
Mapping Main Window

Data show migration movement into urban areas during winter months.



Hovering over the specific spoke shows a detailed pop up of the particular sample.

Data located at the same location can be viewed by hovering over the number. Results are then shown on the spokes.



Goals and Outcomes Achieved

We developed specific temporal and spatial information maps (GIS) that illustrate the temporal and spatial patterns of emerging begomoviruses, and the exotic *Cucurbit yellow stunting disorder virus* (CYSDV), and also curtoviruses (included because of new outbreaks), as well as the whitefly vector in cucurbit fields and endemic and invasive weeds that serve as hosts of these plant viral pathogens and/or the whitefly vector throughout the cucurbit growing season, and in alternate seasons, in non-cucurbit crops and endemic/naturalized, non-cultivated hosts (GOAL). We identified a large number of new wild reservoir species and several new cultivated hosts for whitefly and/or the three groups of plant viruses (begomo, crini, curto) as a result of monitoring. This was based on plant and whitefly samples collected during 2009-2011 (with most in the 2010 of the year for which the project was funded. The no cost extension funds carried over to 2011 were insufficient to conduct whitefly trapping and virus sampling as was carried out in 2010, and was used to complete the sample analysis from the end of the year and additional samples we received from producers and master gardener collector volunteers (GOAL).

The above information was not available to producers and field managers, prior to the project. The whitefly-virus data were placed in the context of a mapping tool available through the website constructed for the project, named The *Whitefly Tracker* located at the URL: http://cals.arizona.edu/whiteflytracker. The URL has been made available to the user community of (at least 20 in the Phoenix area and ~35 in the Yuma-AZ/Imperial V.-CA area) consisting mostly of those involved in melon and watermelon production and distribution, however some cotton and small vegetable producers (unknown numbers) have accessed the website according to a show of hands at a workshop in Yuma during 2011. This tool enables users to employ timely, local community-level information about the seasonal and spatial distribution of whitefly-transmitted-vector reservoirs based on the Year 1 data (BENCHMARK).

Despite an unexpected financial setback did not permit the completion of the proposed three year study, during the funded project year (2010) we evaluated monitoring sites and identified tentative apparently key locations for traps that could be accessed by the extension and master gardener personnel but we were unable to discern if these sites were intercepting locally-produced whiteflies or those dispersing to the region from the southwest where crops (at sea level) finish sometimes before planting in the Phoenix area. The remaining funds were held through a no-cost extension granted for 2011 but were insufficient to hire personnel to continue the field survey in Phoenix. However, we used the funds to conduct virus analysis for the 2010 end of the year plant samples, and additional plant samples provided by producers, PCAs, extension offices, and master gardeners from fields or urban locations during Spring and Summer 2011 (See Appendices), in our best attempt to supplement the dataset in the absence of optimal resources.

We predicted that these vital management materials would influence 50% of producers-PCAs to change their pest management methods by delaying pesticide applications until dispersing whiteflies were documented on traps or on plants (TARGET). As early as 2010 E. Taylor made field visits to clientele in the Phoenix area, and observed this practice was being adopted. Some had placed traps at field edges and were monitoring weekly. In addition, by a show of hands and

through conversations at the Sumer 2010 Vegetable meeting (after demonstrating the website and pilot mapping project E. Taylor and M. Rahr). During summer 2010 farm visits E. Taylor observed that farm managers and producers were less likely to spray for whiteflies before they appeared and some had even placed their own traps at the field edges, simulating the proposed approach (Turning Point). and/or written questionnaires.

GOALS ACHIEVED:

1. New molecular virus identification tools were developed and previously employed assays were modified to achieve more sensitive detection of begomoviruses, curtoviruses, and criniviruses.

2. Previously unidentified hosts of the whitefly vector and viruses were identified in south central Arizona (**Appendix D and Appendix E** (available by request)).

3. Two major 'populations' of whitefly may possibly be involved in outbreaks in southern Arizona. Studies during 2010 suggested certain locations in the Phoenix area harbored whiteflies throughout the winter that increased during early summer time to infest nearby fields. A second population appears to arrive from the southwesterly direction (probably Yuma-Imperial Valley where the melon cropping season begins and ends earlier than in the Phoenix area) *via* prevailing winds, infesting fields and probably carrying virus from infected fields. This observation requires follow-up but could lead to predictive models that guide seasonal upsurges that originate from different sources.

4. The whitefly-virus mapping effort and development of the *Whitefly Tracker* website have been completed. The map can be found through the main website portal at URL: http://cals.arizona.edu/whiteflytracker). Click on 'maps' in right hand corner and download Silverlight software to view maps and hovering functions.

Based on a 2009 survey of stakeholders in Yuma and Phoenix area a number of individuals indicated that they would access the internet to obtain whitefly and virus data and information and that they would find these data useful (time of proposal submission) (TARGET). Further, during a winter 2010 Vegetable producers' meeting five stakeholders agreed to work with E. Taylor in the future by providing whitefly traps from specified locations (determined by the project survey). The survey assessed the response to the pilot website presented at the late spring Vegetable growers meeting (Maricopa Co.), which was highly positive (the information would be useful, they would use the website), and several suggested that a smart phone application for field access of the information would be very useful (TURNING POINTS). Note: when the project was proposed in 2009 only two of 50 stakeholders had smart phones. By the end of 2011, nearly 80% of the stakeholders had smart phones, making the option of a smart phone application feasible and desirable for the future.

Beneficiaries

We estimate that as many as 30 or more producers and field managers (farm holdings are primarily companies and large, individually owned local businesses) involved in vegetable and vegetable-cotton production, and at least 50 homeowner/urban stakeholders (urban-agriculture

interface) in the Phoenix area participated in and benefited from the project. In addition, producers and PCAs in Yuma, AZ and Imperial Valley, CA were given access to the website data set, which complements previous studies (E. Natwick) and Yuma (K. Nolte). The presentation at which the website was unveiled also included encouragement to reduce pesticide use until the first dispersing whiteflies are observed in fields or on sticky traps. This outreach effort was and continues to be beneficial because in Arizona some producers own land in both AZ and CA, and fields are situated across the same major river in the Yuma-Imperial valleys, (management practices thereby affect the region). Sharing the virus and whitefly distribution data and 'best practices' throughout the region provided an ideal means of implementing 'change of practices' on a large scale, since as the culture changes owing to first adopters (large land holding producers, usually) they spread among and between farmers/PCAs in multiple locations.

The establishment of this web-based tool represents the beginning of a kind of model for a means of reporting such data that envisions proactive and pre-emptive approach to protecting our food, fiber, and ornamental/landscape plants in Arizona. It embodies a model, that if extended and expanded to embrace and address new vector borne pathogen disease problems as they arise, will be the first proactive monitoring and reporting system for commercial producers, nursery, and homeowners/gardeners in Arizona.

Producers and field managers: Whitefly counts during whitefly season (Mar-Dec) enabled producers to employ knowledge-based decision-making to manage virus-vector complexes in melon crops. Knowledge of spatial and temporal dispersal patterns for whiteflies and of their over seasoning hosts, permitted better timed pesticide applications and reduce the overall number of applications used per season, resulting in 'economic' and 'environmental' savings. Herbicide application could be more selective because only plant species that are whitefly and/or virus hosts will require treatment. The approach preserved refugia for natural enemies. The product employs a 'systems agriculture' approach to vector-virus management based on local and regional 'knowledge', moving closer to 'best practices' and integrated management solutions.

Small farm producers, home owners in rural and urban areas: The Whitefly Tracker has the capacity to inform not only large-scale agriculture in Arizona but also nursery crop producers of insect vector- and virus-susceptible crops, as well as homeowners interested in caring for their landscapes, citrus, and vegetable gardens. Further, it could eventually be extended to monitoring psyllids that transmit the citrus greening bacterium, the potato psyllid vector of tomato yellows/potato zebra chip bacterium, new curtoviruses transmitted by leafhoppers to vegetable crops, among current examples, and other new, emerging, or introduced insect vectors of plant pathogens that are expected owing to climate alteration.

The State of Arizona: The AZ-Plant Diagnostics Network website http://cals.arizona.edu/azpdn/ will incorporate the *Whitefly Tracker* and provide an outlet for this kind of information, continuing to deliver this and other relevant pathogen-vector data available to the commercial and public sectors to strengthen our ability to protect Arizona agriculture, the security and safety of foods, and improve the quality of life for citizens be they home gardeners, horticultural or other plant-health related efforts in our state. Our motto is healthy plants = healthy economy = healthy people.

Lessons Learned

- The project, which was conceived of as a three-year project (the minimum for which meaningful field data can be obtained), was not funded in the second or third year, and so we could not continue collecting activities, as planned. A three year survey is most desirable because the effort would produce a superior data set from which to establish a baseline that takes into account year to year variation in whitefly population levels, and against which future trends could be compared.
- Similar kinds of projects are emerging throughout the US to monitor vector borne and other plant pathogens using smart phones (our ultimate goal and one that field managers and growers requested via a recent survey) to provide a service that alerts stakeholders about the status of the persistent whitefly pest and vector on an annual basis to guide the timing and application of pesticides for vector control. The 'smart phone app' has now been established for vegetable producers contending with whitefly and other virus-vector complexes in Florida, including stakeholder-extension-research collaboration to take whitefly counts and plant virus identification data sets and post them to the project website where they are accessible via the internet through a computer station, but also through a Smart Phone application.

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Additional Information

Enhancement of competitiveness of Arizona specialty crops: This near-real time management tool can enable field managers to obtain timely, information about local seasonal and spatial distribution of WFT-vector reservoirs to facilitate knowledge-based management. The *WhiteflyTracker* website and email alert system makes it possible to recognize when whitefly dispersal and virus-vector distribution fluxes occur, in relation to planting date/location. Directing pesticide applications to vector hot-spots together with management of key weed reservoirs will better guide and direct practices needed to abate reservoirs of vector-borne viruses of melon crops. Future mapping efforts can be guided by results obtained in the baseline study by identifying strategic locations for trap placement. Long-term trap counts and of virus reservoir distribution will comprise a growing epidemiological data set that over time will lead to exciting predictive capabilities.

PUBLICATIONS:

Notes, Bulletins, Abstract-Poster

Brown, J.K., Guerrero, J.C., Matheron, M., Olsen, M., and Idris, A.M. 2007. Widespread outbreak of Cucurbit yellow stunting disorder virus (CYSDV) in melon, squash, and watermelon crops in the Sonoran Plateau region of the Western USA and Pacific Coast of Mexico. Plant Dis. 91: 773.

Hernandez, C. and Brown, J.K. 2010. First report of a new species of curtovirus, Spinach severe leaf curl virus, in spinach crops in Arizona. Plant Dis. **94**: 917.

Nolte, K. and Brown, J.K. 2007. CYSDV Bulletin for Arizona. Yuma County Extension Office, Yuma, AZ.

Wintermantel, W.M., Gilbertson, R.L., Brown, J.K., and Natwick, E.T. 2010. Emergence and establishment of *Cucurbit yellow stunting disorder virus* in California and Arizona poses a threat to desert melon production. APS Meeting, Nashville TN August 2010 (poster).

Articles:

Combatting CYSDV in Arizona. In S. McGinley [ed.], Science and Education 2009 Impacts, A College of Agriculture and Life Sciences Report to CSREES, The University of Arizona, Tucson, AZ. URL: cals.arizona.edu/impacts/1_5.html

Melon Advances in Arizona. N. Riggs. 2010. http://growingmagazine.com/print.php?id=4994

Websites: The *Whitefly Tracker* URL is: http://cals.arizona.edu/whiteflytracker.

Using A New Reduced Risk Insecticide Technology to Optimize Insect Management

This project was completed on June 30, 2011

Project Summary

Clorantraniliprole, a new insecticide active ingredient which is labeled under the trade names Coragen and Durivo, is the first insecticide that will effectively control lepidopterous larvae (worms) as a soil systemic application. However, use of soil insecticides comes with inherent problems. Proper placement of Coragen soil applications is critical for optimizing worm control. If the product is placed too deep or too shallow below the seed line, Coragen or Durivo activity can be quite erratic, and improper applications at planting may not be noticed until weeks later when control has not achieved. Other misapplication issues can also result in erratic control. In most cases where field performance is poor following applications, growers often assume that either the insecticide was not applied correctly or insects have become resistant to the product. Obviously, the distinction between a bad soil application and insecticide resistance is very important for the sustainable use of these products. Unfortunately, growers presently have no means of determining either. To precisely answer these questions, growers require a method of determining *clorantraniliprole* levels in plants tissue, and how to interpret these results relative to expected insect control.

The objective of this project was to develop a diagnostic tool for using a new reduced-risk insecticide technology that will provide Arizona vegetable growers with a sustainable approach for controlling worms in desert vegetables. Studies were designed to specifically measure the residual uptake and persistence of this compound following planting by evaluating insect efficacy and concurrently measuring *clorantraniliprole* concentrations in plant tissue. As a result of a number of studies conducted in small plot and commercial fields, the average length of expected residual control was estimated, as well as baseline information of *clorantraniliprole* concentrations in lettuce plants at various stages of plant growth following soil application of Coragen/Durivo. This has already allowed vegetable growers to use this information in the event that a control failure or misapplication is suspected to determine whether insecticide concentrations in the plant leaves are within “normal” expected ranges, or whether worm populations have become resistant to the new compounds.

Project Approach

The project was initiated in August 2009 with research plots being planted on the Yuma Agricultural Center (YAC), and with cooperating vegetable growers in the Yuma area during August and September. A total of 4 field trials were established at YAC where Coragen was applied as at-planting, soil treatment at 5 oz /ac in replicated lettuce and broccoli plots. Plants were sampled for the presence of live worms (beet armyworm and cabbage looper) at weekly intervals from untreated and Coragen treated plots using standard protocols for a 6 week period to determine chlorantraniliprole efficacy. Plant leaf tissue samples were collected at 20, 30 and 40 days after planting for chlorantraniliprole chemical analysis. A total of 7 field plots were established in commercial lettuce growers where a similar sampling protocol was followed. Analytical quantification of chlorantraniliprole was conducted by using a protocol originally derived from DuPont Crop Protection and adapted by previous work conducted at YAC. Plant sample consisted of collecting leaves from the 3rd and 5th nodes of plants at each sampling interval. Plant leaf tissue samples were stored in a freezer prior to preparation for analytical quantification of clorantraniliprole in the laboratory that utilized an extraction and analysis methods similar to that used for the neonicotinoid insecticide quantification with HPLC. The study was expanded into the 2010 growing season. A total of 4 research plots were established at YAC where insect samples were collected from treated plots at weekly intervals for 5 weeks post emergence to determine chlorantraniliprole efficacy. At the request of several growers, tissue samples were collected in 16 commercial lettuce fields using the sampling and analytical protocol developed in 2009. Plant leaf tissue samples were collected for chlorantraniliprole chemical analysis at 20 and 30 days after planting.

Results of the efficacy trials conducted at the Yuma Ag Center clearly showed that Coragen applied at a precise placement and at proper rates provided significant residual control of both cabbage loopers and beet armyworms. Data combined over both years, along with data from previous studies, showed that average residual control of cabbage loopers varied from 27-36 days after planting and control of beet armyworms for 26-38 days in lettuce plots. On broccoli, average residual control of cabbage loopers varied from 32-39 days after planting and control of beet armyworms for 24-30 days. These values are based on the earliest presence of 2nd and 3rd instar larvae. In addition, control of both cabbage looper and beet armyworm (based on cooperating PCAs evaluation) varied from 24-32 days after planting in Coragen -treated lettuce and broccoli fields.

Tissue samples from the previous studies, and the 4 trials at YAC in 2009, showed that chlorantraniliprole concentrations in lettuce plant tissue averaged ~850 ppm at 20 days after planting and ~290 ppm at 30 DAP using the sampling protocol and analytical technique developed in this project. Furthermore, tissue samples from the 7 commercial fields in 2009 indicated that chlorantraniliprole concentrations averaged 824 ppm at 20 DAP and 190 ppm at 30 days. Residual control of both cabbage looper and beet armyworm (based on cooperating PCAs evaluation) varied from 24-32 days after planting. Based on these results we concluded that lettuce growers should expect about 4 weeks of residual control following soil applications of Coragen/Durivo with chlorantraniliprole concentrations in plant tissue averaging at or above 800 ppm at 20 DAP, and decreasing significantly thereafter.

However, in 2010 we decided to continue the study because of unusual events occurring in commercial lettuce fields. Beginning in mid-September, four separate growers complained that soil applications of Coragen (similar to those they applied in 2009) were not providing acceptable control of worms (mainly beet armyworm) under commercial growing conditions. Inspection of 16 individual fields in 2010 revealed unacceptable numbers of large larvae (2nd - 3rd instars) found throughout the fields with obvious damage occurring to seedling lettuce plants at anywhere from 14-18 days following planting. Consequently, each of the fields were treated with foliar sprays, unlike the previous year. This level of pest occurrence and damage was not observed this early in the crop in our 2009 commercial lettuce trials. Collections of larvae were taken from 2 fields and bioassayed for resistance to Coragen. Neither was considered a resistant population based on baseline data developed previously at our laboratory at the YAC. Subsequently, we collected tissue samples from each of the 16 fields at 20 and 30 DAP and an analysis for chlorantraniliprole concentrations was conducted using the protocol we developed in 2009. Results showed that chlorantraniliprole levels in all of the commercial lettuce fields were significantly lower than what our baseline data suggested they should be. Concentrations ranged from 41.8-115 ppm among the fields, significantly lower than expected index levels in lettuce plants at 20 DAP. Since insecticide resistance was ruled out, we could only speculate that the lack of performance was likely due to a combination of environmental (high temperatures, excessive worm pressure) and operational (light soil/water stress and misapplication) factors. Results from trials conducted at the YAC in 2010, showed less residual control and lower chlorantranilprole concentrations than 2009, but not at the same levels as were experienced in the commercial lettuce fields. These reduced levels were likely due to high temperatures and excessive worm pressure experienced in these plots for the first 20 days of the crop season.

Goals and Outcomes Achieved

The goal of this project was to further enhance the ability of vegetable growers to properly employ a new insecticide technology by designing studies that specifically defined Coragen/Durivo residual soil activity by correlating worm efficacy with known levels of clorantraniliprole concentrations in leaf tissue collected from treated plants. We believe that all Arizona vegetable growers have benefitted from this information while this new technology becomes integrated into their standard management programs for worm control.

The first project goal was to increase the awareness and technical knowledge of these chemical alternatives and the diagnostic indices developed in this project. We anticipated that one of the outcomes of this would be a significant increase in growers' awareness and technical knowledge of this new chemical and the diagnostic tools that are developed. We proposed that the project would significantly increase their awareness of chlorantraniliprole. We feel confident that this occurred. Although difficult to measure, we have presented the results of this project several times to PCAs and growers at extension meetings including: 2009 Desert Ag Conference, Casa Grande AZ; 2009 and 2010 Pre-season Vegetable Workshops, Yuma AZ; 2010 Desert Crops Workshop, El Centro CA; and at the 2009 and 2010 DuPont Fieldman Seminars, San Diego CA. In addition, information on this project has been provided to most AZ PCAs through our bi-weekly Veg IPM updates. We further proposed to measure this outcome by surveying of PCAs and growers following the 2009 and 2010 season to determining whether they had increased their implementation of this new technology for insect control. Results from our annual Lettuce

Insect Losses Workshops held each April which formally survey PCAs/Growers on their insecticide usage has shown that Coragen use on lettuce in 2008 was applied to 0% of the acreage, increased to 3.1 % in 2009, and was used on 10.3% of the lettuce acreage in 2010. We feel strongly that this project has had an influence on this sharp increase in usage in 2010.

An additional expected outcome we anticipated was to develop a diagnostic tool for evaluating the residual activity and persistence of this new soil applied insecticide technology in leafy vegetables (i.e., concentrations of clorantraniliprole within the plant relative to worm control). Prior to this project no such tools (or baseline data) existed. We have accomplished this goal and now have baseline data on the range of chlorantraniliprole concentrations (ppm) that should be measureable in lettuce and broccoli plant tissue at 20 and 30 DAP. This diagnostic index allowed us to assist growers in 2010 by showing that application errors/environmental factors were responsible for the poor field performance of Coragen in their fields, rather than insecticide resistance by worms.

Beneficiaries

The stakeholders who directly benefitted from this project include leafy vegetable growers, PCAs, and local Agro-chemical Industry representatives. The impact of this project on the beneficiaries is best measured by the significant increase in Coragen/Durivo usage by vegetable growers throughout AZ (see above). Furthermore, the diagnostic index of expected chlorantraniliprole values will soon be published in an extension publication, and is currently available to all growers/PCAs upon request. This is significant since growers who suspect a problem or experience poor product performance will be able to pull tissue samples using our protocol and have them sent to an analytical laboratory (i.e., Primus Labs) to verify chlorantraniliprole concentrations. Using our index, they will be able to compare lab results with the index to determine whether Coragen concentrations found in their fields are at levels that should provide acceptable worm control, or whether they may have other problems (i.e., resistance/application errors).

Lessons Learned

The most helpful lesson learned from this project was that it pays to take the idea a little further. Had we not asked for a no-cost extension and expanded our efforts for a 2nd year, we may not have been in a position to conduct the extensive field sampling in the commercial fields that we did in 2010. This not only allowed us to collect more field data at YAC, but allowed us to work with growers directly to address a question in which this project was designed to answer. This was an unexpected outcome as we had expected to develop the diagnostic index within the timeframe of this project, but did not expect to employ it so soon.

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Additional Information

This new technology (chlorantraniliprole) is an extremely safe insecticide product, particularly when applied to the soil for systemic uptake. Not only is it one of the most environmentally friendly products available, it has almost no adverse effects on human health and food safety. Other studies we've conducted outside of this project have clearly demonstrated that by using the product in the soil, 2-3 foliar sprays can be potentially eliminated on leafy vegetables. Not only is this economically advantageous to AZ growers, but also makes them more competitive as they can produce an extremely safe and high quality crop. Finally, the use of this technology will help eliminate any negative perceptions of excessive insecticide usage often associated with production of specialty crops in our desert cropping systems.

For a complete access to the Veg IPM Updates that cite Coragen usage, please go to:
http://ag.arizona.edu/crops/vegetables/advisories/advisories.html

Publications

Palumbo, J.C. 2009. Evaluation Of Novel Soil Applied Insecticides For Control Of Lepidopterous Larvae On Fall Lettuce. Arthropod Management Tests, Online. Vol 34, Section E33, 2 Pp. Doi: 10.4182/Amt.2009.E5

Palumbo, J.C. 2009.Control Of Lepidopterous Larvae On Fall Lettuce, Arthropod Management Tests, Online. Vol 34, Section E35, 2 Pp. Doi: 10.4182/Amt.2009.E5

Palumbo, J.C. 2009.Evaluation Of Soil Applied Insecticides For Control Of Lepidopterous Larvae And Whiteflies On Broccoli, Arthropod Management Tests, Vol. 34, Section E5, Doi: 10.4182/Amt.2009.E5

Using Weighing Lysimeters for Determination of Evapotranspiration

This project was completed on September 30, 2012

Project Summary

The Colorado River and its tributaries provide municipal and industrial water to about 27 million people and irrigation water to nearly 4 million acres of land in the United States (USBR, 2006). Approximately 4.2 million acre feet (5 billion m^3) of water are diverted at the Imperial Diversion Dam near Yuma to largely irrigate crops in the lower Colorado River region (LCRR). The irrigation of agricultural crops accounts for approximately 81% (4.5 billion m^3) of the overall water consumption in the state of Arizona (Arizona Department of Water Resources, 1991). Although water scarcity had not been considered a problem, it is expected that the increasing demand for fresh water from municipal and industrial sectors of the region will significantly reduce the share of fresh water supply available for irrigation. Tree-ring reconstructions of historical hydrologic conditions in the Colorado Basin show that river flow is currently over-allocated to users (Woodhouse et al., 2006). Over the past several years, the LCRR has experienced a prolonged drought further aggravating competition for the limited water resources. Further, continued drought conditions are forecasted for the LCRR over the next decade (Christensen et al, 2004). Agriculture interests, including those in Arizona, are being challenged to use water more efficiently.

Inefficient irrigation practices have also been cited as important factors contributing to significant nutrient (N and P) losses from irrigated watersheds of southern California and Arizona (Adriano et al., 1972; Letey et al., 1978; Sanchez et al., 1994; Sanchez, 2000). Total salt and nutrient loads in agricultural drainage in the region is directly related to irrigation management (Letey et al., 1977; Rhoades et al., 1973; 1974). Thus, efficient irrigation not only conserves water but also impacts positively on the environment by reducing the transfer of pollutants from irrigated lands to the groundwater and surface-water resources.

Typically, seasonal irrigation applications to vegetables approach 1 m, but estimated consumptive use is 0.2 to 0.3 m (Erie et al., 1963; Martin et al., 1999a; 1999b). Efficient irrigation depends on knowledge of when to irrigate, how much water to apply (water depth), and how to operate the irrigation system to apply the required water depth efficiently. The first two questions pertain to irrigation scheduling while the third question pertains to system design and management. While irrigation management has been an issue, we have developed information aimed at efficient irrigation management for surface systems over the past decade (Sanchez et al., 2008a; 2008b; Zerihun et al., 2001; 2005). However, limited information exists to accurately estimate ET, and appropriate crop coefficients for calculating ETc, from weather based ET^o estimates for irrigation scheduling. Recently, with funding from the United States Bureau of Reclamation we constructed weighing lysimeters and estimated ET and crop coefficients for iceberg lettuce.

The objective of this project was to use the weighing lysimeters constructed with previous funding to expand evaluations of evapotranspiration for other important crops produced in the region. From these data we calculated crop coefficients to be used in irrigation scheduling.

Project Approach

Four lysimeters were constructed using methodology described by others (Allen and Fisher, 1990). The lysimeters are 1.2 by 1.2m in surface dimension and 1.2 meters deep. These lysimeters contain an inner metal box filled with soil attached to an outer metal box with load cells. These load cells are calibrated to record weight change (irrigation and evapotranspiration) with a data logger. These lysimeters have a drainage plumbing tree near the bottom and a port to access and extract drain water after each irrigation and leaching event. These lysimeters were constructed and installed in the summer of 2007. The lysimeters are surrounded by a larger field area that is cropped identically to those produced inside the lysimeters. These lysimeters were successfully used for iceberg lettuce in the winter of 2008-2009. In these experiments we estimated ET for broccoli in 2009-2010 and cauliflower in 2010-2011. In 2008 through 2010 we used data logger where the data had to be annually downloaded in the field. For 2010-2011 we installed new data loggers where the data was transmitted to a computer in the laboratory.

Images of the broccoli fields with lysimeters are shown in Figures 1 through 4. The data collected are shown in figures 7 and 8. Images of the cauliflower fields with lysimeters are shown in figures 5 and 6 and data are shown in figures 9 and 10. The broccoli data, which seems quieter than the cauliflower data, generates kc values that are well above normal peak values of about 1.25. The only reason we can come up with is uneven vegetation height in the field or the lack of plants surrounding the lysimeters. Both of these situations potentially change the

lysimeter from a two dimensional planar evaporative surface to a three dimensional system that has more evaporative surface and is vulnerable to wind penetration from the side.

In the summer of 2010 we removed the lysimeters from the field for maintenance and re-installed them at a lower depth. We also fitted them with new data logging equipment that transmitted the data to a computer in the laboratory. Cauliflower and broccoli experiment were conducted after the lysimeters were re-fitted.

The resulting cauliflower data, while quite noisy, gives realistic crop coefficient values. The weekly data may be of better quality given the noise in some of these data sets.

Figure 1.Lysimeters with broccoli showing four lysimeters data loggers in 2009-2010.

Figure 2. A lysimeter with broccoli and data logger in 2009-2010.

Figure 3. Pumping drainage water from a broccoli lysimeter after drainage event.

Figure 4. Image for three lysimeters and broccoli.

Figure 5. Lysimeters and surrounding cauliflower field in 2010-2011.

Figure 6. A lysimeters with cauliflower during 2010-2011.

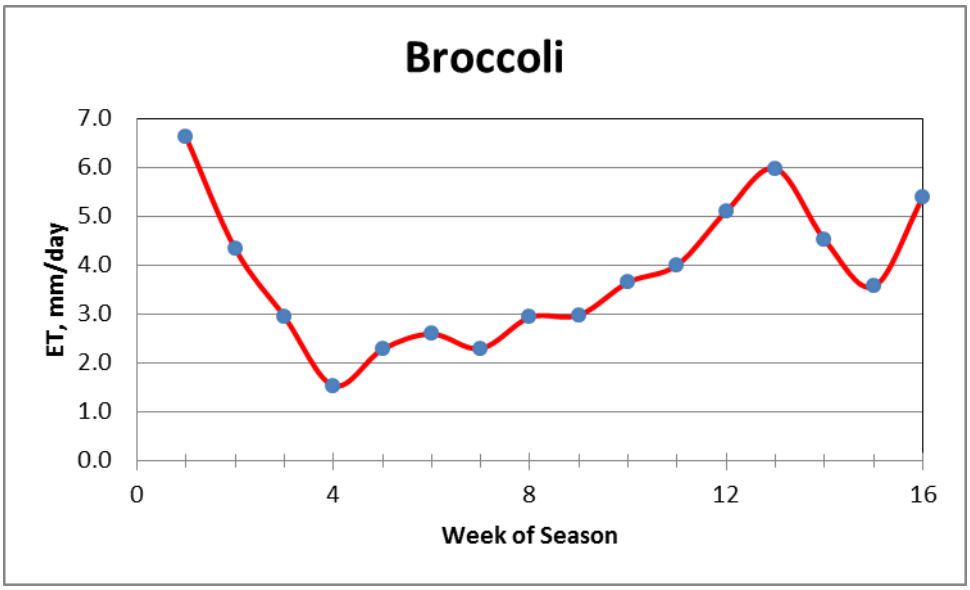

Figure 7. Estimated ET of broccoli in 2009-2010.

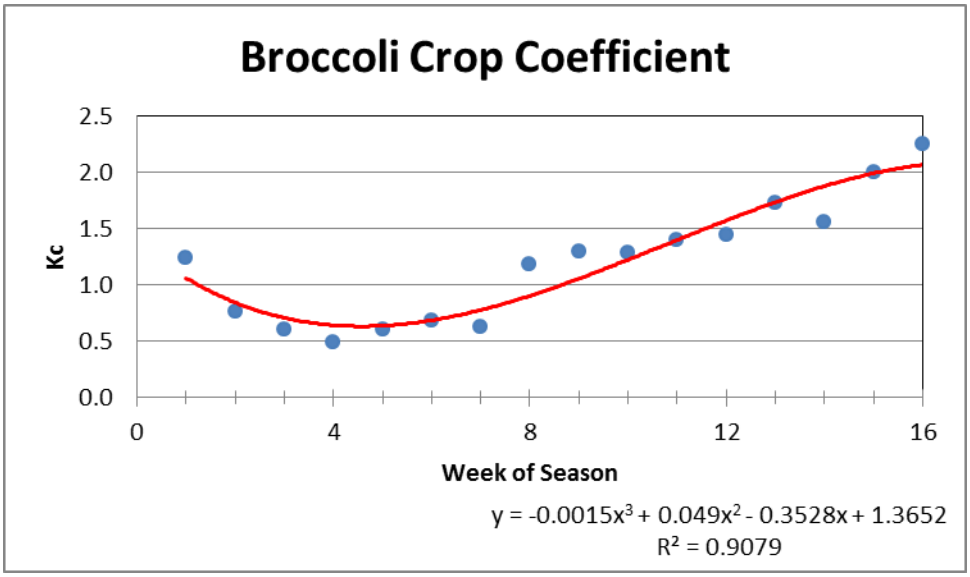

Figure 8. Estimated crop coeficients of broccoli from data collected in 2009-2010.

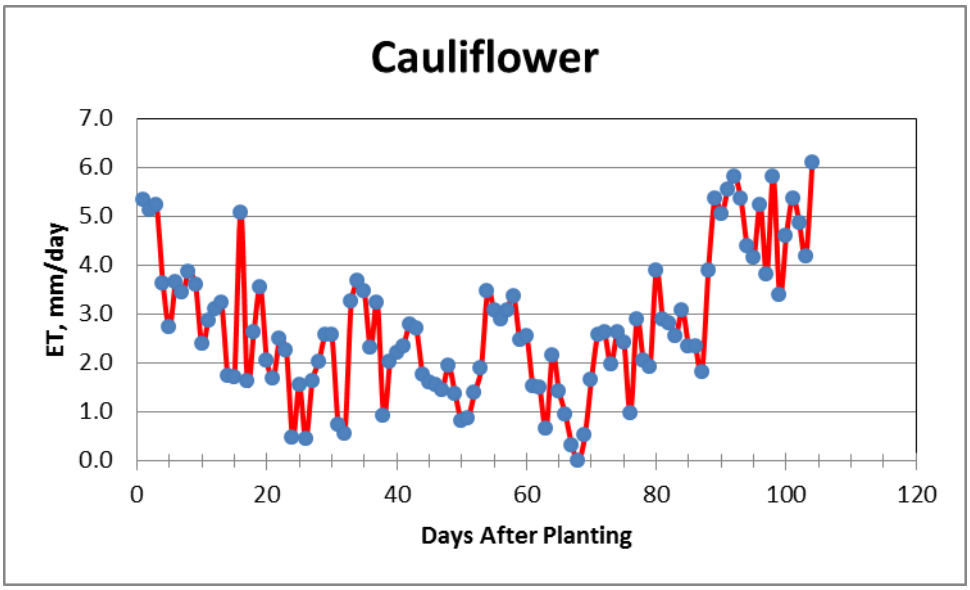

Figure 9.Estmated ET of cauliflower in 2010-2011.

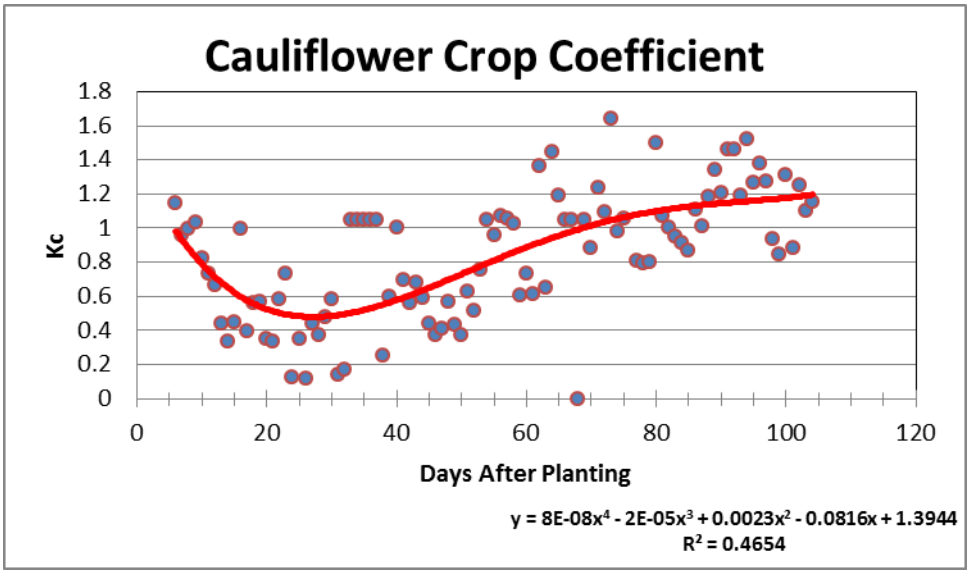

Figure 10. Estimated crops coeficients of cauliflower in 2010-2011.

Goals and Outcomes Achieved

We developed an improved data logging system that sends data from the lysimeters in real time to our laboratory and allows us to monitor for errors and power failure.

We solved height issues regarding the lysimeters, which affected the quality of the data. We calculated preliminary crop coefficients for broccoli and cauliflower. However, because we had lysimeters height issues with broccoli we will seek to validate these data with funding from other studies.

We have demonstrated the lysimeters in field days and we have presented preliminary data. We have only had contacts with about 300 producers and grower advisors. However, outreach activities related to this project are ongoing. We hope reach our goal of 800 contacts as outreach activities continue. We have found that growers are generally declined to fill out survey formed. Our initial experience is over 90% leave the workshop without completing the survey (< 10% participation). Thus we began asking questions by a show of hands. This informal approach indicated about 60% of those surveyed would be inclined to improve water use efficiency if it could be demonstrated that it would be done without compromising yield. However, concerns limiting adaptation include concerns about salt stress (about 70% of participants), inexpensive water costs (about 40% of participants) and a lack of information (about 60%). As noted outreach activities are continuing and we will experiment with alternative survey technologies (such as clicker compilers or real time computer feedback).

We have demonstrated the lysimeters in field days and we have presented preliminary data. However, outreach activities related to this project are ongoing. . We should reach our goal of 800 contacts within the 2012 year. We will also collect survey data in grower meeting scheduled in the spring and fall of 2012. After we validate to broccoli data in the spring of 2012 we will distribute fact sheets. We anticipate that as our outreach programs are fully implemented water use efficiency for broccoli and cauliflower will improve 10 to 20%.

Beneficiaries

The beneficiaries are principally vegetable producers in the low desert. However, water conservation benefits all residents relying in this precious resource in the arid southwestern United States.

Lessons Learned

The lysimeters of the size we constructed could not be used for crops such as cantaloupes that are grown on larger beds. These lysimeters can only be used for crops produced on 1 to 1.2 m beds. We are seeking funding to develop larger lysimeters for wide bed crops (>1.5 m).

The lysimeters have to be close to ground level for best results. We did not have problems with a short crop such as lettuce but ET estimates for broccoli were exaggerated with a wall height only 4 inches above ground level. These were lowered to ground level for cauliflower the second season. The broccoli experiments were repeated during the no-cost extension.

Because of variation, we needed all four lysimeters to be used in replication on a single crop within a growing season.

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Additional Information

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What Factors Lead to Increased Yield and Packout of 'Medjool' Dates?

This project was completed on September 30, 2012

Project Summary

Date seeds were first brought to the United States by Spaniards in the 1700's. From the 1890's through the 1920's the USDA imported many palm offshoots from Egypt and Algeria and planted them in Arizona, California and New Mexico. By 1922, the industry in Coachella/Riverside County was well established. Date orchards were first planted in the Yuma area in 1957. Today, the industry comprises about 13,750 acres. Coachella/Riverside County boasts 60% of the entire area planted to dates in the US, while the Yuma area includes 40%.

The most commonly planted in Coachella Valley/Riverside County has been the 'Deglet Noor', comprising about 60% of the total, but is decreasing in favor. Because of its prominence, and the fact that the great majority of the date research was done before 1980 in Coachella/Riverside County by UC and USDA personnel, all of the fertility information available for dates concerns 'Deglet Noor'. This variety is adaptable to lighter soil, typical of the Coachella Valley, has historically been irrigated using flood irrigation, and produces 100 to 150 kg of fruit per palm.

However, much of the recent plantings (since 1990) comprise the 'Medjool' (about 40% of the total acreage), because quality of 'Medjool' is higher than that of 'Deglet Noor', and the returns to the producer are greater. This variety is thinned to produce larger fruits than 'Deglet Noor' and is harvested 8-10 weeks earlier. 'Medjool' palms produce only 75 to 100 kg of fruit annually. 'Medjools' have been planted on a wide variety of soil types, and are irrigated using both flood and low-volume irrigation systems. Virtually all of the date palms in the Yuma area are 'Medjool'. The Yuma region, including Arizona, the Bard Valley of California and Northern Mexico comprises about 7,000 acres.

Given that the variety, production practices and soils of the Yuma region are distinct, it became important to understand which of these factors might lead to improved yield and packout. These factors would include tree age, tree density, soil characteristics, soil compaction, fertilization practices, leaf nutrient concentrations, pollination methodology, fruit and bunch thinning rates. Thus, a study to collect these data and correlate them in 17 regional blocks of 'Medjool' dates was conducted.

Project Approach

Tree age: We collected tree age information from each of the 17 sites by interviewing the growers and by surveying each site, estimating tree age based on tree height (date palms grow about 1 ft. per year). See Tables 1a and 1b in **Appendix G.**

Tree Density: We collected tree density information from each of the 17 sites by interviewing the growers and by measuring tree spacing, and calculating tree density. See Tables 1a and 1b in **Appendix G.**

Yields and Packout: We collected yields and packouts from grower's records and packinghouse data. See Tables 2 and 3 in **Appendix G.**

Soil Characteristics: We collected soil characteristics data for the sites using the USGS soil survey information and by taking soil samples for analysis for each site. See Tables 1a and 1b in **Appendix G.** Samples were taken at 0-8" and 8-18" depth, then dried, ground, sieved, and sent for analysis to Ward Labs, Kearney, NE. Selected average soil parameters are shown in Table 4 in **Appendix G.**

Soil Compaction: This work to be completed in SCBG 2010-06. We selected 6 of the 17 sites for further investigation.

Fertilization Practices: This information was collected from the growers. We also calculated the amount of fertilizer added per acre. For a summary of fertilization practices, see Table 4 in **Appendix G.**

Leaf Nutrient Concentrations: We collected leaves in the late fall (November), following harvest. They were then dried, ground, sieved, and sent for analysis to Ward Labs, Kearney, NE. Results were returned from the lab after 5 to 8 weeks. We have 2010 and 2011 data. For 2011 data, see Table 5 in **Appendix G.**

Pollination Methodology: Pollination is typically done by workers with squeeze bottles (Palace I, Winterhaven and Colby), by workers with a mechanical blower (Avenue F, Vandevoort Bard, Tacna, Berryman, Lost 20, Block 1, Block 12, Block 13, Block 301, Block 302, Kofa, Gavilanes, and One E), or by remotely controlled blower (Jessen Home).

Fruit and Bunch thinning rates: We estimated total fruit load per palm by estimating arm, string and fruit counts before and after thinning operations by the working crews. See Figure 1 in **Appendix G** for this information.

<u>Significant results, accomplishments, conclusions and recommendations</u>

Tree age: When complete, we will have the first ever estimation of tree age and yield. Our preliminary idealized yield curve is shown as Figure 2 in **Appendix G.** This will allow us to place a value future valuation of trees and acreage based on potential yield.

Tree Density: Most of the date ranches had similar densities, so there are no recommendations.

Yields and Packout: Yield appears to be superior for date trees on heavier soils. This conclusion is tentative; it is based on only two years of data. For the lighter soils, improved fertilization practices may lead to better yields.
Soil Characteristics: Most soil characteristics were similar. Trees where manure was used regularly had more fertile soils. Compost-improved soils led to improved soil fertility. Salts were not a problem, except in one location, where it may affect yield.
Fertilization Practices: Where manure and/or compost are used regularly, yields appear to be improved, as compared to sites where liquid nutrients are the main fertilizer source.
Leaf Nutrient Concentrations: We are completing the first comprehensive work on leaf nutrient concentrations for Medjool dates, and we will be able to correlate this data with yields. Thus, we will be able to develop recommended leaf nutrient concentrations for maximal yield.
Pollination Methodology: There was no apparent effect of pollination methodology upon yield or fruit quality.
Fruit and Bunch thinning rates: We are completing the first comprehensive data set on fruit population before and after thinning. This will allow for yield estimation prior to harvest, which would be useful for Integrated Pest Management for date palms, as well as for scheduling labor.

Goals and Outcomes Achieved

Tree age: Data collection is complete**.**
Tree Density: Data collection is complete.
Yields and Packout: Data collection for 2010-11 and 2011-12 harvest is complete. Yield and packout for 2012-13 season will be available after August 1, 2013. This is because some of the yield for the 2012-13 season is in freezer storage at the DatePac packinghouse and will not be graded until just before it is shipped which will occur as the orders come in.
Soil Characteristics: Data collection is complete.
Soil Compaction: Results to be reported as part of SCBG 10-06.
Fertilization Practices: Data collection for 2012-13 is as yet incomplete, 67% of the collection is finished.
Leaf Nutrient Concentrations: Data collection is 67% complete, Ward Laboratories has not returned the results for the 2012-13 leaf analysis.
Pollination Methodology: Data collection is complete.
Fruit and Bunch thinning rates: Data collection is complete.

Beneficiaries

Beneficiaries of the project are the 15 members of the Bard Valley Medjool Date Growers Association (BVMDGA), the owners of the DatePac cooperative packinghouse, and the other Medjool date growers in the region. The BVMDGA members comprise about 80% of the total growers in the area.

There are about 7,000 acres of dates in the region, and about 4,500 of those acres are in Arizona, with the rest being in Bard, California (across the river from Yuma), and in northern Sonora. Of that quantity, about 3000 acres are mature trees (over 15 years old). Considering just the mature acreage, the net value of the crop is $8,000 per acre, for a total of $24,000,000 annually.

Members of the BVMDGA have business interests in all three areas, and dates from all three areas are packed at DatePac (which is in the city of Yuma). In 2010, about 8,000,000 pounds of dates were packed at DatePac. That figure rose to 11,000,000 pounds in 2011, and will rise to 14,000,000 pounds in 2012. Typical return to the grower is $3.00 per pound, and by this calculation, the value of the industry (DatePac only) is $42,000,000 annually. There is likely another $8,000,000 in value for the portion of the industry that is not packing through DatePac.

This project could likely save the grower 3 to 5%, or from $720,000 to $2,100,000 annually for the entire industry.

Lessons Learned

- Date ranches are not uniform; there are many trees of varying ages in any individual ranch.
- Tree density is remarkably uniform. Tree spacing is about the same, regardless of owner.
- Preliminary yields and packouts vary considerably. This is likely due to variable rates of thinning, and to deleterious effects of the weather (humidity and rain) at harvest time. Packouts are mostly affected by location (valley or upland) and soil type. From 2010 to 2011, yields fell by 5% and fruit quality dropped by 7%. This is likely due to rain during harvest.
- Soil characteristics are similar for those ranches in the valley regions, but quite different for those ranches on upland, sandy soils. These lighter soils are rather infertile.
- Growers record keeping of fertilization practices ranges from good to inadequate. We are still trying to get some of this.
- Up to this point, there have been no date growers who regularly use leaf nutrient concentration as a parameter when deciding to fertilize. Also, there are no recommended leaf nutrient levels for Medjool dates.
- A small amount of date pollen is extremely effective in pollinating the entire crop. Pollination methodology had no effect.
- Growers remove from 70% to 90% of the crop while thinning to achieve the fruit size levels that the market demands. There is a tremendous amount of hand labor involved in thinning and this is an area that deserves additional research so that these costs may be reduced.

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Additional Information

Please see **Appendix G** for tables and figures referenced. We have been meeting quarterly with the growers to provide them updates of this project. As this project has not been funded for additional years by the SCBG program, it is likely that the date growers will fund the entire project for several more years. When enough data is gathered, we will publish our findings in appropriate extension publications. When enough data is gathered, we will publish our findings

in appropriate extension publications. We will also meet with the growers to share the results in one of their quarterly meetings.

Whitefly Management for Nurseries and Landscapes in Arizona

This project was completed on March 31, 2012

Project Summary

Sweetpotato Whitefly, Bemisia tabaci is a major pest of both ornamental and agricultural crops in Arizona. They cause injury such as leave curl, sooty mold as well as transmit viruses that cause plant death. Whitefly populations in Yuma County showed that on average 2000 whiteflies were collected monthly between June and October (Bealmear, 2011). When comparisons were made between the City of Yuma and the agricultural/urban interface, the city whitefly populations were independent of the agricultural/urban interface except in the Western part of the city when a crop free period was in place for agricultural areas. This shows that city whitefly populations can be influenced by agricultural production. This interaction in whitefly migration leads to questions about management.

The incredibly high numbers of whiteflies leave many in the green industry with concerns of whitefly management but are unsure which products to use. In 2008 the Yuma Cooperative Extension office received over 50 questions on whitefly management strategies. Since little is known about the effectiveness of available products clients were often directed on antidotal evidence. More information is needed to make these recommendations; product testing can help with the successful management of whiteflies. This project will focus on non- commercial chemistries since many in the green industry do not use commercial products due to possible legal issues.

This project will evaluate current noncommercial products available to nurseries and landscapers (green industry) for whitefly management and determine the overall range of their effectiveness and persistence. While whiteflies are a major pest of both landscape and agricultural crops, no one in Arizona has evaluated non-commercial pesticides used to control them in the green industry. The chemistries available for whitefly management in both horticultural and agricultural systems could lead to future issues of resistance management. An assessment of chemical usage within the green industry could serve as a baseline for establishing future whitefly control strategies while promoting good stewardship of chemical use. Finally, product evaluation will determine their overall effectiveness and will generate a means for whitefly management recommendations.

1) Through a statewide assessment, identify current whitefly control strategies and provide a broad understanding of current whitefly management strategies within the green industry.
2) Determine the currently available chemistries that are most effective at managing whiteflies in within the green industry.
3) Update whitefly management guidelines for the green industry within Arizona.

Project Approach

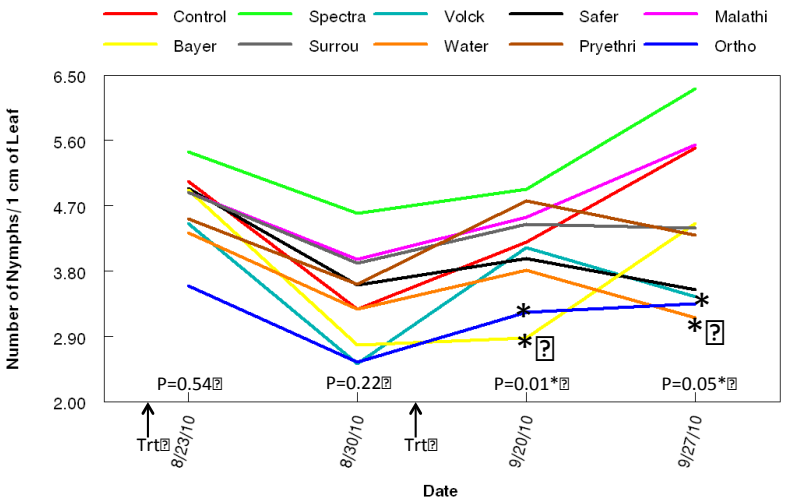
This was a two-part project to determine what pest control methods were being used to control whiteflies and to test different insecticides to see which products worked best. This was done with an online survey of green industry professionals, homeowners and gardeners. It showed that the majority of people were not managing whiteflies. Those who were managing whiteflies were asked to provide the name of the products used. Those products along with others commonly used insecticides were tested to see which ones worked best. This test was run two summers in a row 2010 and 2011. They survey also included other questions regarding whiteflies such as where the participants lived and what type of plants they were have most of their whitefly issues in.

The experiment was set up in three replicated blocks with ten treatments. These treatments were; 1) control, 2) Spectracide Insect Killer (Gamma-Cyhalothirin), 3) Volck Oil (Petroleum oil), 4) Safer Soap (Potassium salts), 5) Malathion, 6) Bayer Advanced (Imidacoloprid), 7) Surround (Kaoline Clay), 8) Water, 9) Pyrethrin, 10) Ortho Max (Acetamiprid). The treatments were placed onto Lantana, which are commonly used landscape plants and a whitefly host plant. Leaf samples were taken three, seven, ten and fourteen days after treatment. On all of these days adults were collected using an insect vacuum and counted. On day seven and fourteen the number of live nymphs were counted on a 1 cm leaf disk. For both of these counts a dissecting scope was used. The data was then analyzed in SAS using proc means and proc glm.

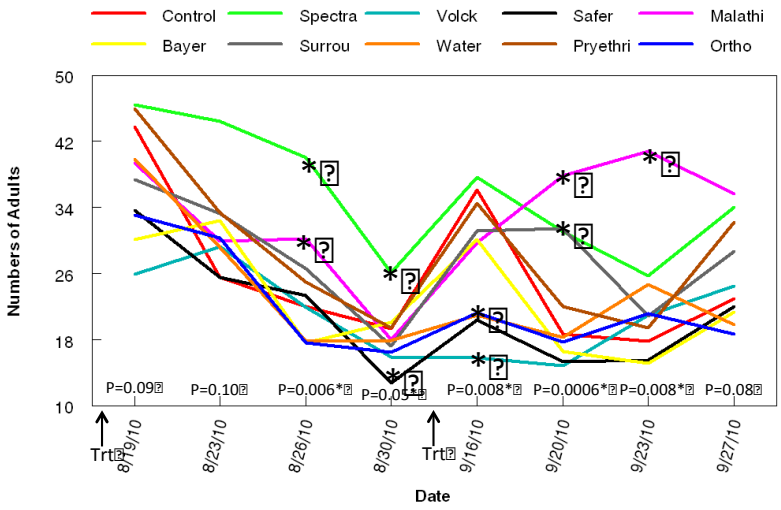
Goals and Outcomes Achieved

As stated above this project started with a survey that was designed and given October of 2009 to February of 2010. The survey was then tabulated and analyzed. From this analysis the efficacy test was designed. In April of 2010 the lantana was planted and the first experiment was run in July of 2010. Two rounds of experiments were completed in 2010 and three were completed in 2011. All of the expected measurable outcomes were met except the publication. I am currently analyzing 2011 data so that I can write the publication.

Nymph Results



Adult Results



- Nymphs

Ortho-max, **Bayer Advanced**, **Water**, **Volck Oil** and **Safer Soap** treatments had **significantly fewer** whitefly nymphs than the control treatment

- Adult

Spectracide and **Malathion** treatments had **significantly more** whitefly adults than the control treatment

Ortho-max, **Surround**, **Water** and **Volck Oil** treatments had **significantly fewer** whitefly adults than the control treatment

- While there were products that reduced whitefly numbers **nothing worked consistently throughout the treatment period**. A combination approach looks to be the best solution
- **Two products (malathion and spectricide) are not to recommend** for adults.

Even though the publication is not done, I have been presenting the first years data to both homeowners and industry. To date I have shared this information with 150 people through presentations. Once the 2011 data is analyzed I still hope to alter the pest control methods of 5% of industry professionals and inform 30% of the industry about the non-commercial whitefly materials available to them and their effectiveness

Expected Measurable Outcomes:
This project will have three outcomes:

1. A web-based assessment tool, was administered to green industry professionals, urban horticulturalists, horticultural agents and master gardeners, and provided a ranking of the most widely used whitefly control products and served as a baseline for current whitefly management protocols.
2. Efficacy trials of non-commercial whitefly management technologies were conducted at the University of Arizona, Yuma Agricultural Center for a 2-year period.
3. A fact sheet will summarize these results and outline whitefly control recommendations for the green industry within Arizona.

Beneficiaries

This project will benefit green industry professionals (nurseries employees and landscapers) as well as homeowners and gardeners. While I have not been able to clearly identify the best product to use to management whiteflies I can say that two products clearly did not work. I'm hoping that after the 2011 data is analyzed that a clear winner will be identified. For now I would not recommend using Spectracide Insect Killer (Gamma-Cyhalothirin) or Malathion. These products did little to reduce whitefly numbers and in the case of Malation it actually made it harder since the whitefly numbers in these plots were three times as high as any other treatment.

As a regular speaker for industry conferences here in Arizona I have the possibility to reach many green industry professionals. I also plan to write a publication, which has the ability to reach many homeowners and professionals. It's hard to say exactly how many but I'd assume the number would be in the hundreds. Both the presentation and the publication will help them to choose products that work instead of relying on products like Malathion, which just makes the problem worse. How many green industry professionals will this benefit? How will it benefit them? How will they access the results of your research?

Lessons Learned

I was surprised that there was not one product that outperformed all the others. According to the 2010 data some worked better than others but only for short periods of time. It was also very surprising to see that a heavy stream of water was just as effective at managing whiteflies as some of the chemical products used.

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Additional Information

Once the publication is completed green industry professionals will know which products to use and recommend for Arizona ornamental specialty crops. This will save them time and money.

Arizona Specialty Crop Reference Guide (Updates)

This project was completed on September 30, 2012

Project Summary

Arizona consumers are unaware of which specialty crops are grown in Arizona, the economic impact of those specialty crops, the benefits of buying local produce, and opportunities available in the agricultural industry. The Arizona Specialty Crop Guide will educate Arizona consumers about Arizona produce and nursery plants and encourage them to seek out and purchase Arizona grown specialty crops. It is important that this information reaches as many Arizona consumers as possible.

The updated educational reference guide for consumers includes:

- Where our food and plants come from and the benefits reaped from buying Arizona grown produce and plants
- Eat, Plant and Buy Local Programs
- Directory of Farmer's Markets and U-Pick Farms
- Listing of Arizona Specialty Crop availability by season

- Agriculture Education Programs offered by state educational institutions
- Career Opportunities in Agriculture
- Food safety information (What's being done and what consumers can do)

The Department has developed, updated and printed approximately 15,000 Specialty Crop Guides since 2008. The guide has been well-received among the public and therefore a request was made to update and re-print the guide in 2012. The information in the previous guide was reviewed, updated and sent to the design company for printing. The Arizona Specialty Crop Guide will increase consumer awareness and consumption of Arizona specialty crops through its distribution at county libraries, cooperative extension offices, and various agricultural events.

Project Approach

In July 2012, the SCBGP Program Coordinator began the process of updating the previous version of the Arizona Specialty Crop Guide. Revisions were made based on the most current information available at the time. Two additional pages were added to highlight the AZ Grown and Plant Something marketing programs.

In addition, 10,000 of the guides were affixed with a post-it type note to the front cover that invited the reader to participate in a survey. Survey participants will be entered into quarterly drawings to win AZ Grown products. These post-its can be removed in the event that there are still guides to distribute when the survey is done or added to additional guides if needed before the survey is done.

In September of 2012, the Department entered into a contract with Esser Design to make the revisions and print approximately 21,500 copies of the updated guide. Distribution of the guides began immediately after production. More than 8,000 of the guides were dropped shipped directly from the printer to public libraries and university extension offices.

Goals and Outcomes Achieved

To date, approximately 8,900 of the new guides have been distributed with the potential of reaching approximately 20,470 Arizona consumers (based on average readership per copy of 2.3).

The guides were distributed to University Cooperative Extension offices (statewide), Public Libraries (statewide), and at other events. The guides will continue to be distributed as requested and at various agricultural events, conferences and meetings (statewide). A copy of the guide is also available on the Department's website at: http://www.azda.gov/ACT/SCBGP.htm and the AZ Grown website at: www.azgrown.org.

An online survey to assist the ADA in determining the increase in awareness of Arizona specialty crops was developed in December 2012. The survey link was posted at: www.azda.gov/scsurvey.htm and www.arizonagrown.org.

Since the survey posted on December 21, 2012, there have been 20 participants. 100% of the participants indicated that the information in the 2013 Arizona Specialty Crop Guide increased their awareness or knowledge of Arizona specialty crops. A summary of the survey results to date are as follows:

Response Summary	**Total Started Survey:**	**20**
	Total Finished Survey:	**20 (100%)**

1. Has the information in the 2013 Arizona Specialty Crop Guide increased your awareness or knowledge of Arizona specialty crops?

Answered Question	**19**
Skipped Question	**1**

	Response Percent	Response Count
Yes	**100.0%**	**19**
No	0.0%	0

2. Which sections of the 2013 Arizona Specialty Crop Guide did you find the most informative or useful? (Check all that apply.)

Answered Question	**19**
Skipped Question	**1**

	Response Percent	Response Count
Benefits of Buying Arizona Grown	31.6%	6
Eat, Plant & Buy Local Programs	52.6%	10
Arizona Farmers' Markets	**57.9%**	**11**
Arizona U-Pick Farms	42.1%	8
Agricultural Opportunities for Kids & Teens	31.6%	6
Agricultural Opportunities for Young Adults	21.1%	4
Arizona Agriculture in Higher Education	15.8%	3
Agricultural Career Opportunities	10.5%	2
Agricultural Scholarship Opportunities	15.8%	3

3. Have your shopping habits or consumption practices changed since reading the 2013 Arizona Specialty Crop Guide?

Answered Question	**20**
Skipped Question	**0**

	Response Percent	Response Count
Yes	**80.0%**	**16**
No	20.0%	4

4. How many people have you shared the information in the 2013 Arizona Specialty Crop Guide with?

Answered Question	**20**
Skipped Question	**0**

	Response Percent	Response Count
0	10.0%	2
1-3	**65.0%**	**13**
4 or more	25.0%	5

The survey will continue for at least one year, but with the initial respondents we have exceeded our goal and target of 80% for question number 1.

Beneficiaries

Nearly 50,000 Arizona consumers will potentially benefit from the 21,500 Specialty Crop Guides that have been printed for this project (based on average readership per copy of 2.3). There will be an unknown number of additional beneficiaries that view the guide electronically on the websites.

Lessons Learned

There were no specific lessons learned regarding this project.

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Addendum 1

Appendix A
referenced from page 3

SOUTHWESTAGSUMMIT

It's More Than Farming...

In partnership with:

Yuma Fresh Vegetable Association

YUMA COLLEGE OF AGRICULTURE AND LIFE SCIENCES

Yuma County Farm Bureau

Yuma, Arizona March 10 & 11, 2010 Yuma Civic Center

FIELD DAY

Wednesday March 10

(3 CEU's/AZ, 3 CEU's/CA & 3 CCA's/AZ, 4 CCA's/CA)

7:00 AM ..... Registration and Breakfast

8:00-Noon ..... Field Demonstration Day
Yuma Ag Center

12:00 PM ..... Pre-Summit Golf Tournament Lunch
Desert Hills Golf Course

WILBUR-ELLIS. WESTERN GROWERS™ Crop Production Services PS

1:00 PM ..... Golf Tournament Shotgun Start
Desert Hills Golf Course

5:30 -9:30 PM ..... Summit Evening Dinner Reception
Kammann Sausage, Carne Asada, Wings, Beer, Wine and Fun
Open to All Registered Summit Attendees
Yuma Civic Center

Demonstrators

1. USDA-ARS ..... Lettuce Disease Demonstration Trial, Dr. Ryan Hayes
2. SITECH Southwest ..... Trimble Autopilot with VRS RTK Connection
3. Keithly-Williams Seeds ..... The Williames Automatic Transplanter
4. Plateau Lasers ..... GPS Precision Leveling and Steering
5. Bayer CropScience ..... Bayer Force One Field Demo Truck
6. Booth Machinery Inc ..... Case IH Ecolo Tiger 870 Disk Ripper
7. RDO Equipment Co ..... Greenstar RTK GPS Autotrac System
8. Bingham Equipment Co ..... Tractor Performance Monitor
9. Delta Plastics ..... Lay Flat Polytubing for Furrow/Flood Irrigation
10. Keithly Williams Seeds ..... The RoboCrop Automated In-Row Weeder/Thinner
11. Rain Bird Corporation ..... LF Sprinkler
12. Empire Southwest/Wilcox Ag Products ..... Conservation Tillage in Vegetable Production Using the Wilcox Eliminator

IRRIGATION CANAL
AVE. E
N
2010 Southwest Ag Summit Field Demos
Yuma Ag Center - Wednesday Morning
(3 CEU's/AZ, 3 CEU's/CA & 3 CCA's/AZ, 4 CCA's/CA)
YUMA
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
USDA
Lettuce Variety Trials, Dr. Ryan Hayes
FARM ROAD
FARM ROAD
PARKING
SITECH
Trimble Autopilot with VRS RTK Connection
KEITHLY-WILLIAMS SEEDS
The Williames Automatic Transplanter
GPS Precision Leveling and Steering
REGISTRATION
FOOD
BAYER
PARKING
RDO
Greenstar RTK GPS Autotrac System
Bingham
Tractor Performance Monitor
Delta Plastics
Lay Flat Polytubing for Furrow/Flood Irrigation
KEITHLY-WILLIAMS SEEDS
The RoboCrop Automated In-Row Weeder/Thinner
RAIN BIRD
LF Sprinkler
Bayer Force One Field Demo Truck
IRRIGATION CANAL
Case IH Ecolo Tiger 870 Disk Ripper
EMPIRE CAT
WILCOX
Conservation Tillage in Vegetable Production Using the Wilcox Eliminator

Mark E. Ellsworth

Marvin Marlatt

WELCOME

On behalf of the Yuma Fresh Vegetable Association, the University of Arizona and the Yuma County Farm Bureau we welcome you to the 4th annual Southwest Ag Summit. The success of the summit has always been a byproduct of side-by-side collaboration among our agricultural industry leaders, University research, teaching and extension faculty. And, continuing with this collaboration, the YFVA and the YCFB are honored to be working side-by-side this year to bring you greater presentation diversity, an expanded vendor trade area and the very popular field demonstration event.

The new collaboration adds a new synergy and flavor to the summit this year. We build on the strength of the YFVA and vegetable production with the addition of YCFB's general agricultural leadership. United, we have created the premiere agricultural event that encompasses virtually every aspect of scientific, technical and practical crop production and related fields.

Our keynote speaker, Mr. Charles Hoppin, will be making a presentation whose topic is woven into the very fabric of our industry, water. Being at the forefront of all California water related issues, Mr. Hoppin will deliver a message that offers us opportunities to become a part of our future water stewardship, and what can be learned from our California neighbors.

Yuma agriculture recognizes the unique role that the University of Arizona plays in both preparing students for the workplace and enhancing the skills of professionals already on the job. In this light, we welcome over 100 local students to our 2010 conference and allow them to see for themselves, that agriculture is certainly more than farming.

The Ag Summit is just one example of the strong partnership within the Yuma agricultural industry. Take pride in our annual event, network with colleagues, participate in a breakout forum or panel discussion, tour the vendor trade show and demonstration day, build new relationships, and enjoy the experience.

Yuma Fresh Vegetable Association

YUMA COLLEGE OF AGRICULTURE AND LIFE SCIENCES

Yuma County Farm Bureau

PRESENTATIONS & EXHIBITS

Thursday March 11

7:00 AM ..... Late Registration/Refreshments

7:45 AM ..... Opening Remarks
Dr. Eugene Sander, Dean
University of Arizona

8:15 AM ..... Morning Keynote
Charlie Hoppin, Chairman
California State Water
Resources Control Board
"Grower Involvement in Future Water Regulatory Issues"

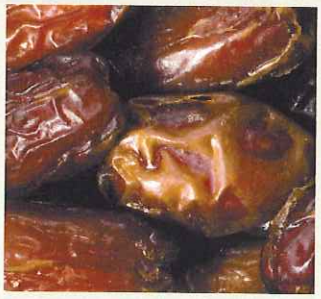
9:15 AM ..... Networking Break, Tour of Vendor Exhibits

9:45 AM ..... Morning Forums

11:45 AM ..... Lunch

12:30 PM ..... Industry Update

1:30 PM ..... Afternoon Forums



Thursday 8:15 AM
Keynote Event
(1 AZ/CA PCA & 1 AZ/CCA CEU's)

HARRIS MORAN SEED COMPANY

GROWER INVOLVEMENT IN FUTURE WATER REGULATORY ISSUES

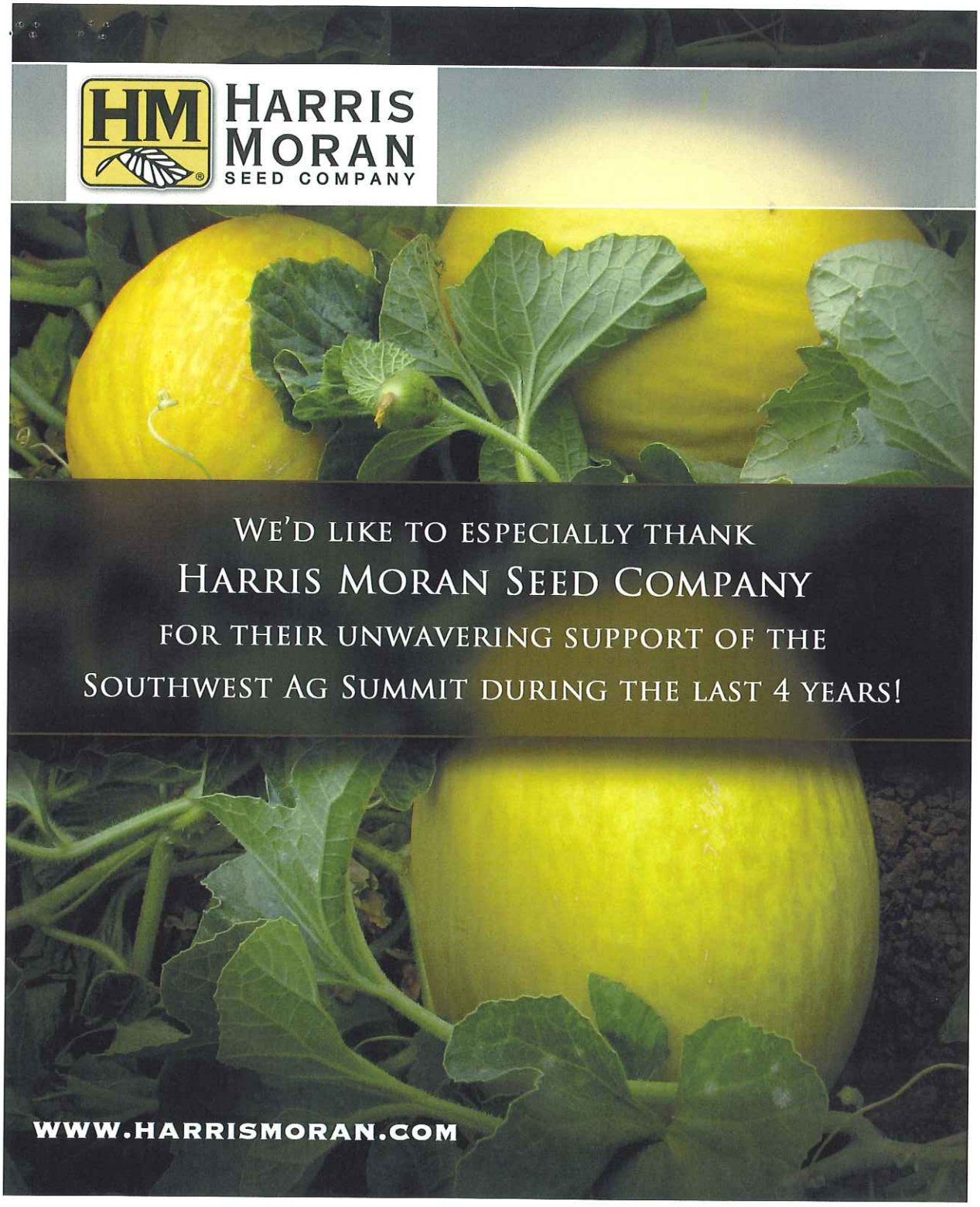
Charlie Hoppin, Chairman
California State Water
Resources Control Board

The three-year natural drought is just one factor contributing to California's water crisis. The others are tougher because they are political: the Sacramento-San Joaquin Delta, the Endangered Species Act, and the lack of water storage. As California's water crisis increases, learn what Arizona producers can do now to protect their future agricultural water supplies.

Charlie Hoppin of Yuba City has served on the State Water Resources Control Board in the position of water quality expert since 2006. In March 2009, Governor Schwarzenegger appointed him Chairman of the State Water Board. He is a partner in a family operated diversified farming operation in Yolo and Sutter counties. The crop base includes, fresh market melons, rice, walnuts, and a variety of small grains and oil seed.

Mr. Hoppin serves on the California State University Advisory Committee, and on the Board of Directors of Farmers Rice Cooperative where he is currently audit and finance Chairman and Vice Chairman of its Board.

Prior to his appointment to the State Water Resources Control Board, Mr. Hoppin served as advisor to then Governor Pete Wilson during the 1997 California Flood Recovery Effort, a Board Member of Sutter Mutual Water Company and a Member of the State Board of Food and Agriculture. He is the immediate past Chairman of the California Rice Industry Association. During his tenure at the Rice Industry Association, Hoppin played a key role in the implementation of many of the industry's well-recognized environmental stewardship efforts.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MORAN
SEED COMPANY
WE'D LIKE TO ESPECIALLY THANK
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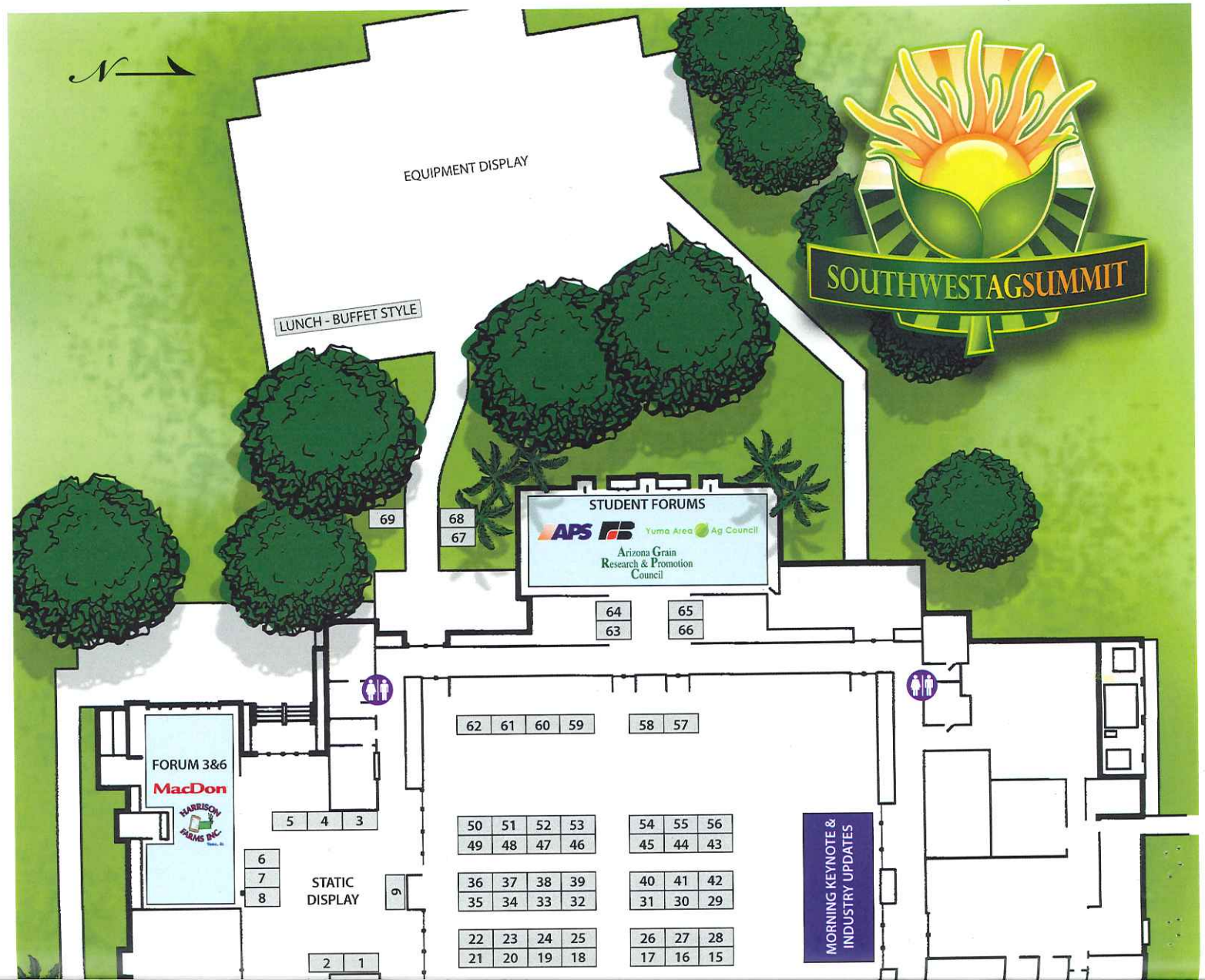
FOR THEIR UNWAVERING SUPPORT OF THE
SOUTHWEST AG SUMMIT DURING THE LAST 4 YEARS!
WWW.HARRISMORAN.COM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EQUIPMENT DISPLAY
LUNCH - BUFFET STYLE
SOUTHWESTAGSUMMIT
STUDENT FORUMS
APS
Yuma Area Ag Council
Arizona Grain Research & Promotion Council
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FORUM 3&6
MacDon
HARRISON FARMS INC.
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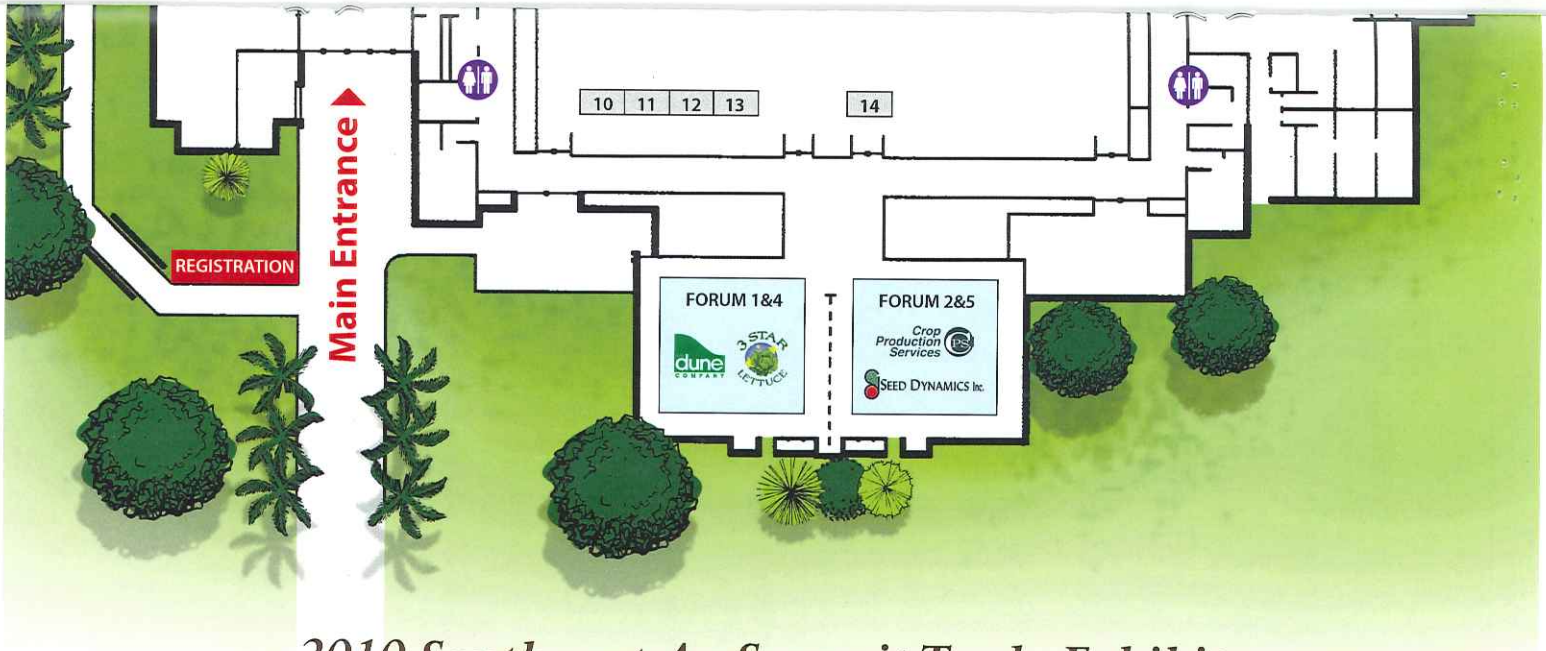
MORNING KEYNOTE & INDUSTRY UPDATES



2010 Southwest Ag Summit Trade Exhibits

1 Westflow Company
2 Farm Credit Services SW
3 Plateau Laser
4 Marrone Bio Innovations
5 UPI
6 Keithly Williams Seed
7 Keithly Williams Seed
8 Keithly Williams Seed
9 Spragues Sports
10 Bayer CropScience
11 Dunn Grain Company
12 Ag Resource
13 Big W Sales
14 John Deere Water Co.
15 Rain For Rent
16 Everfilt Corporation
17 Converted Organics
18 Agra Best LLC
19 Rain Bird Corporation
20 BASF
21 DP Seeds LLC
22 Delta Plastics
23 MANA Inc
24 Ransom Seed Laboratory
25 N-Phuric
26 Si-Tech Southwest LLC
27 Western Farm Press
28 Certis USA
29 Bingham Equipment Co
30 Gearmore Inc
31 Water Tech Ag Supply
32 RSS Business
33 J R Simplot AgriBusiness
34 Arizona Dept of Agricultre
35 Pacific Ag Rentals
36 Dow AgroSciences
37 Chemtura Crop Protection
38 Yuco Gin II
39 Nunhems USA Inc
40 Mas Labor H2A LLC
41 Yuma County Farm Bureau
42 RDO Equipment
43 Yuma Safe Produce Council
44 Yuma Community Food Bank
45 DuPont Crop Protection
46 Ed Whitehead's Tires
47 Yara North America Inc
48 Eurodrip USA
49 Booth Machinery Inc
50 Booth Machinery Inc
51 AgraTech
52 Harris Moran
53 Agra Quest
54 Helena Chemical Company
55 JAIN Irrigation
56 ORO Agri Inc
57 Fisher Wireless
58 SCF Arizona
59 No Sweat Apparel Printshop
60 Weather Advisory Service
61 AMM Seed Testing
62 The Catalyst Product Group
63 University of Arizona
64 University of Arizona
65 Arizona Western College
66 Arizona Western College
67 Arizona Game and Fish
68 Morris Ag Air and Sons Inc
69 Yuma Area Safety Council

Forum 1:

sponsored by THE dune COMPANY

Desert Pest and Disease Management

(2 CEU/AZ, 2 CEU/CA & 2 CCA/AZ, CA)

9:45 AM ..... California Regulatory Update
Mr. Chris Reardon, CDFA

10:30 AM ..... Arizona Regulatory Update
Mr. Jack Peterson, Arizona Dept. of Agriculture

11:15 AM ..... Adjuvant Use in Crop Production
Mr. Jody Richardson, Helena Chemicals
Mr. Larry Tapia, Loveland Industries

Forum 2:

sponsored by Crop Production Services CPS

Desert Fertilizer Workshop

(1 CEU/AZ, 1 CEU/CA & 1 CCA/AZ, CA)

9:45 AM ..... Influence of Nutrition on Plant Diseases
Dr. Terry Tindal, JR Simplot Inc.

10:15 AM ..... Improving Crop Nutrient Management Efficiency
Dr. Jeff Silvertooth, University of Arizona

10:45 AM ..... Scaling Up Fertilizer and Water Research in Vegetable Production Systems
Dr. Randy Hauptmann, Fresh Express

11:15 AM ..... Improving Nitrogen Efficiency and Grower Profits with Controlled-Release Fertilizers
Mr. Andrew Schenk, Agrium Advanced Technologies

CROP PRODUCTION, A NEW UA DEGREE PROGRAM

The University of Arizona in Yuma began a locally dedicated academic agriculture program in 1994 consisting of agricultural business and production courses leading towards a bachelor's of science degree in Agricultural Systems Management. The degree program is a collaborative effort among prominent faculty at the University of Arizona, Northern Arizona University and Arizona Western College and prepares students for employment in the agricultural and business industries.

As part of a proud tradition of providing academic opportunities in agriculture for students in the southwest, the University of Arizona, College of Agriculture & Life Sciences, has recently developed a new degree program in Crop Production. For Yuma students, the new degree program is being offered as a 2+1+1 academic major with 2 years invested in earning an AA Agricultural Science degree at Arizona Western College, 1 year at UA-Yuma and 1 year at the UA main campus, in Tucson. The year in Yuma provides a unique opportunity for students to learn about the actual management of pests/diseases, the cultural or technical aspects of production and gain valuable experience in one of the premier winter vegetable production areas in the world. With the entire Yuma agriculture faculty available for instruction, the University of Arizona in Yuma will impact student learning from a collection of world renowned instructors and scientists, each covering a variety of agriculturally related topic areas.

The new degree program is unique in Arizona. NAU and ASU do not offer similar programs and could be a reason why good students leave the state for a degree in production agriculture. A degree in Crop Production from the University of Arizona provides the competitive edge for those interested in a future in production agriculture. For more information contact Tanya Hodges, the UA-Yuma Academic Program Coordinator, at (928) 271-9560.

Forum 3:

sponsored by HARRISON FARMS INC. Yuma, Az.

Alternative Desert Crops and Technology

9:45 AM ..... Opportunities and Challenges of Bean Production in the Desert Southwest
Mr. Mike Rethwisch,
University of Nebraska Lincoln Extension, Butler County

10:15 AM ..... New Innovations in Mechanized Thinning and Cultivation
Dr. Mark Siemens,
Dept. of Agricultural & Biosystems Engineering,
University of Arizona, Yuma Agricultural Center

10:45 AM ..... Pomegranate and Olive Production in the Desert Southwest
Dr. Glenn Wright,
Dept. of Plant Science, University of Arizona,
Yuma Agricultural Center

11:15 AM ..... Mechanization in Pepper Production
Mr. Ryan Herbon P.E.,
New Mexico State University

11:45 AM – 1:30PM ..... LUNCH BREAK

Industry Updates *(1.5 CEU/AZ, 1.5 CEU/CA & 1 CCA/AZ)*

Certis USA ..... Frank Standfuss
Marrone Bio Innovations ..... Celeste Gilbert
Mas Labor (H2A) ..... Kerry Scott
AgraBest LLC ..... David Vargus
Rainbird ..... Dean Parrish
Weather Advisory Service ..... Jeff Millard
Ag-Resource ..... Jon Weiswasser

Tessenderlo KERLEY

GOWAN SEED COMPANY

FGS

Forum 4:

sponsored by 3 STAR LETTUCE

Food Safety in Leafy Greens

1:30 – 3:30 PM ..... What is and What's not working
AZ LGMA, Panel Discussion.

Forum 5:

sponsored by SEED DYNAMICS Inc.

Desert Pest Management

(2 CEU/AZ, 2 CEU/CA & 2 CCA/AZ, CA)

1:30 PM ..... Plant Parasitic Nematodes of Agricultural Crops
Dr. Donna Henderson, UCCE, Imperial County

2:00 PM ..... Fusarium Wilt of Leafy Greens: Managing a Challenging Disease
Dr. Mike Matheron, University of Arizona, Yuma Agricultural Center

2:30 PM ..... Vegetable Weed Control in the Desert
Mr. Barry Tickes, University of Arizona, Yuma Agricultural Center

3:00 PM ..... The Bagrada Bug, a New Invasive Pest of Cole Crops
Dr. John Palumbo, University of Arizona, Yuma Agricultural Center

Forum 6:

sponsored by **MacDon**

Desert Crop Production

(1 CEU/AZ, 1 CEU/CA & 1 CCA/AZ, CA)

1:30 PM.....Modifying Wheat Irrigation Schedules for Stand Density
Dr. Doug Hunsaker, USDA-ARS

2:00 PM..... Sprinkler Irrigation Management
Dr. Khalid Bali, University of California

2:30 PM.....Update: Round Up Ready Alfalfa
Dr. Peter Risen, Forage Genetics, Inc.

3:00 PM.....Disease Resistance in Lettuce: Research Update
Dr. Ryan Hayes, Research Geneticist, USDA ARS, Salinas. CA.

2010 SOUTHWEST AG SUMMIT STUDENT PROGRAM

Thursday March 11

7:15AM – 9:15AM.....Opening Remarks and Morning Keynote Address

9:15AM – 11:25AM.....Special Concurrent Student Sessions

Vet/Animal Science & MicroBiology
Moderators: Dr. Elaine Marchello and Dr. John Marchello, University of Arizona

Manufacturing & Engineering
Moderator: Dr. Mark Riley, University of Arizona

Business & Technology
Moderators: Dr. Gary Thompson and Dr. James Knight, University of Arizona

Plant Biology & Environmental Sciences
Moderator: Dr. Jeff Silvertooth, University of Arizona

2010 Southwest Ag Summit Vendor Information

1	Westflow Company	(408) 203-0483	www.westflowcompany.com
2	Farm Credit Services SW	(928) 344-3200	www.fcssw.com
3	Plateau Laser	(928) 782-3069	
4	Marrone Bio Innovations	(530) 750-2800	www.marronebioinnovations.com
5	UPI	(559) 250-5725	www.uniphos.com
6	Keithly Williams Seed	(928) 329-7770	www.keithlywilliams.com
9	Spragues Sports	(928) 726-0022	www.spragues.com
10	Bayer CropScience	(928) 210-1004	www.bayercropscience.com
11	Dunn Grain Company	(928) 344-3866	www.dunngrain.com
12	Ag-Resource	760-889-0449	www.mulchfilm.com
13	Big W Sales	(928) 317-2671	www.bigwsales.com
14	John Deere Water Company	(805) 717-9600	www.johndeerewater.com
15	Rain For Rent	(928) 726-8865	www.rainforrent.com
16	Everfilt Corporation	(800) 360-8380	www.everfilt.com
17	Converted Organics	(813) 675-8600	www.convertedorganics.com
18	Agra Best LLC	(661) 477-3663	www.agrabest.com
19	Rain Bird Corporation	(626) 812-3782	www.rainbird.com
20	BASF Corporation	(928) 341-4746	www.basf.com
21	DP Seed LLC	(928) 341-8494	www.growingproduce.com
22	Delta Plastics	(501) 217-4009	www.deltapl.com
23	MANA Inc	(206) 842-8446	www.manainc.com
24	Ransom Seed Laboratory	(805) 684-3427	www.ransomseedlab.com
25	N-Phuric	(559) 436-2931	www.westernfarmservice.com
26	Si-Tech Southwest LLC	(928) 247-7959	www.sitechsouthwest.com
27	Western Farm Press	(559) 645-5283	www.westernfarmpress.com
28	Certis USA	(619) 482-1300	www.certisusa.com
29	Bingham Equipment Co	(928) 726-4701	www.binghamequipment.com
30	Gearmore Inc	(949) 525-8831	www.gearmore.com
31	Water Tech Ag Supply	(760) 344-8000	www.agsupply.com
32	RSS Business	(760) 370-3206	www.rssbiz.com
33	J R Simplot AgriBusiness	(760) 212-6439	www.simplot.com/agricultural
34	Arizona Dept of Agricultre	(602) 542-0984	www.azda.gov
35	Pacific Ag Rentals	(831) 754-8815	www.pacificagrentals.com
36	Dow AgroSciences	(480) 759-5899	www.dowagro.com
37	Chemtura Crop Protection	(805) 312-3290	www.chemtura.com
38	Yuco Gin II	(928) 329-9955	
39	Nunhems USA Inc	(928) 247-3377	www.nunhemsusa.com
40	Mas Labor H2A LLC	(434) 263-4300	www.maslabor.com
41	Yuma County Farm Bureau	(928) 782-5338	www.azfb.com
42	RDO Equipment	(928) 341-7200	www.rdoequipment.com
43	Yuma Safe Produce Council	(928) 726-3738	www.amigofarms.com
44	Yuma Community Food Bank	(928) 819-0716	www.yumafoodbank.org
45	DuPont Crop Protection	(928) 343-1198	www2.dupont.com
46	Ed Whitehead's Tires	(928) 782-1868	www.edstirecountry.com
47	Yara North America Inc	(928) 210-3649	www.yara.us
48	Eurodrip USA	(559) 673-9100	www.eurodripusa.com
49	Booth Machinery Inc	(928) 726-6500	www.boothmachinery.com
51	AgraTech	(925) 432-3399	www.agra-tech.com
52	Harris Moran	(928) 271-1379	www.harrismoran.com
53	Agra Quest	(831) 801-6292	www.agraquest.com
54	Helena Chemical Company	(928) 503-2003	www.helenachemical.com
55	JAIN Irrigation	(559) 459-5312	www.jains.com
56	ORO Agri Inc	(817) 491-2057	www.oroagri.com
57	Fisher Wireless	(928) 344-1020	www.fisherwireless.com
58	SCF Arizona	(866) 284-2694	www.scfaz.com
59	No Sweat Apparel Printshop	(928) 345-1981	
60	Weather Advisory Service	(559) 630-0337	www.weatheradvisoryservice.com
61	AMM Seed Testing	(805) 564-2155	www.ammseedtesting.com
62	The Catalyst Product Group	(480) 814-8318	www.catalystproductgroup.com
63	University of Arizona	(928) 271-9560	www.outreach.arizona.edu
65	Arizona Western College	(928) 317-6000	www.azwestern.edu
67	Arizona Game and Fish	(928) 341-4040	www.azgfd.gov
68	Morris Ag Air and Sons Inc	(928) 344-5009	
69	Yuma Area Safety Council	(928) 344-3898	

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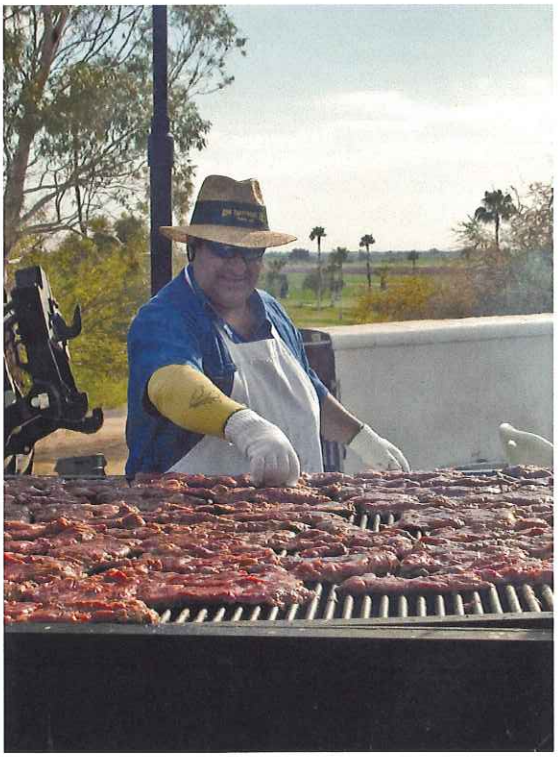

Appendix B

referenced from page 3

TABLE 1

2010 SW Ag Summit Exit Survey

Please help the planning of our 2011 SW Ag Summit

1. **How would you describe your occupation (Circle 1)?**
   a) Grower
   b) PCA or CCA
   c) Marketing/Sales
   d) Management
   e) Technical Support
   f) Student
   g) Other _____

2. **Today, you attended the SW Ag summit as a... (Circle 1)**
   a) Vendor Booth Participant
   b) General Attendee
   c) Summit Staff Member
   d) VIP or Guest
   e) Student

3. **What parts of the summit should we improve next year?**
   a) Improve breakouts and keynote speakers
   b) The event is poorly organized
   c) The food/snacks could be improved
   d) Better development of vendor trade show
   e) The field day needs improvement
   f) Registration
   g) Venue too small
   h) Marketing
   i) Price of admission
   j) Room Identification and signage

4. **How has the SW Ag Summit impacted your business?**
   a) Better informed about fertilizer management
   b) Gained information about new ag equipment
   c) Enhanced general knowledge about desert ag
   d) Developed networking opportunities
   e) Updated on a pest or disease control strategy
   f) Better informed about water stewardship
   g) As a vendor, enhanced marketing opportunities
   h) Please explain _____

5. **Circle TWO reasons why you attended the summit today.**
   a) Networking
   b) CEU's
   c) Keynote Address
   d) Vendor and Booth Displays
   e) Breakouts and Forums
   f) Field Day Event
   g) Golf Tournament/Reception
   h) All of the above
   i) Other _____

6. **Will you share some of the information with others?**
   a) 100%, all of the information (see f, below)
   b) 75% of the information (see f, below)
   c) 50% of the information (see f, below)
   d) 25% of the information (see f, below)
   e) I don't plan to share the information with others
   f) If you plan to share the information, who will you share it with? _____

7. **Is holding the demonstration field event on a separate day a problem?**
   a) Yes b) No

8. **What breakout/keynote topics and field demonstrations would you like to see at a future SW Ag Summit?**

The following questions, below, will better assist our students who are attending the summit today.

9. **What educational preparation would you recommend to young people entering ag as a profession?**
   a) High School only
   b) Associates Degree (2-year)
   c) BS Degree (4-year)
   d) Masters Degree
   e) PhD Degree

10. **What skill sets would you recommend to those just entering college, and pursuing a career in agriculture?**
    a) Science and math
    b) Business/marketing/sales
    c) Communication
    d) Specifically, food safety
    e) Specifically pest management
    f) Engineering

11. **In your opinion, please rank (1- highest priority, 8- lowest priority), the following future hot careers in agriculture.**
    _____ Food Safety
    _____ Business International or other
    _____ Mechanization/Ag Engineering
    _____ General Vegetable Production
    _____ Pest Management
    _____ Fertilizer Management
    _____ Biofuels

12. **In your view, with 5 years of experience and a 4-year degree, circle a typical salary for a person who wants to start a career in agriculture?**
    a) $20,000 – 40,000
    b) $40,000 – 60,000
    c) $60,000 – 80,000
    d) $80,000 or more

The following is a list of content information accessible by those teachers enrolled in the course. The first bullet indicates the lesson title, each of which comes from the Arizona Specialty Crop Lessons (http://cals.arizona.edu/agliteracy/lessons.htm), followed by a video and article that are associated with each lesson, in addition to further resources teacher can access to learn more.

- A is for Apple
  - *Video*: Apple Sorting Sizing and Grading from Compac Sorting Equipment (http://youtu.be/Qu-vb5O61rI)
  - *Article*: Apple Processing (http://www.appleproducts.org/pandt.html)
  - Resources
    - Arizona Orchard Listing http://www.allaboutapples.com/orchard/az.htm
    - Harvesting Nature's Popular Fruits http://www.americasheartland.org/episodes/episode_612/harvesting_nature.htm
    - Arizona Apples http://www.arizonaedventures.com/articles/arizona/arizona-apples
    - Apple Trees in Arizona http://www.ehow.com/list_7370608_apple-trees-arizona.html
    - Apple Harvesting Google image search

- From Mashed to Riches
  - *Video*: Idaho Potato Harvest (http://www.americasheartland.org/episodes/episode_613/potatoes.htm)
  - *Article*: 2011 Potandon Arizona Potato Operations Underway (http://www.perishablenews.com/index.php?article=0015658)
  - Resources
    - The Idaho Center for Potato Research and Education http://www.cals.uidaho.edu/potatoes/FAQ.htm

- To Bee or Not to Bee
  - *Video*: Pollination in Tennessee (http://youtu.be/0LTcT4bALKE)
  - *Article*: Questions and Answers: Colony Collapse Disorder (http://www.ars.usda.gov/News/docs.htm?docid=15572)
  - Resources
    - Buzz About Bees http://www.buzzaboutbees.net/about-bees.html
    - Dancing Honeybee Using Vector Calculus to Communicate http://www.youtube.com/watch?v=4NtegAOQpSs
    - Honeybee Waggle Dance Experiment http://www.youtube.com/watch?v=ywdTfEBVcSY
    - Unsolved Mystery: Vanishing Bees Stump Scientists http://www.cbn.com/media/player/index.aspx?s=/mp4/MMA219v1_WS
    - The Plight of the Bumblebee: Why are they Disappearing? http://www.ars.usda.gov/is/pr/2011/110811.htm

- How Do Plants Make Food?
  - *Video*: Assignment Discovery: Photosynthesis (http://videos.howstuffworks.com/discovery/29603-assignment-discovery-photosynthesis-video.htm)
  - *Article*: Center for Bioenergy & Photosynthesis Why Study Photosynthesis? (http://photoscience.la.asu.edu/photosyn/study.html)
  - Resources
    - Photosynthesis in Action http://www.mofb.org/WebQuest.aspx/Photosynthesis.aspx
    - Photosynthesis Videos
      - Chapter 8 http://vimeo.com/18561766
      - Chapter 9 http://vimeo.com/18561943
    - Photosynthesis Bioflix Animation http://www.blinkx.com/watch-video/photosynthesis-bioflix-animation/zWVQ8TsGQEG7FGsd2MWPTw
    - "Solar Fuel" Research Mimics Photosynthesis http://news.cnet.com/8301-11128_3-20052710-54.html
    - Green Machine: Artificial Leaf Mimics Photosynthesis http://www.newscientist.com/blogs/onepercent/2011/03/green-machine.html

- Pecan Power!
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  - Resources
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    - Resources
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    - *Video*: Desert Plants – Desert Landscaping (http://youtu.be/nwy1GN73Nv8)
    - *Article*: How Plants Cope with the Desert Climate (http://www.desertmuseum.org/programs/succulents_adaptation.php)
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    - *Article*: Arizona Plant Climate Zones (http://aztrees.org/c_az-climate-zones.html)
    - Resources
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    - *Video*: Jim Graham: Meet a Cochise, AZ Specialty Crop (Pistachios) Farmer (http://youtu.be/jYAirX96L5g)
    - *Video*: Tim Dunn: Meet a Yuma, AZ Specialty Crop Farmer (http://youtu.be/V2g2xPZ-kRE)
    - *Video*: John Boelts: Meet a Yuma, AZ Specialty Crop Farmer (http://youtu.be/ZHYfm9xUm98)
    - *Video*: DeWayne Justice: Meet a Waddell, AZ Specialty Crop Farmer (http://youtu.be/96vvC5c2p68)
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Appendix D

as referenced on page 84 and 88

ARIZONA SPECIALTY CROPS Summary Virus Testing

Plant species with detectable virus

PLANT FAMILY	Plant scientific name + Laboratory case number	Common name	Virus Test methods of detection	Total number of tests	Presence of symptoms	Viruses detected	DNA Sequencing results + % identity best match	Genbank accession number	Evidence of whitefly	Virus vector
AMARANTHACEAE	**Amaranthus blitoides**									
	10.10-2	prostrate pigweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.11-5	prostrate pigweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.15-3	prostrate pigweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	Amaranthus albus									
	10.11-2	tumble pigweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.16-8	tumble pigweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	Amaranthus palmeri									
	10.21-5	Palmer's amaranth	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		no	
	10.22-4	Palmer's amaranth	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.24-8	Palmer's amaranth	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf rippling	none	n/a		no	
ASTERACEAE	**Ambrosia ambrosioides**									
	10.04-1	canyon ragweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		yes	
	10.08-1	canyon ragweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.08-6	canyon ragweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.08-12	canyon ragweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.09-10	canyon ragweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.21-1	canyon ragweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		no	
	10.21-3	canyon ragweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		no	
	10.25-3	**canyon ragweed**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	**Begomovirus**	**Cotton leaf crumple virus: 97%**	**AF480940.1**	yes	whitefly
	10.27-1	canyon ragweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	interveinal chlorosis	none	n/a		no	
	10.27-2	canyon ragweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	10.31-5	canyon ragweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf rippling	none	n/a		yes	
	10.33-9	canyon ragweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf rippling	none	n/a		yes	
	Ambrosia deltoidea									
	10.12-2	Triangle leaf bursage	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	Helianthus annuus									
	10.09-3	sunflower	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		no	
	10.09-4	sunflower	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		no	
	10.09-9	sunflower	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		no	
	10.12-6	sunflower	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		no	
	Lactuca sativa									
	10.34-1	lettuce	CYSDV (qPCR), Lettuce Chlorosis Virus (PCR)	2	some yellowing	none	n/a		yes	
	10.34-2	lettuce	CYSDV (qPCR), Lettuce Chlorosis Virus (PCR)	2	some yellowing	none	n/a		yes	
	10.34-3	lettuce	CYSDV (qPCR), Lettuce Chlorosis Virus (PCR)	2	some yellowing	none	n/a		yes	
	Lactuca serriola									
	10.29-3	prickly lettuce	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	4	leaf yellowing	none			yes	
	10.33-4	prickly lettuce	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	4	no	none	n/a		yes	
	Sonchus oleraceus									
	10.08-10	common sowthistle	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.08-15	common sowthistle	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.09-6	common sowthistle	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.22-6	common sowthistle	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		yes	
	10.30-3	common sowthistle	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	Viguiera parishii									
	10.09-14	Parish's goldeneye	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	Verbesina encelioides									
	10.10-9	golden crownbeard	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	Xanthium strumarium									
	10.09-7	cocklebur	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.10-5	cocklebur	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.15-1	cocklebur	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.22-1	cocklebur	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	10.30-1	cocklebur	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	

	10.33-1	cocklebur	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellow/ripple	none	n/a		yes	
AIZOACEA	**Trianthema portulacastrum**									
	10.11-3	horse purslane	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf browning	none	n/a		no	
	10.33-7	**horse purslane**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	**Crinivirus**	**Cucurbit yellow stunting disorder virus: 98%**	**EF547827.1**	yes	whitefly
BRASSICACEAE	**Eruca vesicaria**									
	10.08-02	arugula	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf rippling	none	n/a		no	
	Brassica tournefortii									
	10.08-16	african mustard	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellow/ripple	none	n/a		no	
	10.10-6	african mustard	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
CHENOPODIACEAE	**Chenopodium album**									
	10.09-8	goosefoot	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		no	
CONVULVULACEAE	**Convolulus arevensis**									
	10.10-3	field bindweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	none	n/a		no	
	10.15-2	field bindweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	none	n/a		yes	
	10.22-5	field bindweed	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	Ipomoea sp.									
	10.16-4	morning glory	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	Ipomoea triloba									
	10.33-10	**three-lobed morning glory**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	**Curtovirus**	**Beet severe curly top virus: 94%**	**BCU02311**	yes	leafhopper
						Curtovirus	**Beet mild curly top virus: 94%**	**BCU56975**		leafhopper
CUCURBITACEAE	**Brandegea bigelovii**									
	10.04-2	**desert star vine**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	4	leaf yellow/ripple	**Crinivirus**	**Cucurbit yellow stunting disorder: 99%**	**EF547827.1**	no	whitefly
	10.06-2	desert star vine	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.08-3	**desert star vine**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	**Crinivirus**	no sequencing data for this sample		no	whitefly
	10.08-4	desert star vine	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.12-4	desert star vine	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellow/ripple	none	n/a		no	
	10.21-6	desert star vine	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	Cucumis melo									
	10.14-1	honeydew	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		no	
	10.15-4	honeydew	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	brittle leaves	none	n/a		no	
	10.15-5	honeydew	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.15-6	honeydew	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.16-7	honeydew	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	none	n/a		yes	
	10.22-3	honeydew	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf ripple/rust	none	n/a		yes	
	10.24-9	honeydew	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	brittle leaves	none	n/a		yes	
	10.27-3	honeydew	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	10.29-4	honeydew	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	10.30-2	**honeydew**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	yellowing	**Crinivirus**	**Cucurbit yellow stunting disorder virus: 99%**	**EF547827.1**	yes	whitefly
	10.32-1	**honeydew**	CYSDV (PCR and qPCR)	2	brittle/chlorotic leaves	**Crinivirus**	no sequencing data for this sample		yes	whitefly
	10.33-2	honeydew	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	brittle/chlorotic leaves	none	n/a		yes	
	10.33-6	**honeydew**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	**Crinivirus**	**Cucurbit yellow stunting disorder virus: 99%**	**EF547827.1**	yes	whitefly
	11.08-6	melon	CYSDV (PCR), Begomovirus	2	yellowing	none	n/a			
	Cucumis melo var. flexous									
	10.16-1	Armenian cucumber	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	none	n/a		yes	
	Cucurbita pepo									
	11.08-7	zucchini	CYSDV (PCR), Begomovirus	2	leaf ripple, mosaic	none	n/a		yes	
	Citrullus lanatus									
	10.16-2	watermelon	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.22-11	watermelon	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		yes	
	10.22-12	watermelon	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	10.24-7	watermelon	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	10.29-1	watermelon	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf rippling	none	n/a		yes	
EUPHORBIACEAE	**Euphorbia serpyllifolia**									
	10.22-7	hyssop spurge	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	none	n/a		yes	
	Euphorbia marginata									
	10.10-4	rattlesnake euphorbia	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
FABACEAE	**Hoffmanseggia densiflora**									
	10.09-2	hog potato	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	Lablab purpureus									
	10.09-12	hyacinth bush	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	n/a	none	yes		yes	
	10.31-9	hyacinth bush	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf rippling	none	yes		yes	

	Medicago sativa										
	10.11-7	alfalfa	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	none	n/a			no	
	10.16-6	alfalfa	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			no	
	10.21-4	alfalfa	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			no	
	10.29-5	alfalfa	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	none	n/a			yes	
	10.31-2	alfalfa	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a			yes	
LEGUMINACEAE	**Phaseolus vulgaris**										
	10.31-7	green bean	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis/ripple	none	n/a			yes	
LAMICEAE	**Ocimum basilicum**										
	10.31-10	basil	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellow/ripple	none	n/a			yes	
MALVACEAE	**Alcea rosea**										
	10.09-11	hollyhock	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	n/a	none	n/a			yes	
	10.33-11	hollyhock	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	heavy leaf ripple	none	n/a			yes	
	Gossypium hirsutum										
	10.08-14	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf rippling	none	n/a			no	
	10.12-5	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	slight leaf ripple	none	n/a			yes	
	10.15-7	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			yes	
	10.16-5	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	slight leaf ripple	none	n/a			no	
	10.21-7	**cotton**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	**Begomovirus**	**Cotton leaf crumple virus: 98%**	**AF480940.1**		yes	whitefly
	10.22-9	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			yes	
	10.24-1	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			yes	
	10.24-3	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellow/mosaic	none	n/a			yes	
	10.25-1	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			yes	
	10.25-2	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf necrosis	none	n/a			yes	
	10.30-4	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	n/a	none	n/a			yes	
	10.31-1	**cotton**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	**Begomovirus**	**Cotton leaf crumple virus: 98%**	**AF480940.1**		yes	whitefly
	10.31-6	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a			yes	
	10.33-5	cotton	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a			yes	
	Hibiscus sabdariffa										
	10.31-8	**hibiscus tea**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	heavy ripple/chlorosis	**Begomovirus**	**Sida yellow mottle virus: 91%**	**HQ822123.1**		yes	whitefly
	Malva parviflora										
	10.06-1	**common mallow**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf ripple/mosaic	**Begomovirus**	**Cotton leaf crumple virus: 97%**	**AF480940.1**		yes	whitefly
	10.08-9	common mallow	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	stunting	none	n/a			no	
	10.09-5	common mallow	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a			no	
	10.10-1	common mallow	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	none	n/a			no	
	10.10-8	common mallow	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			yes	
	10.13-1	common mallow	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis/mosaic	none	n/a			yes	
	Sphaeralcea ambigua										
	10.07-1	**desert globemallow**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	**Begomovirus**	**Squash leaf curl virus: 99%**	**DQ285016.1**		yes	whitefly
	10.08-5	desert globemallow	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			no	
	10.09-13	desert globemallow	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	n/a	none	n/a			yes	
	10.15-8	desert globemallow	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf browning	none	n/a			yes	
	10.22-8	desert globemallow	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	rust on leaves	none	n/a			yes	
MYRTACEAE	**Psidium sp.**										
	10.15-9	white guava	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	brittle leaves	none	n/a			yes	
NYCTAGINACEAE	**Boerhavia coccinea**										
	10.08-11	red spiderling	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			no	
	10.33-3	red spiderling	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	slight leaf yellowing	none	n/a			yes	
PAPILLIONACEAE	**Phaseolus vulgaris**										
	11.08-9	**Red noodle long bean**	CYSDV (PCR), Begomovirus	2	leaf rippling	**Begomovirus**	**Tomato yellow leaf curl virus Arizona: 98%**	**EF210554.1**		yes	whiteflly
POLYGONACEAE	**Erigonum deflexum**										
	10.12-1	skeleton buckwheat	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a			no	
	Rumex crispus										
	10.09-1	curly dock	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			no	
PORTULACACEAE	**Portulaca oleraceae**										
	10.11-4	common purslane	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			no	
	10.24-6	common purslane	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			no	
RANUNCULACEAE	**Clematis sp.**										
	10.08-7	clematis	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			no	
SOLANACEAE	**Datura wrightii**										
	10.22-10	sacred datura	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a			yes	

	10.31-4	sacred datura	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	some leaf curling	none	n/a		yes	
	Nicotiana obtusifolia										
	10.08-8	desert tobacco	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	some leaf yellowing	none	n/a		no	
	10.08-13	desert tobacco	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.31-3	**desert tobacco**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf ripple/chlorosis	**Begomovirus**	**Cotton leaf crumple virus: 97%**	**AF480940.1**	yes	whitefly
	Nicotiana rustica										
	10.21-2	**wild (indian) tobacco**	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	**Curtovirus**	**Spinach curly top Arizona virus: 98%**	**HQ443515.1**	yes	leafhopper
						Begomovirus	**Bean golden yellow mosaic virus: 99%**	**D00201.1**		whitefly
	Physalis acutifolia										
	10.22-2	Wright's groundcherry	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	leafhopper
	Solanaceae eleagnifolium										
	10.10-7	silverleaf nightshade	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	
	10.11-1	silverleaf nightshade	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.12-3	silverleaf nightshade	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.16-3	silverleaf nightshade	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	
	10.24-2	silverleaf nightshade	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	whitefly
	10.29-2	silverleaf nightshade	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		yes	whitefly
	Solanum lycopersicum										
	10.39-1	**tomato**	Begomovirus (PCR)	1	leaf rippling, yellowing	**Begomovirus**	**Tomato yellow leaf curl virus Arizona isolate: 97%**	**EF210554.1**	yes	whitefly
	10.41-1	**tomato**	Begomovirus (PCR)	1	some leaf rippling	**Begomovirus**	**Tomato yellow leaf curl virus Arizona isolate: 98%**	**EF210554.1**	yes	whitefly
	10.41-2	**tomato**	Begomovirus (PCR)	1	some leaf rippling	**Begomovirus**	**Tomato yellow leaf curl virus Arizona isolate: 97%**	**EF210554.1**	yes	whitefly
	10.41-3	**tomato**	Begomovirus (PCR)	1	some leaf rippling	**Begomovirus**	**Tomato yellow leaf curl virus Arizona isolate: 98%**	**EF210554.1**	yes	whitefly
	10.41-4	**tomato**	Begomovirus (PCR)	1	some leaf rippling	**Begomovirus**	**Tomato yellow leaf curl virus Arizona isolate: 98%**	**EF210554.1**	yes	whitefly
	10.43-1	**tomato**	Begomovirus (PCR)	1	stunted small leaves	**Begomovirus**	**Tomato yellow leaf curl virus Arizona isolate: 99%**	**EF210554.1**	yes	whitefly
	11.08-8	**tomato**	Begomovirus (PCR)	1	stunted small leaves	**Begomovirus**	**Tomato yellow leaf curl virus Arizona isolate: 98%**	**EF210554.1**	yes	whitefly
VERBENACEAE	**Lantana camara**										
	10.09-15	lantana	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	n/a	none	n/a		yes	n/a
	10.11-8	lantana	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf browning	none	n/a		yes	n/a
	10.24-10	lantana	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf chlorosis	none	n/a		yes	n/a
	10.29-6	lantana	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf yellowing	none	n/a		yes	n/a
ZYGOPHYLLACEAE	**Tribulus terrestris**										
	10.11-6	puncturevine	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	n/a
	10.24-4	puncturevine	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	leaf rippling	none	n/a		no	n/a
	10.33-8	puncturevine	CYSDV (PCR and qPCR), Begomovirus (PCR), Curto 1 (PCR), Curto 2 (PCR)	5	no	none	n/a		no	n/a

Appendix F

as referenced on page 84

Whitefly Data for 2008, 2009 and 2010							
Brown Lab Case	**latitude**	**longitude**	**Date Sent**	**Whitefly**	**Diagnosis**	**Host Type**	**Host name**
Case Number						**Cultivated/non-cultivated**	
08.40.01A	N33 30.265	W112 28.115	30-Jun-08	0	1	cultivated	zucchini
08.40.01B	N33 30.265	W112 28.115	30-Jun-08	0	1	cultivated	zucchini
08.47.01	N33 31.820	W111 51.223	14-Jul-08	0	1	non-cultivated	Wright's ground cherry
08.47.02	N33 31.820	W111 51.223	14-Jul-08	0	1	non-cultivated	velvet leaf
08.49.01B	N33 30.268	W112 28.104	16-Jul-08	0	1	cultivated	cantaloupe
08.49.02B	N33 36.615	W112 24.833	16-Jul-08	0	1	cultivated	watermelon
08.49.03A	N33 36.911	W112 25.365	16-Jul-08	0	1	cultivated	Armenian cucumber
08.49.03B	N33 36.911	W112 25.365	16-Jul-08	0	1	cultivated	Armenian cucumber
08.54.01	N33.30.268	w112.28.104	24-Jul-08	0	1	cultivated	Armenian cucumber
08.54.02	N33.30.268	w112.28.104	24-Jul-08	0	1	cultivated	Armenian cucumber
08.60.01	N33 30.270	W112 28.159	7-Aug-08	0	1	cultivated	okra
08.60.02A	N33 30.268	W112 28.076	7-Aug-08	0	1	non-cultivated	mallow
08.60.02B	N33 30.268	W112 28.076	7-Aug-08	0	1	non-cultivated	mallow
08.60.02C	N33 30.268	W112 28.076	7-Aug-08	0	1	non-cultivated	mallow
08.60.03A	N33 30.268	W112 28.076	7-Aug-08	0	1	non-cultivated	cheeseweed
08.60.03B	N33 30.268	W112 28.076	7-Aug-08	0	1	non-cultivated	cheeseweed
08.60.05A	N33 36.550	W112 24.838	7-Aug-08	0	1	non-cultivated	Palmer's amaranth
08.60.05B	N33 36.550	W112 24.838	7-Aug-08	0	1	non-cultivated	Palmer's amaranth
08.60.07A	N33 31.773	W111 51.395	7-Aug-08	0	1	non-cultivated	goathead
08.60.07C	N33 31.773	W111 51.395	7-Aug-08	0	1	non-cultivated	goathead
08.60.08A	N33 31.773	W111 51.395	7-Aug-08	0	1	non-cultivated	pigweed
08.60.09A	N33 30.268	W112 28.076	7-Aug-08	0	1	non-cultivated	purslane
08.60.09B	N33 30.268	W112 28.076	7-Aug-08	0	1	non-cultivated	purslane
08.65.01	N33 30.344	W112 28.114	26-Aug-08	0	1	non-cultivated	hibiscus
08.65.02	N33 30.270	W112 28.159	26-Aug-08	0	1	non-cultivated	goosefoot
08.65.03	N33 30.270	W112 28.159	26-Aug-08	0	1	non-cultivated	red spiderling
08.65.03A	N33 30.270	W112 28.159	26-Aug-08	0	1	non-cultivated	red spiderling
08.65.03B	N33 30.270	W112 28.159	26-Aug-08	0	1	non-cultivated	red spiderling
08.65.04A	N33 24.417	W111 59.283	26-Aug-08	0	1	non-cultivated	red spiderling
08.65.06B	N33 30.268	W112 28.076	26-Aug-08	0	1	non-cultivated	sunflower
08.65.07A	N33 24.417	W112 28.159	26-Aug-08	0	1	cultivated	okra
08.65.07B	N33 24.417	W112 28.159	26-Aug-08	0	1	cultivated	okra
08.65.07W	N33 24.417	W112 28.159	26-Aug-08	0	1	cultivated	okra
08.71.01A	N33 26.100	W111 53.332	9-Sep-08	0	1	non-cultivated	primrose
08.74.03A	N33 30.344	W112 28.114	24-Sep-08	0	1	non-cultivated	hibiscus
08.74.06B	N33 32.149	W111 50.539	24-Sep-08	0	1	cultivated	watermelon
08.74.07A	N33 31.706	W111 51.575	24-Sep-08	0	1	non-cultivated	horse purslane
08.74.08A	N33 24.417	W111 59.283	24-Sep-08	0	1	cultivated	Armenian cucumber
08.74.09A	N33 24.417	W111 59.283	24-Sep-08	0	1	non-cultivated	devil's claw
08.74.10A	N33 24.417	W111 59.283	24-Sep-08	0	1	cultivated	heirloom squash
08.74.12A	N33 24.417	W111 59.283	24-Sep-08	0	1	non-cultivated	hollyhock
08.82.01	N33 32.493	W111 54.320	13-Oct-08	0	1	non-cultivated	hisbiscus
09.14-1	No codes	No codes	26-May-09	0	1	cultivated	melon
09.14-2	N33 31.591	W112 25.069	26-May-09	3	1	cultivated	watermelon
09.14-3	N33 36.816	W112 24.768	26-May-09	3	1	non-cultivated	Wright's ground cherry
09.14-4	N33 58.577	W113 13.731	26-May-09	3	0	cultivated	garbanzo bean
09.14-4	No codes	No codes	26-May-09	0	1	cultivated	garbanzo bean
09.14-5	N33 22.009	W113 10.083	26-May-09	3	1	cultivated	cantaloupe
09.15-1	N33 31.447	W111 49.289	2-Jun-09	0	1	cultivated	watermelon
09.20-1	N33 21.809	W113 11.155	18-Jun-09	0	1	cultivated	honeydew
09.21-1	N33 30.235	W112 28.070	23-Jun-09	3	1	cultivated	galia melon
09.29-1	N33 31.704	W111 50.881	14-Jul-09	3	1	cultivated	watermelon
09.29-2	N33 31.704	W111 50.881	14-Jul-09	3	1	non-cultivated	devil's claw

09.32.1	N33 57.018	W113 10.078	23-Jul-09	3	1	cultivated	crenshaw melon
09.32.2	N33 57.165	W113 10.231	23-Jul-09	3	2	cultivated	casaba melon
09.32.3	N33 57.252	W113 10.066	23-Jul-09	0	1	cultivated	crenshaw melon
09.32.4	N33 57.299	W113 10.071	23-Jul-09	3	1	cultivated	crenshaw melon
09.32.5	N33 57.669	W113 10.341	23-Jul-09	0	1	cultivated	cantaloupe
09.32.6	N33 56.819	W113 11.628	23-Jul-09	0	1	cultivated	unspecified melon
09.32.7	N33 57.119	W113 06.884	23-Jul-09	0	1	cultivated	cantaloupe
09.32.8	N33 57.018	W113 10.078	23-Jul-09	0	1	non-cultivated	purslane
09.32.9	N33 57.018	W113 10.078	23-Jul-09	0	1	non-cultivated	Wright's ground cherry
09.32.10	N33 57.018	W113 10.078	23-Jul-09	0	1	non-cultivated	tumble pigweed
09.32.11	N33 57.299	W113 10.071	23-Jul-09	0	1	non-cultivated	silverleaf nightshade
09.38.1	N33 57.010	W113 10.074	6-Aug-09	0	1	cultivated	watermelon
09.38.2	N33 56.819	W113 11.628	6-Aug-09	0	2	cultivated	melon
09.41-1	N33 24.417	W111 59.283	13-Aug-09	0	1	non-cultivated	devil's claw
09.41-2	N33 24.417	W111 59.283	13-Aug-09	0	1	non-cultivated	hollyhock
09.41-3	N33 24.417	W111 59.283	13-Aug-09	0	1	cultivated	black-eye pea
09.41-4	N33 24.417	W111 59.283	13-Aug-09	0	1	non-cultivated	sunflower
09.41-5	N33 24.417	W111 59.283	13-Aug-09	0	1	cultivated	Armenian cucumber
09.41-6	N33 24.417	W111 59.283	13-Aug-09	0	1	cultivated	tomato
09.41-7	No codes	No codes	13-Aug-09	0	1	cultivated	okra
09.41-8 (2)	N33 56.819	W113 11.628	13-Aug-09	0	1	non-cultivated	purslane
09.41-9 (3)	N33 56.819	W113 11.612	13-Aug-09	0	1	non-cultivated	Wright's ground cherry
09.41-10	N33 57.014	W113 10.075	13-Aug-09	0	1	cultivated	watermelon
09.41-11	N32 58.200	W112 43.032	13-Aug-09	0	1	non-cultivated	canyon ragweed
09.41-12 (11)	No codes	No codes	13-Aug-09	0	1	non-cultivated	purslane
09.41-13	N33 24.417	W111 59.283	13-Aug-09	0	1	cultivated	decorative gourd
09.41-14	N33 24.417	W111 59.283	13-Aug-09	0	1	cultivated	peanut
09.41-15	N33 24.417	W111 59.283	13-Aug-09	0	1	cultivated	eggplant
09.41-16 (9)	N33 56.759	W113 10.67	13-Aug-09	0	5	cultivated	watermelon
09.41-17 (1)	N33 56.819	W113 11.628	13-Aug-09	0	2	cultivated	cantaloupe
09.41-18	N33 56.759	W113 10.67	13-Aug-09	0	1	cultivated	watermelon (2nd sample)
09.41-19 (5)	N33 56.819	W113 11.628	13-Aug-09	0	1	non-cultivated	Wright's ground cherry
09.41-20 (6)	N33 56.819	W113 11.612	13-Aug-09	0	1	non-cultivated	common mallow
09.41-21 (7)	N33 56.819	W113 11.612	13-Aug-09	0	1	non-cultivated	hyssop spurge
09.41-22 (4)	N33 56.819	W113 11.628	13-Aug-09	0	5	cultivated	cantaloupe
09.41-23	N33 07.772	W112 41.063	12-Aug-09	0	1	non-cultivated	hog potato
09.41-24	N33 08.646	W112 41.073	12-Aug-09	0	1	non-cultivated	morning glory
09.41-25 (10)	N33 56.759	W113 10.67	13-Aug-09	0	1	non-cultivated	silverleaf nightshade
09.43-1 (1)	1AC Field4 Border4-5		18-Aug-09	0	1	cultivated	cotton (1)
09.43-2 (2)	N33 03.4830	W111 58.3247	18-Aug-09	0	4	cultivated	cotton (2)
09.43-3 (3)	N33 04.2020	W111 59.04	18-Aug-09	0	1	cultivated	cotton (3)
09.43-4 (3)	N33 04.2020	W111 59.04	18-Aug-09	0	1	non-cultivated	Wright's ground cherry
09.43-5 (3)	N33 04.2020	W111 59.04	18-Aug-09	0	2	cultivated	cantaloupe
09.43-6 (3)	N33 04.2020	W111 59.04	18-Aug-09	0	1	non-cultivated	prostrate spurge
09.43-7 (3)	N33 04.2020	W111 59.04	18-Aug-09	0	1	non-cultivated	purslane
09.43-8 (4)	N33 07.0432	W111 58.0367	18-Aug-09	0	2	cultivated	cantaloupe
09.43-9 (4)	N33 07.0432	W111 58.0367	18-Aug-09	0	1	cultivated	cotton (4)
09.43-10 (5)	N33 03.4734	W111 58.2467	18-Aug-09	0	1	non-cultivated	sesbania
09.43-11 (5)	N33 03.4734	W111 58.2467	18-Aug-09	0	1	non-cultivated	alyce clover
09.43-12 (5)	N33 03.4734	W111 58.2467	18-Aug-09	0	1	cultivated	lablab bean
09.43-13 (7)	N33 03.4831	W111 58.1138	18-Aug-09	0	1	non-cultivated	sunflower
09.43-14 (8)	N33 03.4831	W111 58.1138	18-Aug-09	0	4	cultivated	tepary bean
09.43-15 (6)	N33 03.4734	W111 58.2467	18-Aug-09	0	4	cultivated	cowpea
09.44-1(1)	N33 30.478	W113 06.670	25-Aug-09	0	1	cultivated	honeydew
09.44-2 (1)	N33 30.478	W113 06.670	25-Aug-09	0	1	non-cultivated	horse purslane
09.44-3 (1)	N33 30.478	W113 06.670	25-Aug-09	0	1	non-cultivated	puncturevine
09.44-4 (2)	N33 29.536	W113 07.104	25-Aug-09	0	1	cultivated	honeydew
09.44-5 (2)	N33 29.536	W113 07.104	25-Aug-09	0	1	non-cultivated	tumble pigweed
09.44-6 (3)	N33 28.930	W113 06.906	25-Aug-09	0	1	cultivated	honeydew

09.44-7 (4)	N33 25.252	W113 12.704	25-Aug-09	0	1	cultivated	honeydew
09.44-8 (4)	N33 25.252	W113 12.704	25-Aug-09	0	1	non-cultivated	Palmer's amaranth
09.44-9 (4)	N33 25.252	W113 12.704	25-Aug-09	0	1	non-cultivated	purslane
09.44-10 (4)	N33 25.252	W113 12.704	25-Aug-09	0	1	non-cultivated	hyssop spurge
09.44-11 (5)	N33 26.125	W113 12.619	25-Aug-09	0	1	cultivated	honeydew
09.44-12 (5)	3 26.125 W113 12.6	W113 12.619	25-Aug-09	0	1	non-cultivated	purslane
09.44-13 (5)	N33 26.125	W113 12.619	25-Aug-09	0	1	cultivated	honeydew
09.44-14 (6)	N33 26.122	W113 12.744	25-Aug-09	0	2	cultivated	honeydew
09.44-15 (6)	N33 26.122	W113 12.744	25-Aug-09	0	1	non-cultivated	purslane
09.44-16 (7)	N33 25.772	W113 12.817	25-Aug-09	0	2	cultivated	honeydew
09.44-17 (3)	N33 28.930	W113 06.906	25-Aug-09	0	1	non-cultivated	Wright's ground cherry
09.47-1 (1)	No codes	No codes	31-Aug-09	0	1	cultivated	melon
09.47-2 (1)	No codes	No codes	31-Aug-09	0	1	cultivated	melon
09.47-3 (1)	No codes	No codes	31-Aug-09	0	1	cultivated	melon
09.47-4 (1)	No codes	No codes	31-Aug-09	0	1	non-cultivated	pigweed
09.47-5 (2)	No codes	No codes	31-Aug-09	0	2	cultivated	cantaloupe
09.47-6 (3)	No codes	No codes	31-Aug-09	0	2	cultivated	honeydew
09.47-7 (3)	No codes	No codes	31-Aug-09	0	1	non-cultivated	horse purslane
09.47-8 (4)	No codes	No codes	31-Aug-09	0	1	cultivated	okra
09.47-9 (4)	No codes	No codes	31-Aug-09	0	1	non-cultivated	datura
09.47-10 (5)	No codes	No codes	31-Aug-09	0	5	cultivated	watermelon
09.47-11 (6)	No codes	No codes	31-Aug-09	0	5	cultivated	melon
09.47-12 (7)	No codes	No codes	31-Aug-09	0	2	cultivated	watermelon
09.47-13	No codes	No codes	31-Aug-09	0	1	cultivated	alfalfa
09.50-1	No codes	No codes	31-Aug-09	0	1	cultivated	cantaloupe
09.50-2	No codes	No codes	31-Aug-09	0	1	cultivated	cantaloupe
09.50-3	No codes	No codes	31-Aug-09	0	1	cultivated	cantaloupe
09.55-1	No codes	No codes	28-Oct-09	0	2	cultivated	papaya
09.55-2	No codes	No codes	28-Oct-09	0	2	cultivated	melon
09.55-3	No codes	No codes	28-Oct-09	0	2	cultivated	melon
09.55-4	No codes	No codes	28-Oct-09	0	2	cultivated	melon
10.04-1	N33 11.142	W112 42.299	7-Apr-10	3	1	non-cultivated	canyon ragweed
10.07-1	N33 41.655	W113 28.481	21-Apr-10	0	4	non-cultivated	globemallow
10.08-1	N32 58.263	W112.43.044	10-May-10	0	1	non-cultivated	canyon ragweed
10.08-2	N32 58.262	W112 43.046	10-May-10	0	1	non-cultivated	arugula
10.08-3	N32 58.210	W112 43.043	10-May-10	0	2	non-cultivated	desert star vine
10.08-4	N32 58.248	W112 43.045	10-May-10	0	1	non-cultivated	desert star vine
10.08-5	N32 58.248	W112 43.045	10-May-10	0	1	non-cultivated	globemallow
10.08-6	N32 58.248	W112 43.045	10-May-10	0	1	non-cultivated	canyon ragweed
10.08-7	N32 58.210	W112 43.043	10-May-10	0	1	non-cultivated	clematis
10.08-8	N32 58.210	W112 43.043	10-May-10	0	1	non-cultivated	desert tobacco
10.08-9	N33 05.547	W112 40.051	10-May-10	0	1	non-cultivated	common mallow
10.08-10	N33 05.546	W112 40.050	10-May-10	0	1	non-cultivated	common sowthistle
10.08-11	N33 05.544	W112 40.043	10-May-10	0	1	non-cultivated	red spiderling
10.08-12	N33 11.141	W112 42.301	10-May-10	0	1	non-cultivated	canyon ragweed
10.08-13	N33 11.145	W112 42.251	10-May-10	0	1	non-cultivated	desert tobacco
10.08-14	N33 09.383	W112 40.821	10-May-10	0	1	noncultivated	feral cotton
10.08-15	N33 14.699	W112 47.226	10-May-10	0	1	non-cultivated	common sowthistle
10.08-16	N33 14.698	W112 47.224	10-May-10	0	1	non-cultivated	african mustard
10.09-1	N33 27.907	W113 07.655	12-May-10	0	1	non-cultivated	curly dock
10.09-2	N33 27.907	W113 07.655	12-May-10	0	1	non-cultivated	hog potato
10.09-3	N33 28.758	W113 06.928	12-May-10	0	1	non-cultivated	sunflower
10.09-4	N33 28.758	W113 06.928	12-May-10	0	1	non-cultivated	sunflower
10.09-5	N33 29.579	W113 07.637	12-May-10	0	1	non-cultivated	mallow
10.09-6	N33 29.579	W113 07.637	12-May-10	0	1	non-cultivated	common sowthistle
10.09-7	N33 29.579	W113 07.637	12-May-10	0	1	non-cultivated	cocklebur
10.09-8	N33 29.579	W113 07.637	12-May-10	0	1	non-cultivated	goosefoot
10.09-9	N33 29.579	W113 07.637	12-May-10	0	1	non-cultivated	sunflower
10.09-10	N33 28.120	W112 59.746	12-May-10	0	1	non-cultivated	canyon ragweed

10.09-11	N33 24.387	W111 59.249	12-May-10	3	1	non-cultivated	hollyhock
10.09-12	N33 24.391	W111 59.254	12-May-10	3	1	non-cultivated	hyacinth bean
10.09-13	N33 24.404	W111 59.252	12-May-10	3	1	non-cultivated	desert globemallow
10.09-14	N33 24.416	W111 59.252	12-May-10	3	1	non-cultivated	Parish's goldeneye
10.09-15	N33 24.421	W111 59.001	12-May-10	3	1	non-cultivated	lantana
10.10-1	N33 56.596	W113 11.361	24-May-10	1	1	non-cultivated	mallow
10.10-2	N33 56.596	W113 11.361	24-May-10	0	1	non-cultivated	prostrate pigweed
10.10-3	N33 56.609	W113 11.378	24-May-10	0	1	non-cultivated	field bindweed
10.10-4	N33 56.147	W113 07.474	24-May-10	0	1	non-cultivated	rattlesnake euphorbia
10.10-5	N33 56.147	W113 07.474	24-May-10	0	1	non-cultivated	cocklebur
10.10-6	N33 56.147	W113 07.474	24-May-10	1	1	non-cultivated	african mustard
10.10-7	N33 52.223	W113 27.767	24-May-10	2	1	non-cultivated	silverleaf nightshade
10.10-8	N33 52.223	W113 27.767	24-May-10	2	1	non-cultivated	mallow
10.10-9	N33 52.223	W113 27.767	24-May-10	2	1	non-cultivated	golden crownbeard
10.11-1	N32 59.531	W111 36.048	26-May-10	1	1	non-cultivated	silverleaf nightshade
10.11-2	N32 58.037	W111 34.557	26-May-10	1	1	non-cultivated	tumble pigweed
10.11-3	N32 58.037	W111 34.557	26-May-10	1	1	non-cultivated	horse purslane
10.11-4	N32 58.037	W111 34.557	26-May-10	1	1	non-cultivated	common purslane
10.11-5	N32 58.037	W111 34.557	26-May-10	1	1	non-cultivated	prostrate pigweed
10.11-6	N32 58.037	W111 34.557	26-May-10	1	1	non-cultivated	puncturevine
10.11-7	N32 57.181	W111 35.796	26-May-10	1	1	cultivated	alfalfa
10.11-8	N32 57.181	W111 35.796	26-May-10	3	1	non-cultivated	lantana
10.12-1	N33 11.167	W112 42.296	2-Jun-10	1	1	non-cultivated	skeleton buckwheat
10.12-2	N33 07.681	W112 40.296	2-Jun-10	1	1	non-cultivated	triangle leaf bursage
10.12-3	N33 05.470	W112 40.043	2-Jun-10	1	1	non-cultivated	silverleaf nightshade
10.12-4	N32 58.235	W112 43.406	2-Jun-10	1	1	non-cultivated	desert star vine
10.12-5	N33 09.451	W112 40.864	2-Jun-10	2	1	noncultivated	wild cotton
10.12-6	N33 14.726	W112 47.248	2-Jun-10	1	1	non-cultivated	annual sunflower
10.13-1	N33 04.847	W112 39.979	2-Jun-10	3	1	non-cultivated	mallow
10.14-1	N33 51.565	W-113 32.682	16-Jun-10	1	1	cultivated	honeydew
10.15-1	N33 56.154	W-113 07.476	16-Jun-10	2	1	non-cultivated	cocklebur
10.15-2	N33 56.610	W-113 11.374	16-Jun-10	3	1	non-cultivated	bindweed
10.15-3	N33 58.323	W-113 11.909	16-Jun-10	1	1	non-cultivated	prostrate pigweed
10.15-4	N33 58.323	W-113 11.909	16-Jun-10	1	1	cultivated	melon
10.15-5	N33 52.223	W113 27.767	16-Jun-10	1	1	non-cultivated	silverleaf nightshade
10.15-6	N33 52.223	W113 27.767	16-Jun-10	1	1	cultivated	melon
10.15-7	N33 52.223	W113 27.767	16-Jun-10	3	1	cultivated	cotton
10.15-8	N33 41.655	W113 28.481	16-Jun-10	3	1	non-cultivated	desert globemallow
10.15-9	N33 24.409	W111 59.266	16-Jun-10	2	1	non-cultivated	white guava
10.16-1	N33 24.390	W111 59>265	23-Jun-10	3	1	cultivated	cucumber
10.16-2	N32 59.329	W111 36.229	23-Jun-10	1	1	cultivated	watermelon
10.16-3	N32 59.329	W111 36.229	23-Jun-10	1	1	non-cultivated	nightshade
10.16-4	N32 59.305	W111 36.229	23-Jun-10	1	1	non-cultivated	morning glory
10.16-5	N32 59.329	W111 36.229	23-Jun-10	1	1	noncultivated	feral cotton
10.16-6	N32 57.181	W111 35.783	23-Jun-10	1	1	cultivated	alfalfa
10.16-7	N32 58. 669	W111 35.945	23-Jun-10	1	1	cultivated	honeydew
10.16-8	N32 58. 669	W111 35.945	23-Jun-10	1	1	non-cultivated	tumble pigweed
10.21-1	N32 58.209	W112 43.034	5-Aug-10	3	1	non-cultivated	canyon ragweed
10.21-2	N32 58.209	W112 43.035	5-Aug-10	3	6	non-cultivated	wild (indian) tobacco
10.21-3	N33 05.419	W112 40.046	5-Aug-10	3	1	non-cultivated	canyon ragweed
10.21-4	N33 20.991	W112 41.686	5-Aug-10	1	1	cultivated	alfalfa
10.21-5	N33 20.991	W112 41.686	5-Aug-10	1	1	non-cultivated	Palmer's amaranth
10.21-6	N32 58.211	W112 43.036	5-Aug-10	1	1	non-cultivated	desert star vine
10.21-7	N33 20.991	W112 41.686	5-Aug-10	3	4	cultivated	cotton
10.22-1	N33 56.154	W113 07.476	11-Aug-10	3	1	non-cultivated	cocklebur
10.22-2	N33 56.360	W113 07.481	11-Aug-10	1	1	non-cultivated	abutilon
10.22-3	N33 56.156	W113 07.491	11-Aug-10	3	1	cultivated	cantaloupe
10.22-4	N33 56.156	W113 07.491	11-Aug-10	1	1	non-cultivated	Palmer's amaranth
10.22-5	N33 56.610	W113 11.374	11-Aug-10	3	1	non-cultivated	field bindweed

10.22-6	N33 56.308	W113 10.369	11-Aug-10	3	1	non-cultivated	sowthistle
10.22-7	N33 56.308	W113 10.369	11-Aug-10	3	1	non-cultivated	hyssop spurge
10.22-8	N33 41.655	W113 28.481	11-Aug-10	3	1	non-cultivated	globemallow
10.22-9	N33 41.782	W113 29.182	11-Aug-10	3	1	non-cultivated	okra leaf cotton
10.22-10	N33 25.265	W113 12.568	11-Aug-10	3	1	non-cultivated	datura
10.22-11	N33 25.265	W113 12.568	11-Aug-10	3	1	cultivated	honeydew
10.22-12	N33 25.265	W113 12.568	11-Aug-10	3	1	cultivated	watermelon
10.24-1	N32 59.342	W111 36 958	20-Aug-10	3	1	cultivated	cotton
10.24-2	N32 59.544	W111 35.045	20-Aug-10	1	1	non-cultivated	silverleaf nightshade
10.24-3	N32 59.544	W111 35.045	20-Aug-10	3	1	cultivated	cotton crop
10.24-4	N32 58.562	W111 85.989	20-Aug-10	1	1	non-cultivated	puncturevine
10.24-5	N32 58.562	W111 85.989	20-Aug-10	1	1	non-cultivated	horse purslane
10.24-6	N32 58.562	W111 85.989	20-Aug-10	1	1	non-cultivated	common purslane
10.24-7	N32 58.562	W111 85.989	20-Aug-10	3	1	cultivated	watermelon
10.24-8	N32 58.562	W111 85.989	20-Aug-10	1	1	non-cultivated	Palmer's amaranth
10.24-9	N32 58.562	W111 85.989	20-Aug-10	2	1	cultivated	melon
10.24-10	N32 57.181	W111 35.796	20-Aug-10	3	1	non-cultivated	lantana
10.25-1	N33 21.065	W112 39.598	26-Aug-10	3	1	cultivated	cotton
10.25-2	N33 20.911	W112 41.686	26-Aug-10	3	1	noncultivated	feral cotton
10.25-3	N33 05.419	W112 40.046	26-Aug-10	3	4	non-cultivated	canyon ragweed
10.27-1	N33 05.419	W112 40.046	2-Sep-10	1	1	non-cultivated	canyon ragweed
10.27-2	N33 28.104	W112 59.764	2-Sep-10	3	1	non-cultivated	canyon ragweed
10.27-3	N33 25.246	W113 12.567	2-Sep-10	3	1	cultivated	cantaloupe
10.29-1	N32 59.545	W111 36.042	9/14/2010	3	1	cultivated	watermelon
10.29-2	N32 59.273	W111 31.459	9/14/2010	3	1	non-cultivated	silverleaf nightshade
10.29-3	N32 59.273	W111 31.459	9/14/2010	3	1	non-cultivated	prickly lettuce
10.29-4	N32 58.669	W111 35.945	9/14/2010	3	1	cultivated	melon seedlings
10.29-5	N32 57.181	W111 35.783	9/14/2010	3	1	cultivated	alfalfa crop
10.29-6	N32 57.156	W111 35.799	9/14/2010	3	1	non-cultivated	lantana
10.30-1	N33 56.144	W113 07.478	9-Sep-10	3	1	non-cultivated	cocklebur
10.30-2	N33 56.156	W113 07.491	9-Sep-10	3	2	cultivated	cantaloupe
10.30-3	N33 58 313	W113 10.369	9-Sep-10	3	1	non-cultivated	annual sowthistle
10.30-4	N33 51.776	W113 27.506	9-Sep-10	3	1	cultivated	cotton
10.31-1	N33 20.914	W112 41.687	5-Oct-10	3	4	noncultivated	feral cotton
10.31-2	N33 20.915	W112 41.688	5-Oct-10	3	1	cultivated	alfalfa
10.31-3	N32 58.209	W112 43.035	5-Oct-10	3	4	non-cultivated	desert tobacco
10.31-4	N32 58. 256	W112 43.024	5-Oct-10	3	1	non-cultivated	sacred datura
10.31-5	N33 05.548	W112 40.044	5-Oct-10	3	1	non-cultivated	canyon ragweed
10.31-6	N33 04.985	W112 39.380	5-Oct-10	3	1	non-cultivated	feral cotton
10.31-7	N33 24.393	W111 59.267	5-Oct-10	3	1	cultivated	green beans-bush
10.31-8	N33 24.393	W111 59.257	5-Oct-10	3	4	non-cultivated	hibiscus tea
10.31-9	N33 24.397	W111 59.254	5-Oct-10	3	1	non-cultivated	hyacinth bush
10.31-10	N33 24.392	W111 59.261	5-Oct-10	3	1	cultivated	basil
10.33-1	N33 56.154	W113 07.476	19-Oct-10	3	1	non-cultivated	cocklebur
10.33-2	N33 56.156	W113 07.489	19-Oct-10	3	2	cultivated	cantaloupe
10.33-3	N33 56.258	W113 07.476	19-Oct-10	1	1	non-cultivated	red spiderling
10.33-4	N33 56.593	W113 11.344	19-Oct-10	2	1	non-cultivated	prickly lettuce
10.33-5	N33 51.778	W113 27.508	19-Oct-10	3	1	cultivated	cotton
10.33-6	N33 51.781	W113 27.514	19-Oct-10	3	2	cultivated	cantaloupe
10.33-7	N33 51.781	W113 27.514	19-Oct-10	1	2	non-cultivated	horse purslane
10.33-8	N33 51.781	W113 27.514	19-Oct-10	1	1	non-cultivated	puncturevine
10.33-9	N33 41.618	W113 28.405	19-Oct-10	3	1	non-cultivated	canyon ragweed
10.33-10	N33 24.413	W111 59.306	19-Oct-10	3	3	non-cultivated	three-lobed morning glory
10.33-11	N33 24.413	W111 59.256	19-Oct-10	3	1	non-cultivated	hollyhock

Appendix G

as referenced on page 106 and 108

Site No. 1

Block: Yuma Valley (Ave. F)

Soil Type:	Kofa Clay
Spacing: 30	30
Total of Palms: 213	213
Empty Spaces (No trees): 15	15
Total Acres	4.71
Productive Acres	3.99
Tree Density	45.22

Height (ft)	No. of Palms	Percent
20 - 25	162	76.06%
15 - 19	14	6.57%
10 - 14	20	9.39%
5 - 9	12	5.63%
1 - 4	5	2.35%
Total	213	100%

Site No. 2

Block: Lost 20

Soil Type:	Kofa Clay (upper)/Gadsden Clay (lower)
Spacing: 30 ft	30
Total of Palms: 1,247	1247
Empty Spaces (No trees): 2	2
Total Acres	25.81
Productive Acres	25.66
Tree Density	48.32

Height (ft)	No. of Palms	Percent
12 - 16	1,139	91.34%
6 - 8	98	7.86%
4 - 5	7	0.56%
3	1	0.08%
2	2	0.16%
Total	1,247	100%

Site No. 3

Block: Jessen Home

Soil Type:	Holtville Clay
Spacing: 30 ft	30
Total of Palms: 133	133
Empty Spaces (No trees): 0	0
Total Acres	2.75
Productive Acres	2.73
Tree Density	48.40

Height (ft)	No. of Palms	Percent
26 - 30	11	8.27%
21 - 25	77	57.89%
16 - 20	30	22.56%
11 - 15	11	8.27%
6 - 10	3	2.26%
1 - 5	1	0.75%
Total	133	100%

Site No. 4

Block: Kofa

Soil Type:	Superstition Sand
Spacing: 30 ft	30
Total of Palms: 4,500	4500
Empty Spaces (No trees): 0	0
Total Acres	92.98
Productive Acres	37.19
Tree Density	48.40

Height (ft)	No. of Palms	Percent
10 - 12	450	10.00%
7 - 9	450	10.00%
2 - 6	3,600	80.00%
Total	4,500	100%

Site No. 5

Block: Gavilanes

Soil Type:	Superstition Sand
Spacing: 30 ft	30
Total of Palms: 1,200	1200
Empty Spaces (No trees): 0	0
Total Acres	24.79
Productive Acres	24.79
Tree Density	48.40

Height (ft)	No. of Palms	Percent
20	960	80.00%
19	120	10.00%
18	120	10.00%
Total	1,200	100%

Site No. 6

Block: One E

Soil Type:	Superstition Sand
Spacing: 30 ft	30
Total of Palms: 2,760	2760
Empty Spaces (No trees): 0	0
Total Acres	57.02
Productive Acres	57.02
Tree Density	48.40

Height (ft)	No. of Palms	Percent
14 - 17	2,070	75.00%
9 - 13	414	15.00%
6 - 8	276	10.00%
Total	2,760	100%

Site No. 7

Block: River Ranch

Soil Type:	Antho Fine Sandy Loam
Spacing: 30 ft	30
Total of Palms: 990	990
Empty Spaces (No trees): 0	0
Total Acres	20.45
Productive Acres	20.45
Tree Density	48.40

Height (ft)	No. of Palms	Percent
8 - 10	990	100.00%
Total	990	100%

Site No. 8

Block: Kolby

Soil Type:	Kofa Clay
Spacing: 30 ft	30
Total of Palms: 451	451
Empty Spaces (No trees): 11	11
Total Acres	9.55
Productive Acres	8.33
Tree Density	47.25

Height (ft)	No. of Palms	Percent
22 - 25	1	0.22%
19 - 21	2	0.44%
16 - 18	133	29.49%
13 - 15	158	35.03%
10 - 12	67	14.86%
7 - 9	31	6.87%
4 - 6	22	4.88%
0 - 3	37	8.20%
Total	451	100%

Table 1a. Ranch size, tree age, tree density and tree height for 8 of the 17 sites in this study.

Site No. 9		
Block: Vandervoort		
Soil Type:	Kofa Clay	
Spacing: 30 ft	30	
Total of Palms: 329	329	
Empty Spaces (No trees): 11	11	
Total Acres	7.02	
Productive Acres	6.51	
Tree Density	46.83	
Height (ft)	No. of Palms	Percent
51 - 55	37	11.25%
41 - 50	230	69.91%
31 - 40	27	8.21%
21 - 30	13	3.95%
11 - 20	16	4.86%
0 - 10	6	1.82%
Total	329	100%

Site No. 10		
Block: Palace 1		
Soil Type:	Ripley Silt Loam	
Spacing: 30 ft	30	
Total of Palms: 1,230	1230	
Empty Spaces (No trees): 20	20	
Total Acres	25.83	
Productive Acres	24.77	
Tree Density	47.63	
Height (ft)	No. of Palms	Percent
51 - 55	18	1.46%
46 - 50	627	50.98%
40 - 45	437	35.53%
31 - 39	54	4.39%
21 - 30	32	2.60%
11 - 20	40	3.25%
0 - 10	22	1.79%
Total	1,230	100%

Site No. 11		
Block: Barryman		
Soil Type:	Kofa Clay	
Spacing: 30 ft	30	
Total of Palms: 416	416	
Empty Spaces (No trees): 49	49	
Total Acres	9.61	
Productive Acres	7.52	
Tree Density	43.30	
Height (ft)	No. of Palms	Percent
42 - 50	413	99.28%
5	3	0.72%
Tot	416	100%

Site No. 12		
Block: 12		
Soil Type:	Kofa Clay/Ripley Silt Loam	
Spacing: 30 ft	30	
Total of Palms: 333	333	
Empty Spaces (No trees): 234	23	
Total Acres	7.36	
Productive Acres	6.10	
Tree Density	45.27	
Height (ft)	No. of Palms	Percent
31 - 35	2	0.60%
26 - 30	30	9.01%
21 - 25	111	33.33%
16 - 20	148	44.44%
11 - 15	15	4.50%
6 - 10	12	3.60%
1 - 5	15	4.50%
Total	333	100%

Site No. 13		
Block: 13		
Soil Type:	Kofa Clay	
Spacing: 30 ft	30	
Total of Palms: 827	827	
Empty Spaces (No trees): 58	58	
Total Acres	18.29	
Productive Acres	14.71	
Tree Density	45.23	
Height (ft)	No. of Palms	Percent
21 - 25	43	5.20%
16 - 20	341	41.23%
11 - 15	305	36.88%
6 - 10	81	9.79%
1 - 5	57	6.89%
Total	827	100%

Site No. 14		
Block: Block 1		
Soil Type:	Indio Silt Loam	
Spacing: 30 ft	30	
Total of Palms: 325	325	
Empty Spaces (No trees): 14	14	
Total Acres	7.00	
Productive Acres	6.43	
Tree Density	46.40	
Height (ft)	No. of Palms	Percent
50 - 54	49	15.1
48- 49	276	84.90
Total	325	100

Site No. 15		
Block: Winterhaven		
Soil Type:	Gadsden Clay	
Spacing: 30 ft	30	
Total of Palms: 455	455	
Empty Spaces (No trees): 7	7	
Total Acres	9.55	
Productive Acres	9.12	
Tree Density	47.67	
Height (ft)	No. of Palms	Percent
51 - 55	2	0.4
41 - 50	260	57.1
31 - 40	125	27.5
21 - 30	33	7.3
11 - 20	22	4.8
0 - 10	13	2.9
Total	455	100.0

Site No. 16		
Block: 302 SE		
Soil Type:	Kofa Clay	
Spacing: 30 ft	30	
Total of Palms: 396	396	
Empty Spaces (No trees): 4	4	
Total Acres	8.26	
Productive Acres	8.10	
Tree Density	47.92	
Height (ft)	No. of Palms	Percent
50 - 55	189	47.6
46 - 49	202	51
41 - 45	1	0.3
31 - 40	3	0.8
21 - 30	0	0
0 - 20	1	0.3
Total	396	100.0

Site No. 17		
Block: 301		
Soil Type:	Kofa Clay	
Spacing: 30 ft	30	
Total of Palms: 98	98	
Empty Spaces (No trees): 2	2	
Total Acres	2.07	
Productive Acres	1.98	
Tree Density	47.43	
Height (ft)	No. of Palms	Percent
41 - 50	84	85.8
31 - 40	12	12.2
21 - 30	1	1
11 - 20	0	0
0 - 10	1	1
Total	98	100.0

Table 1b. Ranch size, tree age, tree density and tree height for 9 of the 17 sites in this study

	2010		2011					
	Yield (lbs.)	yield/ac	Yield (lbs.)	yield/ac	Total Yield/ac	Avg. Yield/ac	Yield/ac gain or loss	% Yield/ac gain or Loss
Berryman	129,825.00	12,982.50	122,082.00	12,208.20	25,190.70	12,595.35	-774.30	-6%
Lost 20	104,907.00	4,196.28	158,240.00	6,329.60	10,525.88	5,262.94	2,133.32	51%
Jessen	31,681.00	11,520.36	34,540.00	12,560.00	24,080.36	12,040.18	1,039.64	9%
Gavilanes	721,267.00	4,507.92	899,224.00	5,620.15	10,128.07	5,064.03	1,112.23	25%
One E	411,781.00	2,573.63	615,440.00	3,846.50	6,420.13	3,210.07	1,272.87	49%
Kofa	21,273.00	132.96	13,475.00	84.22	217.18	108.59	-48.74	-37%
Block 1	131,037.00	2,620.74	114,939.00	2,298.78	4,919.52	2,459.76	-321.96	-12%
Block 12	56,978.00	11,395.60	64,599.00	12,919.80	24,315.40	12,157.70	1,524.20	13%
Block 13	102,776.00	10,277.60	77,205.00	7,720.50	17,998.10	8,999.05	-2,557.10	-25%
301 Organic	185,880.00	12,392.00	170,943.00	11,396.20	23,788.20	11,894.10	-995.80	-8%
302 Organic	152,705.00	10,180.33	119,193.00	7,946.20	18,126.53	9,063.27	-2,234.13	-22%
Vandevoort Bard	279,707.00	9,323.57	244,197.00	8,139.90	17,463.47	8,731.73	-1,183.67	-13%
Avenue F	95,297.00	3,665.27	87,751.00	3,375.04	7,040.31	3,520.15	-290.23	-8%
Tacna (River)	196,573.00	2,457.16	73,134.00	914.18	3,371.34	1,685.67	-1,542.98	-63%
Winterhaven	115,496.00	11,549.60	103,946.40	10,394.64	21,944.24	10,972.12	-1,154.96	-10%
Palace 1	385,354.00	14,272.37	346,818.60	12,845.13	27,117.50	13,558.75	-1,427.24	-10%
Colby	45,791.00	4,579.10	41,211.90	4,121.19	8,700.29	4,350.15	-457.91	-10%
Average							-347.46	-5%

Table 2. Yields, of the 17 date sites.

	2010					2011				
	Jumbo	Large	Extra Fancy	Fancy	Other	Jumbo	Large	Extra Fancy	Fancy	Other
Berryman	2.33%	24.83%	48.19%	4.03%	20.63%	0.93%	9.27%	40.62%	19.86%	29.32%
Lost 20	3.76%	18.99%	59.56%	3.27%	14.42%	4.18%	5.11%	46.67%	26.25%	17.80%
Jessen	3.51%	17.74%	62.88%	3.75%	12.12%	5.25%	8.25%	43.82%	18.28%	24.39%
Gavilanes	0.22%	8.29%	57.25%	1.13%	33.11%	0.59%	5.53%	55.12%	14.37%	24.40%
One E	0.63%	7.50%	55.69%	1.41%	34.77%	0.69%	4.39%	48.09%	15.86%	30.97%
Kofa	0.26%	4.86%	44.78%	1.76%	48.34%	0.00%	0.90%	35.10%	43.10%	20.90%
Block 1	1.02%	18.65%	57.88%	6.23%	16.21%	0.10%	6.10%	54.00%	17.14%	22.67%
Block 12	3.73%	10.14%	60.10%	14.25%	11.79%	0.31%	4.53%	33.73%	27.14%	34.29%
Block 13	2.29%	7.62%	63.55%	12.52%	14.01%	0.50%	3.99%	27.74%	30.12%	37.65%
301 Organic	1.70%	22.34%	56.87%	6.44%	12.65%	0.12%	1.70%	52.65%	24.11%	21.43%
302 Organic	1.47%	18.43%	60.39%	6.77%	12.94%	0.08%	0.89%	46.86%	28.88%	23.29%
Vandevoort Bard	0.96%	18.84%	59.64%	7.03%	13.52%	0.89%	5.35%	51.21%	19.16%	23.39%
Avenue F	1.73%	15.28%	62.51%	5.73%	14.75%	0.86%	7.81%	41.97%	15.54%	33.81%
Tacna (River)	2.29%	37.04%	45.34%	3.21%	12.12%	0.72%	3.52%	32.08%	27.34%	36.33%
Winterhaven	2.33%	24.83%	48.19%	4.03%	20.63%	1.59%	25.99%	47.79%	5.07%	19.56%
Palace 1	3.76%	18.99%	59.56%	3.27%	14.42%	2.55%	18.78%	60.01%	3.33%	15.33%
Colby	3.51%	17.74%	62.88%	3.75%	12.12%	2.49%	15.29%	63.37%	3.34%	15.51%
Average Jumbo to Fancy				81.26%					74.65%	

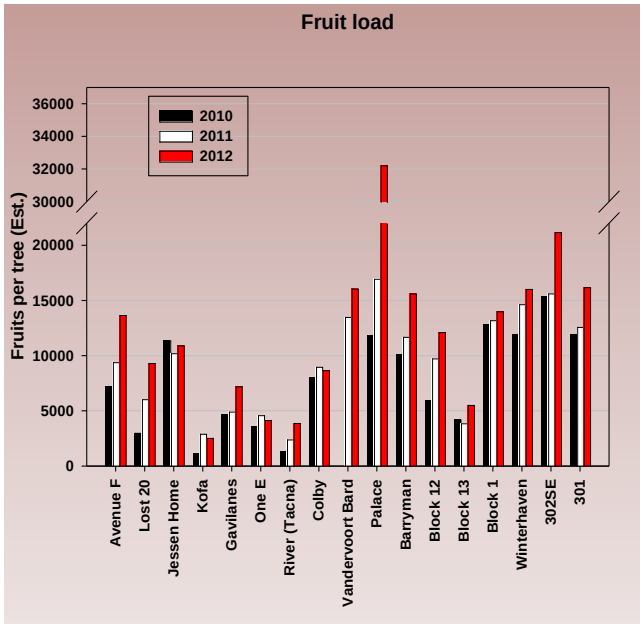
Table 3. Packout of the 17 date sites.

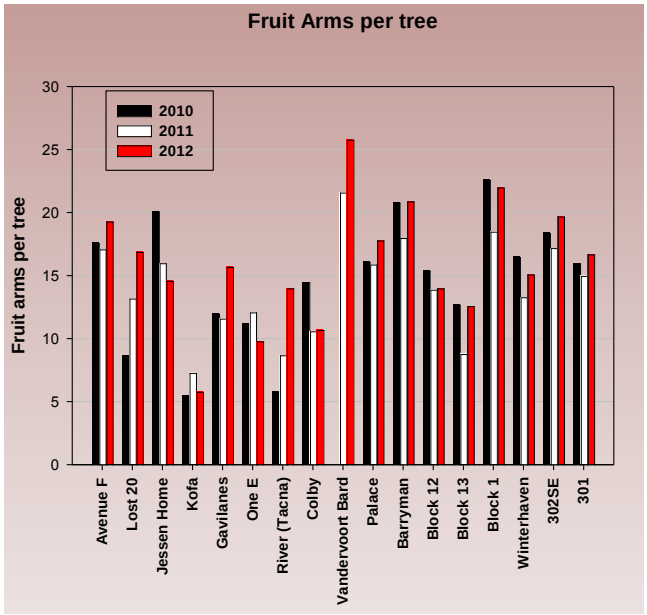
	Depth (in)	pH	Organic Matter (%)	Nitrate N (ppm N)	N (Lbs./ac)	% Na Sat.	SAR	Fertilization Practices
Avenue F	0 – 8	8.17	2.23	7.10	24.00	6.00	1.62	Fertilization exclusively with manure. Conventionally farmed.
	8 - 18	8.17	1.00	3.07	7.67	6.00	1.43	
Lost 20	0 – 8	8.20	3.17	10.90	23.00	6.00	1.72	Conventional fertilization with liquid N and P sources and occasional compost and/or manure. Conventionally farmed.
	8 - 18	8.10	1.53	6.50	13.67	7.00	1.83	
Jessen Home	0 – 8	8.07	4.07	16.50	56.00	6.50	1.72	Conventional fertilization with liquid N and P sources and occasional compost and/or manure. Conventionally farmed.
	8 - 18	8.27	1.40	6.93	17.00	8.50	2.24	
Kofa	0 – 8	8.20	2.50	7.67	14.67	9.00	1.23	Fertilized exclusively with liquid N, P and micronutrients through the drip line. Conventionally farmed.
	8 - 18	8.27	1.87	7.47	13.33	7.00	0.98	
Gavilanes	0 – 8	8.47	2.07	6.87	9.00	8.00	1.35	Fertilized exclusively with liquid N, P and micronutrients through the drip line. Conventionally farmed.
	8 - 18	8.60	0.63	3.13	6.00	6.50	1.07	
One E	0 – 8	8.40	1.40	12.90	32.00	7.00	1.05	Fertilized exclusively with liquid N, P and micronutrients through the drip line. Conventionally farmed.
	8 - 18	8.50	0.77	7.50	22.33	6.50	1.01	
Tacna (River)	0 – 8	8.23	1.83	12.13	21.67	22.50	6.41	Fertilized exclusively with liquid N, P and micronutrients through the drip line. Conventionally farmed.
	8 - 18	8.27	1.40	17.10	42.67	24.00	7.14	
Colby	0 – 8	8.10	5.13	37.67	92.00	3.00	0.63	Fertilization exclusively with manure. Organically farmed.
	8 - 18	8.30	6.23	32.73	53.33	6.50	1.62	
Vandevoort Bard	0 – 8	8.07	4.73	11.13	15.33	2.00	0.39	Conventional fertilization with liquid N and P sources and occasional compost and/or manure. Conventionally farmed.
	8 - 18	8.33	5.10	15.60	8.67	2.00	0.28	
Palace 1	0 – 8	8.23	6.17	18.13	50.33	11.00	2.86	Fertilization exclusively with manure. Organically farmed
	8 - 18	8.17	2.27	9.47	15.67	11.00	2.73	
Berryman	0 – 8	8.07	3.10	8.83	42.67	8.50	2.56	Conventional fertilization with liquid N and P sources and occasional compost and/or manure. Conventionally farmed.
	8 - 18	8.20	1.43	3.43	8.00	11.00	3.34	
Block 12	0 – 8	8.20	2.00	3.97	11.33	5.50	1.45	Conventional and organic fertilization with liquid N and P sources and occasional compost and/or manure. Conventionally farmed.
	8 - 18	8.23	1.13	2.43	5.00	6.00	1.53	
Block 13	0 – 8	8.27	1.93	3.40	12.33	7.00	2.00	Conventional and organic fertilization with liquid N and P sources and occasional compost and/or manure. Conventionally farmed.
	8 - 18	8.17	1.30	1.80	4.33	7.50	2.20	
Block 1	0 – 8	8.23	2.37	5.83	27.33	9.50	2.64	Conventional and organic fertilization with liquid N and P sources and occasional compost and/or manure. Conventionally farmed
	8 - 18	8.37	0.97	2.40	5.33	8.00	1.83	
Winterhaven	0 – 8	8.20	6.80	19.37	69.67	9.50	2.90	Fertilization exclusively with manure. Organically farmed
	8 - 18	8.30	4.43	13.23	17.67	7.00	1.84	
302	0 – 8	7.90	2.53	5.30	42.33	5.50	1.71	Fertilization exclusively with manure. Organically farmed
	8 - 18	8.20	1.10	2.37	6.00	4.50	0.90	
301	0 - 8	7.93	1.93	3.70	42.00	7.50	2.31	Fertilization exclusively with manure. Organically farmed
	8 - 18	8.13	0.67	1.67	5.67	5.00	0.98	

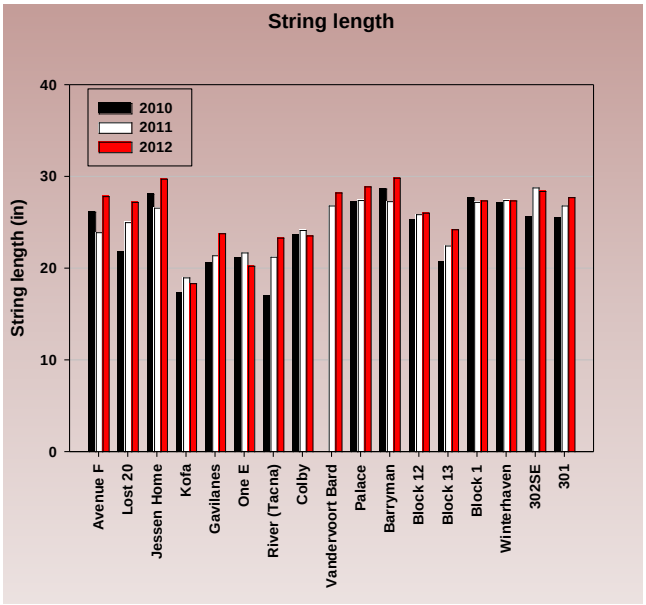
Table 4. 2010 – 2012 Average soil characteristics of the 17 sites

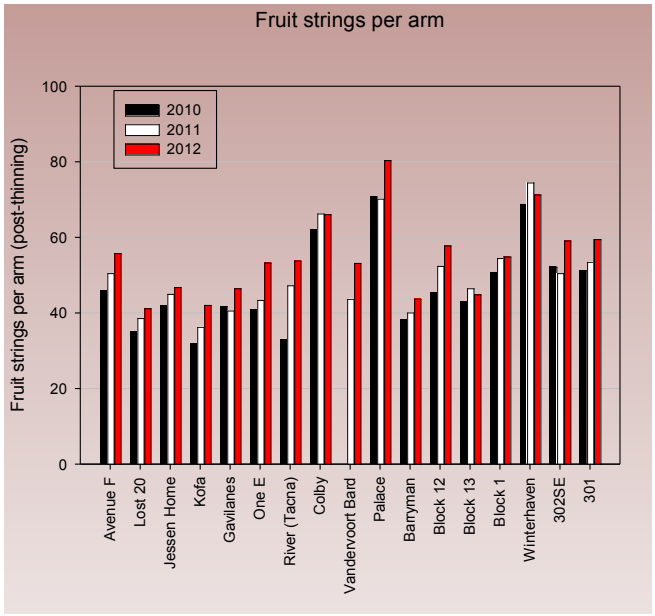
	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Zinc (ppm)	Iron (ppm)	Manganese (ppm).	Copper (ppm)
Avenue F	1.442	0.129	0.995	18.3	340.6	40.0	7.6
Lost 20	1.912	0.134	0.888	16.0	296.1	63.7	9.1
Jessen Home	1.879	0.132	1.120	24.1	379.3	149.8	6.4
Kofa	1.974	0.135	0.903	15.8	320.1	48.6	8.8
Gavilanes	1.682	0.103	0.815	13.0	292.8	45.7	8.5
One E	1.774	0.115	0.809	13.8	225.5	51.6	5.7
Tacna (River)	1.619	0.120	1.250	12.2	156.6	114.5	8.8
Colby	1.766	0.123	1.074	23.7	191.6	29.9	10.5
Vandevoort Bard	1.826	0.126	1.142	16.5	234.6	43.4	6.8
Palace 1	2.013	0.131	1.108	23.5	245.4	106.5	6.3
Berryman	1.815	0.147	1.037	26.6	221.9	50.7	10.0
Block 12	1.687	0.188	1.259	18.6	277.3	98.7	8.9
Block 13	1.552	0.158	0.995	19.9	287.1	89.6	8.8
Block 1	1.936	0.141	0.839	21.3	265.6	209.4	10.7
Winterhaven	1.962	0.134	0.992	23.7	295.5	122.7	12.3
302	2.001	0.146	0.817	26.0	249.4	128.0	7.1
301	1.841	0.146	0.761	22.7	260.5	91.5	7.3

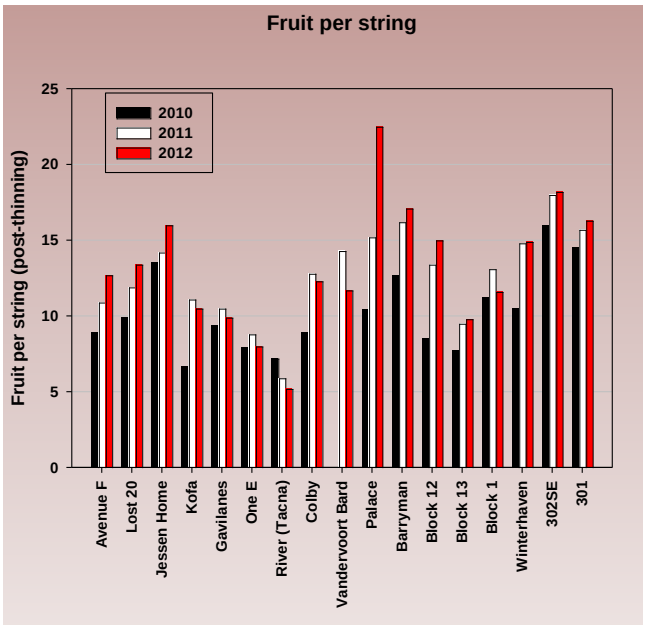
Table 5. Leaf analysis for 10 randomly selected trees at the 17 sites for 2011.

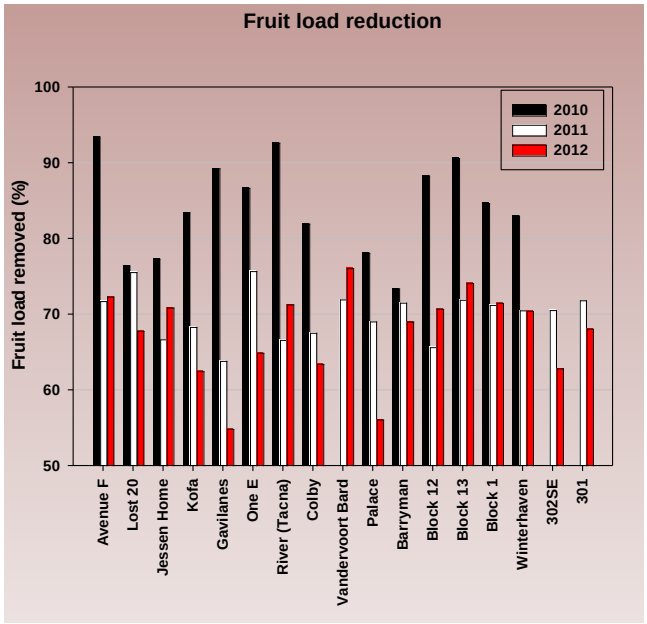

Fruit load
Fruits per tree (Est.)
36000
34000
32000
30000
20000
15000
10000
5000
0
2010
2011
2012
Avenue F
Lost 20
Jessen Home
Kofa
Gavilanes
One E
River (Tacna)
Colby
Vandervoort Bard
Palace
Barryman
Block 12
Block 13
Block 1
Winterhaven
302SE
301


Fruit Arms per tree
Fruit arms per tree
30
25
20
15
10
5
0
2010
2011
2012
Avenue F
Lost 20
Jessen Home
Kofa
Gavilanes
One E
River (Tacna)
Colby
Vandervoort Bard
Palace
Barryman
Block 12
Block 13
Block 1
Winterhaven
302SE
301


String length
String length (in)
40
30
20
10
0
2010
2011
2012
Avenue F
Lost 20
Jessen Home
Kofa
Gavilanes
One E
River (Tacna)
Colby
Vandervoort Bard
Palace
Barryman
Block 12
Block 13
Block 1
Winterhaven
302SE
301


Fruit strings per arm
Fruit strings per arm (post-thinning)
100
80
60
40
20
0
2010
2011
2012
Avenue F
Lost 20
Jessen Home
Kofa
Gavilanes
One E
River (Tacna)
Colby
Vandervoort Bard
Palace
Barryman
Block 12
Block 13
Block 1
Winterhaven
302SE
301





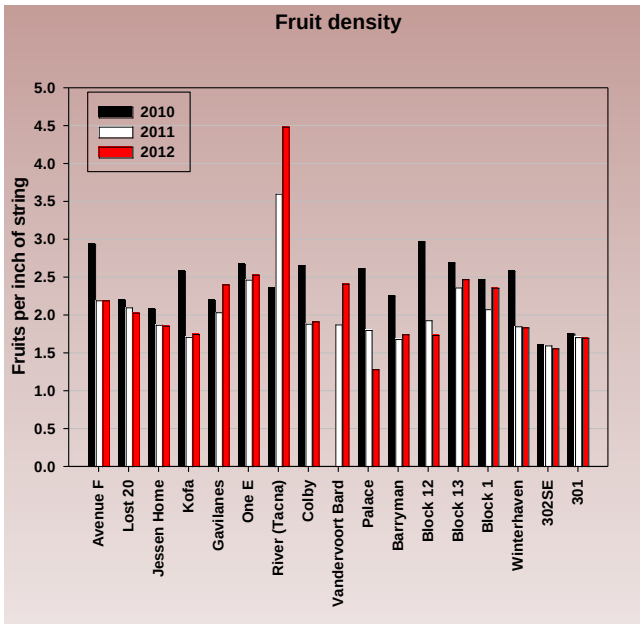


Figure 1. Fruit, arm, and string parameters for 17 date palm sites in the Yuma region.

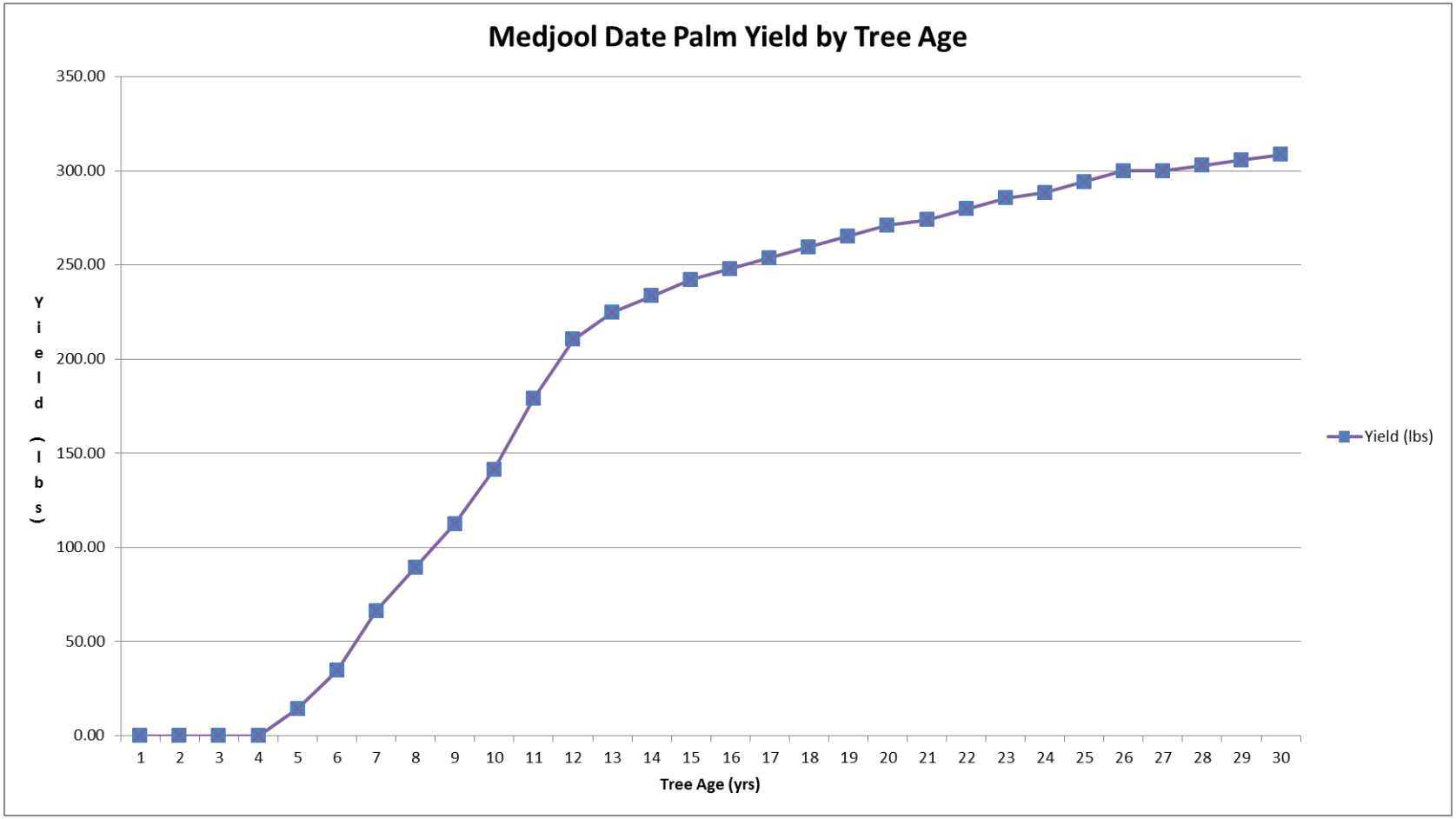


Figure 2. Preliminary Idealized yield curve for date palms based on age.