Arizona Department of Agriculture

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Introduction

On September 24, 2010, 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 $1,175,326.21 in FY10 Specialty Crop Block Grant Program – Farm Bill funds to fund sixteen projects specifically designed to increase the consumption and enhance the competitiveness of Arizona Specialty Crops. Projects within the Arizona State Plan include four marketing projects, two education projects and ten research projects and are one to three years in duration. On June 29, 2012, an amendment to the State Plan included a change in scope and budget for one education project and the addition of two new education projects. The expiration of the grant period was September 30, 2013.

2011 Southwest Ag Summit – An Interactive Educational Experience

This project was completed on September 30, 2011

Project Summary

With each successful Southwest Ag Summit, the Steering Committee evaluates and builds on the year's achievements to ensure continued progress. The 2011 Southwest Ag Summit, scheduled for March, will provide an interactive forum between educators, specialists, farmers, and students of the southwest desert specialty crop industry at general sessions, academic workshops and hands-on field demonstrations. To further the goals of the 2011 SWAS and expand its reach to other specialty crop producers, the Steering Committee has determined that a marketing coordinator and a website upgrade are essential.

Project Approach

The Southwest Ag Summit had its debut year in 2007 as a one-day event. Since then it has grown to two full days of specialty crop related educational experiences. A large group of industry professionals, specialty crop producers and research scientists banded together, dedicated to increasing the Southwest Ag Summit's impact by presenting up to date and progressive research and technology. Focusing on specialty crops, the Southwest Ag Summit has become an example of strong partnerships within the agriculture industry. The University of Arizona and the Arizona Farm Bureau have both contributed greatly to making this the largest industry specific event in the desert region of Arizona, delivering key information to hundreds of members of the specialty crop industry. Their participation also increases the dissemination of specialty crop information among groups of industry professionals, research scientists and educators, producers and students. In hopes of creating more buzz about the 2011 Southwest Ag Summit, a new alliance was formed with the Yuma Visitors' Bureau to create a marketing strategy which included three 10-page informational magazines and an official program of events, as well as social networking. The increased success of the Southwest Ag Summit is a direct result of close collaboration among these groups.

The 2011 Southwest Ag Summit Steering Committee was spearheaded by Steve Alameda, a local specialty crop grower, Dr. Kurt Nolte, University of Arizona, Yuma County Cooperative Extension Service Director, and Bruce Gwynn, a local chemical representative. These men all have connections within the specialty crop industry. Along with the Ag Summit Coordinator, the event was overseen from initial planning of the event through evaluation and final report. Held

March 9th and 10th, 2011, the 2011 Southwest Ag Summit provided a forum for relationship building and networking between specialty crop educators, industry professionals, industry representatives and students. As information needs to be current in order to be effective, the Steering Committee sought to recruit enlightened speakers to discuss topics of interest to the specialty crop industry.

Dr. Kurt Nolte, along with the assistance of Dr. John Palumbo and Dr. Mark Siemens from the University of Arizona Yuma Ag Center assembled a network of knowledgeable and innovative presentations and speakers based on evaluation of previous successful Southwest Ag Summit field demonstrations and information collected by querying specialty crop industry growers. The 2011 Southwest Ag Summit real-life, not simulated field demonstrations were expanded from prior years, providing new and emerging technologies in specialty crop production to industry professionals, students and producers. Being a premier agricultural event in the desert southwest, the Southwest Ag Summit is contacted months ahead of time by companies eager to participate. The companies that were involved with the 2011 Southwest Ag Summit field demonstrations provided a good representation of various types of agricultural equipment and displays, including transplanters, a weeder/thinner, several discs/plows, polytubing and nozzles for irrigation, as well as other equipment. Lettuce variety trials were performed by more than one demonstrator. This day also included a solar array demonstration. The wide variety of presentations ensured there was something of interest for each member of the crowd.

On the second morning of the Southwest Ag Summit, the keynote speaker, Dr. Jeanette Thurston from the USDA, Agriculture and Food Safety Research Initiative, addressed the general session. Following this address, workshops applicable to the desert southwest specialty crop industry were presented utilizing relative, up-to-date information about food safety, irrigation strategies, chemical management, crop protection, and advanced technologies in agriculture. Originally, six academic forums were scheduled; however, the program was expanded to include one more. The seven timely and effective educational workshops were held throughout the day, comprised of both morning and afternoon sessions. The speakers from across the country presented information and answered participants' questions. Dr. Monica Ozores-Hampton traveled from the University of Florida, Southwest Florida Research & Education Center to present an entire workshop on organic vegetable production. Dr. Ozores-Hampton is internationally recognized as the leader in compost utilization and biology as well as the editor of the Journal of Sustainable Agriculture and the executive editor of the scientific journal Compost Science and Utilization. A copy of the schedule of events for the day is attached and marked as **Appendix A.** This listing includes all field demonstrations as well as session topics and speakers.

Concurrently with the development of the hands-on field demonstrations and the educational workshops, Southwest Ag Summit Steering Committee members and staff coordinated outreach and logistics of the entire event to ensure a smooth, uninterrupted program for this multi-day experience. Striving to further the reach of the Southwest Ag Summit and increase attendance over prior years, the Arizona Farm Bureau was instrumental in promotion of the event to industry members in all parts of Arizona.

In order to further expand the reach of the 2011 Southwest Ag Summit and include more specialty crop producers, the Yuma Visitors Bureau was contracted to coordinate the marketing and outreach for the event. They produced and distributed three additions of the *Ag Summit*

Insider, which showcased the Yuma specialty crop industry. These publications were divided into sections entitled, "Innovative, Intuitive, Inspirational, and Informative." They provided information about the 2011 Southwest Ag Summit and articles on topics ranging from combating cucurbit yellow stunting disorder virus in melons to minimizing spray drift to using compost safely in organic agriculture. Each *Insider* was distributed to 5,000 agricultural leaders in Arizona, California, Nevada and New Mexico. The colorful pictures and inviting presentation of the Ag Summit Insider was well received and complimented as "highly professional."

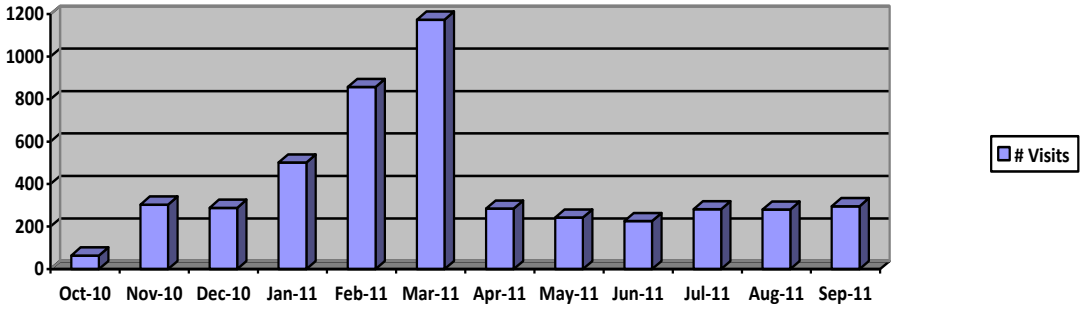
Goals and Outcomes Achieved

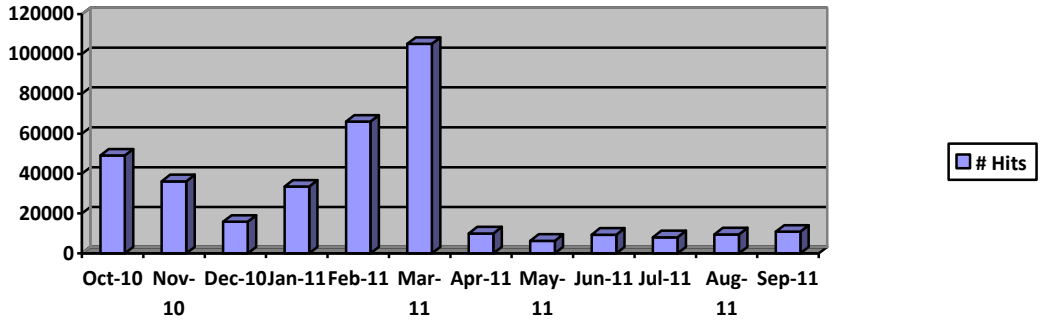
- Increasing the outreach of the 2011 Southwest Ag Summit was an important in increasing participation by specialty crop personnel. To this end the addition of the Yuma Visitors Bureau as marketing coordinator was key. The addition of the *Ag Summit Insider* publications that were distributed across the southwestern region of the United States was instrumental in increasing awareness of our event throughout the specialty crop industry.

- As a result of our aggressive outreach approach, attendees registered sporadically via telephone, mail and the internet between the early planning months of November and December, and then daily during the months of January through March. Due to the sudden departure of the Southwest Ag Summit Coordinator and the hiring of a new Coordinator only two months prior to the March event, the Steering Committee's expectations of achieving our attendance goal of 700 were slim. Approximately 650 people from the vegetable and melon industries registered and attended the 2011 Southwest Ag Summit educational programs. The actual participation in the Southwest Ag Summit was 7% under our original target of 700; however, this was a slight margin and surpassed our expectations.

- Also due to the sudden departure of the Southwest Ag Summit Coordinator and the hiring of a new Coordinator only two months prior to the March event, the Steering Committee's expectations of achieving our target of 250 participants at the Southwest Ag Summit field demonstrations were slim. Approximately 150 people from the vegetable and melon industries actually attended the 2011 Southwest Ag Summit field demonstrations.

- The goal that greatly exceeded everyone's expectations involved the use of the website. The third goal of this year's Southwest Ag Summit was to install a counter to track website hits and original visits. The website, which did not originally have this capability, was upgraded so the Southwest Ag Summit Steering Committee would be able to follow the use of our website by potential participants and gauge how important this website was in conveying information. The Steering Committee was especially surprised and pleased by the amount of usage the website receives during the 'off-season' time of year. The statistics derived from these numbers show that our website, www.swagsummit.com, is continuing to be a valuable tool in expanding the reach of the Southwest Ag Summit to potential customers in the specialty crop industry.





Beneficiaries

Since it began in 2007 the goal of the Southwest Ag Summit has been to institute greater efficiencies for the vegetable and melon industries of the desert southwest region through advanced technology, improved management and enhanced growing techniques. Toward this end, the 2011 Southwest Ag Summit reached out and encompassed specialty crop producers, research scientists, industry representatives and students interested in pursuing careers related to specialty crop production.

On the final day of the 2011 Southwest Ag Summit, participants completed a survey intended to provide feedback about the Ag Summit's direct and indirect impact on the specialty crop industry. A copy of the exit survey is attached and marked as **Appendix B.** This informational survey exhibited to the Steering Committed the diversity of participants, as well as their goals and interests at the Southwest Ag Summit.

38% of participants in the survey noted they had attended the field demonstrations the previous day.

An astounding 97% of attendants who completed the survey indicated they would share the information they obtained from the Southwest Ag Summit with others.

The information obtained at the Southwest Ag Summit will be shared with:

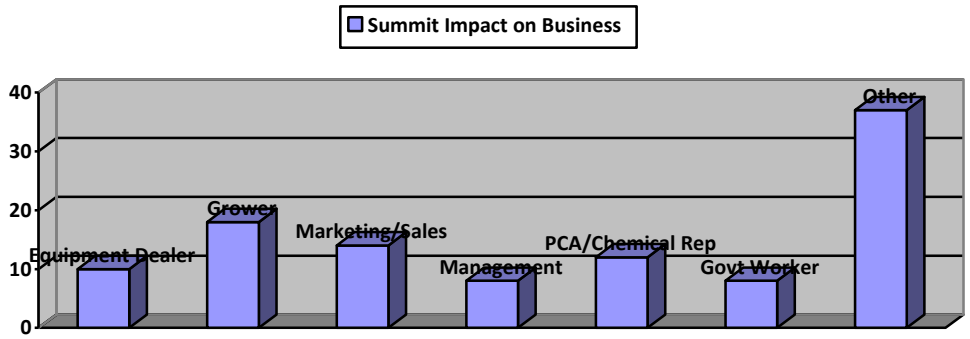
- Staff
- Coworkers
- The media
- Friends and family

The Southwest Ag Summit affected the businesses of those who attended by:

- Better informing them about desert agriculture
- Enhancing marketing opportunities
- Gaining information about food safety
- Developing networking opportunities

With essentially the same attendance figures as the previous year, the exit survey indicated our participants comprised of:

- 24% specialty crop producers
- 20% PCAs and chemical related personnel
- 13% seed related personnel
- 11% University/government related personnel
- 10% wholesale/retail related personnel
- 7% professional/support personnel
- 7% equipment dealers
- 7% water related personnel
- 1% of our participants came from miscellaneous industries



Attendees from all occupations who responded also indicated the reasons the reasons for attending their Southwest Ag Summit:

- Academic breakout sessions
- Keynote address
- Booth displays
- Field demonstration
- Marketing opportunities
- Continuing education credits
- Networking opportunities

Numerous beneficiaries of the 2011 Southwest Ag Summit received information relevant to specialty crop production even though they may not have attended the Ag Summit. It is anticipated that information will be distributed to specialty crop producers in our target audience area of Arizona, New Mexico, Nevada, California and Northern Mexico.

For specialty crop producers and associated industry members in the desert southwest region of Arizona, the potential economic impact of the 2011 Southwest Ag Summit is astounding. 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 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.

Lessons Learned

1. Utilizing the information gained by upgrading our website and tracking usage, we can see that this is a useful tool in our outreach efforts to contact potential customers in the specialty crop industry.
2. By changing the venue of the 2011 Southwest Ag Summit general sessions and academic workshops, we allowed for more coordination with other agricultural events occurring around the same time.
3. The highly professional efforts of the Yuma Visitors Bureau as marketing coordinator have increased the reach of the Southwest Ag Summit. Their scope of work provided the vehicle to further the reach of the Southwest Ag Summit and include more specialty crop producers.
4. Although the Southwest Ag Summit suffered a sudden resignation of the Coordinator two months prior to the event, the Steering Committee and Yuma Visitors Bureau teamed together to demonstrate their determination in ensuring success. This attitude regarding overcoming obstacles speaks volumes about the commitment and partnerships involved with the Southwest Ag Summit.
5. Despite the change in staff only two months prior to our March event, participation in the Ag Summit fell short of the Steering Committee's target by only a small margin of 7%. However, as a result of not meeting our goal and in an effort to further increase attendance, one of the sub-committees we are planning for the upcoming 2012 Southwest Ag Summit will be charged with the task of recruiting additional attendees.
6. Unfortunately, this was not the case with the field demonstrations, which fell 40% short of the target of 250 participants. This will, however, give us insight for future years as to how we can and should assertively market this portion of the Southwest Ag Summit as an important educational experience for the specialty crop growers.
7. The size of the annual Southwest Ag Summit demands many hours of preparation and includes a multitude of volunteers. For 2011, ongoing meetings of the Southwest Ag Summit Steering Committee ensured a nearly flawless event. It has been recommended that in future years the planning of this event be broken down to many smaller committees under the purview of the Summit Coordinator, with recommendations from each committee being brought to the Steering Committee for final approval.
8. 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. Each year efforts are expanded to reach a greater number of people involved in this industry.

Securing an engaging keynote speaker and informative workshop speakers with topics that are relevant to specialty crop producers has been key to the growth of this event. The Southwest Ag Summit strives 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. While the Southwest Ag Summit Steering Committee applauds the efforts of Dr. Kurt Nolte, along with the assistance of Dr. John Palumbo and Dr. Mark Siemens to recruit knowledgeable and innovative speakers, there became a glaring need for better communication with these speakers prior to the event. Suggestions for improving the experience for our speakers, which we plan to put into effect for the upcoming Southwest Ag Summit include assigning a specific person to be in charge of a/v equipment for speakers so that it is all suitable for each room and in place when needed and putting in place a plan in which the Southwest Ag Summit Coordinator has more direct contact with speakers, thus providing them with better information about schedule, hotel accommodations, and travel reimbursement. A packet will be prepared for each speaker providing them with this information.

9. During the 2011 Southwest Ag Summit there was an issue with CEU registration being held outside at the registration tables. This caused congestion at the tables, as well as missed registration for attendees needing to register for CEUs. In the future we plan to move CEU registration tables closer to the meeting rooms affected.
10. Onsite registration of the 2011 Southwest Ag Summit was handled by the staff of the Yuma County Extension office. They worked in conjunction with the Summit Coordinator all through the planning stages to compile a comprehensive list of attendants as it was their responsibility to provide a name badge for each of the participants. At the conclusion of the event it was discovered there were many instances in which names were missing from the registration list. It is planned to use an online document next year, so all parties adding names to the registration list will have an up-to-date list to work with.
11. The Official Event Program was handed out this past year at the registration tables, which was already a busy, congested area out of the way of the Ag Summit main entry doors. Also, its cover design was similar to the marketing publications of the prior months leading to the summit. Many people did not pick one up, thinking it was something they already had. While we plan to continue passing out the programs at the registration tables, they are being redesigned so they are more distinguishable, hopefully leading to less confusion about the contents.

As the Southwest Ag Summit Steering Committee and staff prepare for the 2012 Ag Summit in March, we are utilizing the lessons learned from 2011 to make sure next year's event helps Arizona specialty crop producers enhance their competitiveness in the global market.

We are still waiting to receive final bills from a few people for advertising and labor services. Once these are received we will pay them and be done with the payables for the Ag Summit. Additionally, once these final bills are received and paid we will have an accurate accounting of the program income for the 2011 Southwest Ag Summit.

Contact Persons

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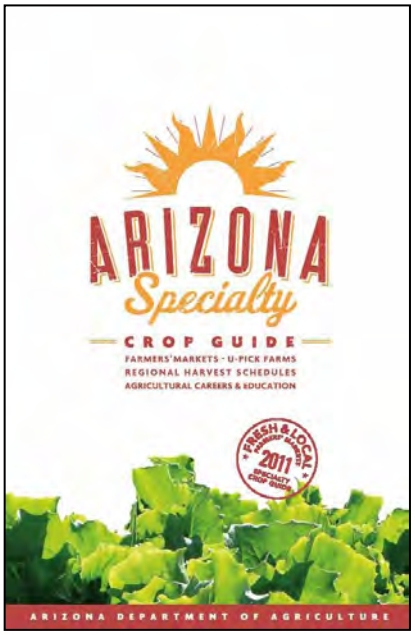
Arizona Specialty Crop Reference Guide (Updates)

This project was completed on September 30, 2011

Project Summary

To update and reproduce an educational reference guide for consumers which will include:

- Where our food and plants come from and the benefits reaped from buying Arizona grown produce and plants
- 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 printed 5,000 Specialty Crop Guides in the 2006-2007 grant cycles and that inventory was depleted. The guide was well-received among the public and therefore a request was made to update and re-print the guide. 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 November of 2010, 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.

In February of 2011, the Department entered into a contract with Esser Design to make the revisions and print approximately 10,000 copies of the updated guide. The new guides were

delivered to the Department in March of 2011. Distribution of the guides began immediately upon delivery.

Goals and Outcomes Achieved

The goal of reaching approximately 18,000 Arizona consumers by distributing at least 8,000 copies of the new guide was surpassed. More than 9,100 guides were distributed between March 2011 and September 2011, reaching nearly 21,000 Arizona consumers (based on average readership per copy of 2.3).

The guides were distributed to University Cooperative Extension offices (statewide), Public Libraries (statewide), the Summer Ag Institute, and various other events, conferences and meetings (statewide). Additional copies of the guide are still available and continue to be distributed as requested. A copy of the guide is also available on the Department's website at: http://www.azda.gov/ACT/SCBGP.aspx

Lessons Learned

Farmer's Market and U-Pick Farm information that was included in the guide is difficult to keep current as the locations, schedules, etc. change frequently. A disclaimer was added to the guide, advising the reader to verify the information prior to their visit.

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Implementing an Arizona GHP/GAP Certification Training and Promotion Program

This project was completed on September 30, 2011

Project Summary

The University of Arizona, Yuma County Cooperative Extension, in collaboration with the Arizona Department of Agriculture, Agricultural Consultation and Training (ACT) Program, developed and implemented a USDA, GHP/GAP Training Program for Arizona specialty crop producers from October 2010 through September 2011. The focus of the training program provides workshop participants a means to initiate the USDA, GHP/GAP certification process and adhere to the recommendations made in the Food and Drug Administration's Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables.

This initial, 1-year outreach curriculum was to be piloted specifically within the Yuma, Arizona area with the overall intent of expanding the program into other Arizona growing regions during subsequent years as the program developed and matured. As most Yuma area produce growers already use production guidelines outlined within the Arizona Leafy Greens Marketing Agreement, it was determined that Yuma-based GHP/GAP training would be made available as a one-on-one, in office, format instead of a group workshop setting.

As a result, the program grew from a piloted commercial producer Yuma-based focus into a program that covered many Producers/Growers, Distributors, Wholesalers, and Handlers throughout Arizona.

Project Approach

As a means to mitigate food safety risks by implementing an Arizona GHP/GAP training program, the project addressed the following objectives:

- Objective 1: Design, develop and implement a GHP/GAP training curriculum for commercial growers, shippers, coolers, distributers and warehouses within the piloted Yuma region, later expanding the program to include other regions within Arizona. The development of the curriculum was based on the USDA GHP/GAP audit itself, and was segmented into 7 key food safety aspects that covered crop growing, harvesting, processing, storage, traceability, warehousing and security. On April 4, 2011, Dr. Nolte and Ms. Edwards met with Department staff and specialty crop stakeholders to gather input on the training materials. Workshop participants were provided with a collection of user-friendly worksheets, records, documents and policies which enabled users to fully implement a GHP/GAP food safety plan and begin the process of record keeping and certification.
- Objective 2: Offer and provide a certification fee, cost share reimbursement program for fresh fruit and vegetable producers that become USDA GHP/GAP certified. Through collaboration with the Arizona Department of Agriculture, Agricultural Consultation and Training (ACT) Program, workshop participants were provided a collection of documentation enabling those certified in GHP/GAP to apply for the cost-share recovery program. Up to 75% of the costs (not exceeding $750) are reimbursed to eligible GHP/GAP certified completers for cost incurred during the third party audit process.

Goals and Outcomes Achieved

A total of 79 people participated in the training program, the bulk of which occurred outside the Yuma area during the summer of 2011. Regions within Arizona which specifically requested and received GHP/GAP training included, Tucson (17 participants), Prescott (21 participants), Flagstaff (14 participants), Nogales (12 participants), Phoenix (13 participants) and Yuma (2 participants).

The overall goal of the project was to increase the number of specialty crop farmers certified/approved by ADA as being in compliance with GHP/GAP. While specifically targeting the Yuma area, at project initiation, the number of GHP/GAP certified was zero. As a result of the program, two Yuma-based producers have successfully passed GHP/GAP audits and are currently USDA certified.

The GHP/GAP training program spread to include five areas within the state and 77 growers outside Yuma participated in the curriculum. As a result of this statewide effort, 16 Arizona producers have completed GHP/GAP audits and are currently in USDA compliance. Essentially, this is double the number (7) of USDA GHP/GAP certified in Arizona since September 2010.

Beneficiaries

The GHP/GAP training program rapidly grew into a statewide curricula designed for large and small specialty crop producers. The number and nature of GHP/GAP participants in workshops across the state suggests that the program has a greater reach in Arizona than originally assumed. While specialty crop growers, processors and distributors continue to be a central focus, the numbers of smaller growers seeking a means of satisfying the Arizona Approved Source requirements are interested in becoming GHP/GAP certified. This is in addition to Arizona school garden programs, some farmers markets and county health departments that are interested in coordinating and implementing a food safety standard within their regions or counties.

Lessons Learned

Overall, the GHP/GAP training program was integrated into the state at a much faster pace than originally expected. As such, the supply and travel budgets exceeded what was originally proposed. Greater communication among state leaders within the area of GHP/GAP would have been helpful prior to proposal submission. Also, the number of small growers participating in the program was not anticipated. And, as a consequence of this, considerable debate and dialog ensued among these groups during training workshops concerning added governmental oversight of specialty crop production and distribution to small producers which detracted from the overall purpose of the program.

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Additional Information

The GHP/GAP training curricula is currently being developed into an online, web-based adaptation. This version, when complete, will allow those interested in GHP/GAP certification the ability for immediate knowledge and without the delay and travel constraints.

Continuation of an Arizona GHP/GAP Certification Training and Promotion Program

This project was completed on September 30, 2013

Project Summary

The University of Arizona, Yuma County Cooperative Extension, in collaboration with the Arizona Department of Agriculture, Agricultural Consultation and Training (ACT) Program, continued the development and implementation of the USDA, GHP/GAP Training Program for Arizona specialty crop producers from October 2012 through September 2013. The focus of the training program provides workshop participants a means to initiate the USDA, GHP/GAP certification process and adhere to the recommendations made in the Food and Drug Administration's Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables.

The outreach curriculum, initially established in 2011, has grown from a piloted commercial producer, Yuma-based focus into a program that covers many Producers/Growers, Distributors, Wholesalers, and Handlers throughout Arizona. Since its inception, roughly 326 participants have taken advantage of the program.

Project Approach

As a means to mitigate food safety risks by implementing an Arizona GHP/GAP training program, the project addressed the following objectives:

- Objective 1: Continue to design, develop and implement the GHP/GAP training curriculum for commercial growers, shippers, coolers, distributers and warehouses within Arizona. The development of the curriculum was based on the USDA GHP/GAP audit itself, and was segmented into 7 key food safety aspects that covered crop growing, harvesting, processing, storage, traceability, warehousing and security. A series of 5, Arizona GHP/GAP training workshops were conducted during the funding period (October, 2012 – September, 2013). Workshop participants are provided with a collection of user-friendly templates which include records, documents and policies which enable users to fully implement a GHP/GAP food safety plan and begin the process of record keeping and certification. The Arizona Department of Agriculture, Agriculture Consultation and Training (ACT) is a key collaborative component of the program, providing a program liaison (Mr. Stewart Jacobson) who initiates follow-up, guidance and consultation for participants after the training as they begin the process of gaining USDA certification.
- Objective 2: A comprehensive survey (see **Appendix C**) of all certified and noncertified workshop participants was assessed to determine the impact of GHP/GAP training within their operation. This evaluation component was determined to be a valuable tool for enhancing future GHP/GAP workshops, and delivered insight into the utility of the GHP/GAP certification process in Arizona.

Goals and Outcomes Achieved

Workshop Participation and USDA Certified GHP/GAP Producers

A total of 80 people participated in the 2012-2013 training program, the bulk of which were identified as small Arizona specialty crop producers. Regions within Arizona which specifically requested and received GHP/GAP training included, Maricopa (28 participants, 2 workshops), Cottonwood (21 participants), Flagstaff (12 participants), and Snowflake (19 participants).

The overall goal of the project is to increase the number of specialty crop growers certified/approved by the USDA as being in compliance with the GHP/GAP guidelines. As a result of the program, two producers have successfully passed GHP/GAP audits during the funding period and are currently USDA certified.

Publications

Nolte, K.D., S. Ravishankar and S. Jacobson. 2013. Good Agricultural and Good Handling Practices: Compliance by Everyone? Abstract published in the proceedings at the 2013 American Society for Horticultural Science Annual Meeting, Palm Desert, CA. URL: http://ashs.org/abstracts/2013/abstracts13/abstract_id_15948.html

Nolte, K.D. 2013. The Track and Scat Fresh Produce Safety Handbook for Southwest, Arizona. Abstract published in the proceedings at the 2013 American Society for Horticultural Science Annual Meeting, Palm Desert, CA. URL: http://ashs.org/abstracts/2013/abstracts13/abstract_id_15926.html

Beneficiaries

The GHP/GAP training program rapidly grew into a statewide curricula designed for large and small specialty crop producers. The number and nature of GHP/GAP participants in workshops across the state suggests that the program has had a greater reach in Arizona than originally assumed. While specialty crop growers, processors and distributors continue to be a central focus, the numbers of smaller growers seeking a means of satisfying the Arizona Approved Source requirements have shown interest in becoming GHP/GAP certified. This is in addition to Arizona school garden programs, some farmers markets as they too are interested in coordinating and implementing food safety standards within their regions or counties.

Lessons Learned

Assessing the GHP/GAP Training and Certification Program

Since the GHP/GAP training program was initiated, we understand that the number of specialty crop producers completing certification has not reached our anticipated expectations. As a result, a program assessment was conducted during June/July, 2013, that involved all GHP/GAP workshop participants to date. Assessment findings suggest:

1. GHP/GAP programming indicates that Arizona growers participating in workshops are gaining a greater understanding of good growing and handling practices.
2. Activities that some small Arizona growers are most commonly pursuing are participating in GHP/GAP training, writing some form of a food safety plan, and making convenient on-farm food safety modifications.
3. Knowledge in GHP/GAP is not necessarily leading to behavior change in the form of USDA GHP/GAP certification. Change is primarily occurring among growers when they are required by those buying their produce to provide evidence of on-farm food safety practices.
4. Growers are not specifically developing a culture of food safety by keeping records that food safety plans are being acted upon, documenting potential food safety risks or requesting on-farm site visits. Given that only a marginal number of growers are applying for certification, evidence indicates that only a select number of buyers are currently mandating third party compliance from small producers.
5. Growers reported that the primary reason they did not carry out any of these GAP behaviors is that they are not required to do so, indicating that the external expectations of produce buyers is currently the primary driver in generating grower behaviors. Time, money, and the technical complexity of requirements are also viewed as barriers to implementation.

In this light, we anticipate continued, and greater involvement from the Arizona Department of Health Services and County Health Departments in Arizona who are key in supporting approved food sourcing in Arizona for large and small buyers of specialty crops. We feel that extended outreach from their perspective, and others, will enhance the culture and awareness of Arizona food safety and increase those that either seek certification or actual certification completers.

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Additional Information

The GHP/GAP training curricula has also been developed into an online, web-based bilingual adaptation (http://cals.arizona.edu/fps/GHP-Online). This version of training allows those interested in GHP/GAP certification the ability for immediate knowledge and without delay or travel constraints.

Implementing an Arizona GHP/GAP Certification Cost-Share Program

This project was completed on March 31, 2013

Project Summary

There was an increased demand by buyers and consumers of specialty crop products for independent verification and certification that producers and other fresh produce handlers were following Good Handling Practices (GHP) and Good Agricultural Practices (GAP) to improve food safety. The University of Arizona, Yuma County Cooperative Extension and the Arizona Department of Agriculture, Agricultural Consultation and Training (ACT) Program collaborated to implement a USDA GHP/GAP cost-share program to assist Arizona specialty crop producers/growers, distributors, wholesalers and handlers with the costs of GHP/GAP certification over a three year period.

Project Approach

In April of 2011, the program was announced on the Department's website at: http://www.azda.gov/act/ghpgap.aspx. The web page includes links to the reimbursement application (**Appendix D**), information about the GHP/GAP training program and the GHP/GAP audit as well as frequently asked questions. In October of 2011 and 2012, the website information and the application were updated to include the next fiscal year as funds remained available.

A total of 28 applications were received from April 2011 thru March 2013. Fourteen of the twenty-eight applicants had participated in the GHP/GAP training provided by the UofA and the Specialty Crop Block Grant Program.

The cost-share program was promoted during the GHP/GAP trainings. Additionally, in October 2012, cost-share program information was sent to all audit participants listed on the USDA audit program website.

Due to the low number of applications and lower average reimbursement amounts, the budget for this project was reduced from $35,000 to $9,993 for the 3-year period.

Goals and Outcomes Achieved

The goal of this project was to increase the number of GHP/GAP Audit participants who would subsequently participate in the cost-share program to reduce their audit costs.

Year one fell just short of the goal of 10 participants with a total of 9 participants, year two yielded 12 of the anticipated 15 participants and year three had just 7 participants compared to the goal of 20.

Overall, there were 28 participants in the 3-year period where we anticipated a total of 45. Based on a program assessment conducted by the GHP/GAP Training Program Coordinators, "growers reported that the primary reason they did not carry out any of these GAP behaviors is that they are not required to do so, indicating that the external expectations of produce buyers is currently the primary driver in generating grower behaviors. Time, money, and the technical complexity of requirements are also viewed as barriers to implementation."

The cost-share program did not appear to be incentive enough for growers to complete a GHP/GAP Audit.

Beneficiaries

Specialty crop producers, distributors, wholesalers and handlers benefited, by reduced audit costs, and maintaining or increasing their market share. The economic benefit to fresh fruit and vegetable producers was reduced costs for implementing a GHP/GAP program and maintaining profitability by meeting (what was understood to be) buyer demands for GHP/GAP implementation.

GHP/GAP Cost-Share applicants were reimbursed an average of $359.56 per audit.

Lessons Learned

There were some initial delays with the first few applications received due to a new mandatory statewide procurement system which affected the way payments were processed. Participation in the program was not as great as originally anticipated due to the voluntary nature of the GHP/GAP audit program itself. The average reimbursement amount was much less than anticipated which led to the budget adjustment (reduction) in funding for this project.

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Agricultural Literacy – School Garden Food Safety

This project was completed on September 30, 2013

Project Summary

The Agricultural Literacy School Garden Food Safety Program provides school district personnel and Garden Managers with research-based strategies to implement a garden food safety program as well as introduce agricultural concepts into their current curriculum. The garden food safety component is a priority since many schools are utilizing the fruits and vegetables grown in school gardens for consumption in the classroom and want to provide this produce to the school cafeteria. The program content allows Kindergarten through Twelfth grade classroom teachers to increase their knowledge about Arizona's Specialty Crop industry while meeting Arizona's College and Career Ready Academic Standards in Mathematics, Language Arts, and Science which includes nutrition. The subjects of Science, Mathematics, and Language Arts were chosen because these are the subjects currently included in Arizona's Instrument to Measure Standards test that students are required to pass.

The need to develop a school garden program including a food safety component is extremely important. Many schools already have gardens and other schools are implementing gardens. The University of Arizona College of Agriculture and Life Sciences Cooperative Extension has employees in several counties who are working with schools and school districts to provide the necessary knowledge to grow gardens successfully utilizing research-based information. The need to provide the information for students and teachers to use garden food safety practices is extremely important from a cafeteria food code perspective.

The School Garden Food Safety Program is important and timely because there is a demand by teachers to implement gardens as a vehicle to enhance lessons in their classrooms. Utilizing gardens allows the teachers to implement learning strategies that are relevant to their students but are aligned to the academic standards and enhance the curriculum the teachers are required to use. There is also an increase in schools to educate students on healthy fruits and vegetables. Students growing their own fruits and vegetables in school gardens are more likely to want to consume the produce. This increase in awareness of what can be grown can potentially increase the consumption of Arizona grown fruits and vegetables. Implementing the garden food safety component will ensure that the harvested produce is safe for human consumption and meets the health standards for use in the school cafeteria or the classroom.

Project Approach

When the grant was written there were no food safety guidelines for schools and school grown produce was not allowed to be prepared or served in the school cafeteria. Upon implementation of the grant it was determined that the AZ Department of Health Services (ADHS) would need to be an important partner in the grant. The ADHS Director recognized the value of implementing a food safety approval process for schools to utilize the produce in the cafeteria. The Director approved funding for a full-time Sanitarian position within the Department. This position was filled in January 2013.

Simultaneously with the above mentioned discussions with ADHS, the PI began research on Food Safety Guidelines for school gardens. The technical expert indicated attendance at the next small farms GHP/GAP training would be beneficial to the PI's understanding of food safety

practices prior to writing school guidelines. Multiple meetings were held with ADHS employees, directors of all the county health departments and pertinent health inspectors.

Internet research helped in the preparation of guidelines that mirrored what other states were doing. The guidelines went through numerous drafts between the technical expert, ADHS, AZ Department of Education (ADE), and AZ Department of Agriculture (ADA). School community members were excited to hear about the development of the guidelines and provided input throughout the writing. The guidelines were then submitted to the University of Arizona, College of Agriculture and Life Sciences for national peer review. After minimal changes were made based on peer comments the guidelines are now an official publication of the University.

An interest survey was developed and sent to school contacts with the express request to share the survey with additional school personnel. Consequently the response rate was very high and additional names were added to the listserv for training announcements. Names are added on a weekly basis since the interest is so high.

It was originally thought that multiple trainings across the state would need to be held to train the goal of 100 teachers. This goal was exceeded in only three trainings in two locations. A training manual was created with accompanying report forms. It is anticipated these items will be available on the college website within the next few months.

Monica Kilcullen Pastor, Associate Programmatic Agent, UA College of Agriculture and Life Sciences Cooperative Extension (UA CALS CE): Served as PI on the grant facilitating the writing, editing and publishing of the peer-reviewed School Garden Food Safety Guidelines, implementation of a listserv with approximately 800 educators receiving updated information about trainings and changes to the guidelines, coordinating the workshops and evaluations, sharing the implementation of the program at three National Meetings, plus coordinating the interactions with the partners.

Brandon Moak, Program Coordinator, Sr., UA CALS CE: Served as Program Manager to coordinate day-to-day logistical functions of the program, schedule trainings, and organizing workshop materials; as technology expert to facilitate streamlined communications with educators, develop and implement effective electronic evaluations, and coordination of training documents including presentations as well as report forms.

Kurt Nolte, Area Agent and Director, UA CALS CE, Yuma County: Served as technical expert and lead trainer for the three workshops.

Ashley Schimke, Farm to School & School Garden Program Specialist, AZ Department of Education (ADE): Initiated the discussion to implement food safety for schools with gardens, co-authored the peer- reviewed guidelines, facilitated communications with educators through ADE contact lists, and facilitates the AZ School Garden Network meetings.

Diane Eckles, formally Chief, Office of Environmental Health, AZ Department of Health Services (ADHS): Initiated the discussion with the Director of ADHS to authorize funding for a School Garden Sanitarian within the department and co-authored the peer- reviewed guidelines.

Kathryn Mathewson, School Garden Sanitarian, ADHS: Coordinates department input on the guidelines, developed website for educators to access department forms, trainer on the ADHS requirements for garden certification, certifies qualifying gardens, and continually updates ADHS guidelines to reflect current research.

Stewart Jacobson, Food Safety Projects Coordinator, AZ Department of Agriculture: Served in an advisory capacity during the development of the guidelines, facilitated discussions with other states implementing similar programs, and attended workshops as a department liaison.

Goals and Outcomes Achieved

Due to the perceived interest Arizona schools have in developing or properly cultivating school gardens, it was postulated that schools and school districts would benefit from access to workshops that would implement food safety practices in their school gardens. This project began with the development of a survey to assess the level of interest schools have in gardening, the garden's use as an educational tool, and the ability to safely grow the garden's produce for consumption in the school cafeteria. This survey was distributed to our listserv and yielded 248 responses. Of those, 138 (55.6%) reported that they already have a school garden. Of those who already have a school garden, 127 (92.0%) reported that they do not use their garden's produce in their cafeteria, and 113 (81.9%) report a desire for training to be able to serve that produce in their school's cafeteria. Of those who do not have a school garden (i.e. the remaining 110 or 44.4% of survey responders), 99 (90.0%) report a desire for training to implement a school garden. These findings support our initial hypothesis.

Three workshops were conducted, one in Flagstaff and two within the greater Phoenix area, for a total of 120 (the goal was to reach 100) educators and Health Department Employees. Each participant was able to receive a copy of the School Garden Food Safety guidelines; a copy of the Arizona Specialty Crop Lessons which contains 30 lessons with well-defined objectives to enhance instructional strategies and content knowledge concerning science, mathematics, writing and reading, and healthy lifestyles; and information on gardening basics for their particular climate, elevation, and soil.

Outcome measures are long term and documentation of the achievements will be reflected in the second year of the funding. Documentation will be provided that shows the guidelines have been utilized, that students gain an understanding of food safety practices in their school garden, a verification of classroom hours spent on the food safety and Specialty Crop lessons instruction as well as measurements indicating increased consumption of Arizona grown produce. Currently, the most significant progress that has been made towards achievement includes the implementation of the guidelines with approval from the ADHS as well as the employment by ADHS of a School Garden Sanitarian. School s must work with ADHS to receive the certification. Two schools have received certification. They are the Pima County Juvenile Detention facility and Greenlee High School.

Comparison of actual accomplishments with the goals established for the reporting period:

- Benchmark: no GHP/GAP curriculum for school gardens
  - Goal: develop GHP/GAP curriculum for school gardens and provide instructional workshops (accomplished)
  - Target: a minimum of 100 teachers will participate in workshops (accomplished; 120

participated)
  - Performance Measure: participants will document that the guidelines were used (ongoing in the second year of funding since schools will be implementing these during this school year)
- Benchmark: teachers will document student knowledge about and consumption of specialty crops
  - Goal: teachers will utilize Specialty Crop lessons (ongoing)
  - Target: at least three lessons will be utilized and 70% of students will increase their knowledge (ongoing)
  - Performance Measure: teach at least one nutrition lesson and document student consumption of specialty crop foods (ongoing)

The baseline data was collected in the survey. Eighty-two percent of the schools that have gardens wanted to participate in food safety training. Ninety-nine percent of schools without a garden wanted to participate in food safety training.

Beneficiaries

The groups that benefited from the completion of the project include schools with gardens, schools that want to implement gardens, county and Arizona departments of health, county health department employees, and specialty crop growers since student awareness has been raised about the types of crops grown in Arizona. School cafeteria's also benefited because they can utilize school garden grown produce in their cafeteria once the garden is certified.

School Garden Food Safety Guidelines were implemented and approved through a peer review process for publication. University of Arizona College of Agriculture and Life Sciences Cooperative Extension publication AZ1604 is attached to the report.

Three workshops were conducted, one in Flagstaff and two in Maricopa County. Survey responses are as follow

Flagstaff Evaluations:

- Conducted on-line evaluation of the training. Participants were free to participate in any or all of the three sections of training. All evaluation questions used a Likert scale with 1 = Strongly Disagree and 5 = Strongly Agree. Each class was evaluated separately (asking if the training objectives were met, if the activities were educational, if the training was helpful, and if the training met their expectations), each presenter was evaluated separately (rating preparedness and personableness), and the entire workshop was evaluated overall (rating the organization of the workshop, the appropriateness of the facility, and likelihood of referring others to the workshop). Below are the results of the evaluation with an indicated response rate.

<u>Food Safety Guidelines (34.9% response rate – 15 respondents out of 43 attendees)</u>

Overall	Objectives	Activities	Helpful	Expectations	Prepared (Nolte)	Personable (Nolte)	Prepared (Mathewson)	Personable (Mathewson)
3.47	4.14	3.79	4.00	3.64	4.79	4.71	3.50	3.57

Classroom Incorporation (23.3% response rate – 7 respondents out of 30 attendees)

Overall	Objectives	Activities	Helpful	Expectations	Prepared (Pastor)	Personable (Pastor)
4.67	4.67	5.00	5.00	5.00	5.00	5.00

Gardening 101 (23.3% response rate – 7 respondents out of 30 attendees)

Overall	Objectives	Activities	Helpful	Expectations	Prepared (Madden)	Personable (Madden)
3.71	4.14	4.00	4.00	4.14	4.29	4.57

Entire Workshop (38.6% response rate – 17 respondents out of 44 attendees)

Organization	Facilities & Amenities	Referral
4.47	4.33	3.93

Maricopa County evaluations:

- Conducted on-line evaluation of the trainings. Participants were free to participate in any or all of the three sections of training. All evaluation questions used a Likert scale with 1 = Strongly Disagree and 5 = Strongly Agree. Each class was evaluated separately (asking if the training objectives were met, if the activities were educational, if the training was helpful, and if the training met their expectations), each presenter was evaluated separately (rating preparedness and personableness), and the entire workshop was evaluated overall (rating the organization of the workshop, the appropriateness of the facility, and likelihood of referring others to the workshop). Below are the results of the evaluation with an indicated response rate.

Food Safety Guidelines

Training Date	Response Rate	Overall	Objectives	Activities	Helpful	Expectations	Prepared (Nolte)	Personable (Nolte)	Prepared (Mathewson)	Personable (Mathewson)
7/31	49.1%	3.86	4.25	4.04	4.00	4.04	4.43	4.29	4.21	4.21
8/1	27.8%	4.80	5.00	4.20	5.00	5.00	5.00	5.00	4.40	4.80

Classroom Incorporation

Training Date	Response Rate	Overall	Objectives	Activities	Helpful	Expectations	Prepared (Pastor)	Personable (Pastor)
7/31	49.1%	4.41	4.59	4.56	4.59	4.59	4.85	4.81
8/1	27.8%	4.00	4.60	4.40	4.60	4.40	4.80	4.80

Gardening 101

Training Date	Response Rate	Overall	Objectives	Activities	Helpful	Expectations	Prepared (M.G)	Personable (M.G)
7/31	49.1%	4.11	4.30	4.33	4.22	4.15	4.52	4.44
8/1	16.8%	3.67	4.67	4.33	4.33	4.33	4.67	4.67

Entire Workshop (38.6% response rate – 17 respondents out of 44 attendees)

Training Date	Response Rate	Organization	Facilities & Amenities	Referral
7/31	61.4%	4.44	4.59	4.38
8/1	33.3%	4.83	4.67	4.67

Lessons Learned

The most important lesson learned was the desire by schools to implement food safety practices in their school garden. Whenever a presentation, email, or phone call was conducted the overwhelming response was "thank you for taking leadership" on this implementation. It was also anticipated that multiple workshops would need to be conducted to reach the attendance goal of 100 participants. Only three were held and there were 120 participants.

One negative is the estimation of time to implement a new program that, by necessity, needed to have input from many stakeholders. As a university program, certain science-based guidelines needed to be included, but ADHS, which is certifying the gardens, also needed to establish protocols in which the agency was willing to take leadership and certification approval. The Guidelines underwent many drafts prior to approval by university peer review. ADHS, ADE and ADA all provided valuable input into the development of the guidelines.

An unexpected outcome of implementing this project is the acknowledgement of programs outside Arizona of the importance of the guidelines. Proposals for presenting the project were submitted for four National Conferences and all four proposals were accepted after a peer-review process. After completion of the presentation many participants indicated they intended to try implementation of the guidelines in their state.

The implementation of the guidelines necessitated conducting training late in the school year so performance measures cannot be gathered until the end of this school year. It was anticipated that trainings could be conducted in early spring 2013 but the first training was not held until April 2013.

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Additional Information

Documentation is not yet available to show how the project increased consumption of Arizona specialty crops. But, school-garden based programs show promise as a method of hands-on

learning that promotes and increases fruit and vegetable consumption among school-aged children. Morris and Zidenberg-Cherr (2002) evaluated the effectiveness of a nutrition education program, based on Social Cognitive Theory, on improving children's vegetable preferences. Fourth grade students ages 9 to 10 (n=205) were split into three groups; nutrition education only (NL), nutrition education plus gardening (NG), and a control group (CO). The students completed pre- and post-nutrition knowledge questionnaires and vegetable preference surveys and took part in 17 bi-weekly nutrition education sessions (NL) and school gardening projects (NG) that complemented the nutrition lesson plans. Nutrition knowledge scores for students in the NL and NG groups were significantly higher than those in the control group. Vegetable preference scores for the NL and NG groups were greater than the CO group. Results indicated that exposure to nutrition education lessons improved nutrition knowledge and exposure to new vegetables improved student's preferences for several vegetables. Results were also verified at six-month follow-up; both the NK and NG groups remained significant for carrots, and the NG group was still significant for broccoli, snow peas and zucchini.

Attached is a copy of the postcard (**Appendix E**), training agenda (**Appendix F**), and training manual (**Appendix G**) that were created as well as the School Garden Food Safety Guidelines publication AZ1604 (**Appendix H**).

Arizona Landscape Marketing Program Part II

This project was completed on June 30, 2013

Project Summary

The Arizona Nursery Association (ANA) applied for a continuation of the "Arizona Grown Plant & Tree Marketing Program" grant funded in 2009. This grant continued the promotion and encouragement of the production, sale and use of Arizona grown regionally adapted landscape plants and trees with the "Plant Something" marketing program. Educating both producers and consumers of the environmental and aesthetic value of landscape plants is at the core of ANA's service to its members and the public. ANA used this grant to create additional marketing venues for the campaign. These venues included retail point of purchase materials and web and social media. This grant had a significant impact on the long term success of the Arizona nursery industry. The Arizona Nursery industry had a need for marketing to the consumers of landscape & nursery plants and this grant fulfilled that need by providing funds for these activities. These promotions in turn, increased awareness of the economic, health and monetary benefits of planting which, in turn, has a goal of increasing the competitiveness of nursery stock.

Project Approach

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

Promotion to the public –Communication components included:

- Retail advertising kits and Onsite/Point-of-Purchase Collateral – ANA continued to provide advertising products to our retail members including sample advertisements, small plant stakes, clings and large plant stakes. Hats were also printed for distribution at the annual SHADE educational conference.
- Website – Created an interactive "Plant Something" website allowing individuals to learn about the environmental benefits of planting with the ability to locate retailers in their area from which to purchase plants. This website was enhanced with the grant to account for

growing this promotion nationally and as a result Idaho, Massachusetts and Minnesota were added to the website.

- Paid Advertising - 30 and 60 second radio advertisements were aired as well as print advertisements and promotion at public events throughout the state like Home & Garden Shows and Earth Days. ANA also worked local and national shows to expand the program to the national nursery industry.

Development of On-line Media Tool and site – The Plant Something website was finished and enhanced with this grant (www.plant-something.org) and our first 3 partner states were added to the drop-down menu. A fully functional Arizona Plant Something page with a zip code retail nursery locator was also added. The Plant Something Facebook page was also developed and launched in October 2012 with these grant funds. ANA also worked with an attorney in order to apply for a national trademark for Plant Something.

All components work toward the central goal of increasing the competitiveness and long term sustainability of the Arizona nursery industry.

Goals and Outcomes Achieved

The central goal of this grant and the Plant Something campaign is to increase the competitiveness and long term sustainability of the Arizona nursery industry through promoting its products to consumers and community members.

ANA targeted three measurable outcomes for this grant project:

1) **Arizona grown low water use plant sales will increase during the promotional period.**
   ANA emailed surveys to retail nurseries to report plants sales during same month cycles in 2010 compared to 2011 to measure the effectiveness of the promotion. In the same survey, ANA proactively gathered results for 2011 compared to 2012.

   Reported results were as follows:
   Comparing ANA member retail nursery sales in 2010 to 2011, an average increase of 17.5% was reported.
   Comparing ANA member retail nursery sales in 2011 to 2012, an average increase of 14% was reported.

   This increase was certainly due somewhat to the Plant Something campaign, it should be noted a recovering economy and a winter freeze contributed to these sales figures.

2) **Tracking Hits and Number of Stakes on Website –** ANA tracked the number of visitors to the www.plant-something.org website using Google Analytics. The stakes were not tracked as this portion of the grant was not completed due to a decision it would not be a cost effective addition to the website.

   Statistics are:

May 2010 - June 2011	531 visitors	80% returning and 10% new
June 2011 – May 2012	4282 visitors	36% new and 64% returning

3) **Tracking the Number of Fans and Plant Profilers on Facebook –** ANA created a Facebook page for Plant Something and tracked the number of LIKES for our page. We also said we would track the number of people who visit the "plant profilers" section however this was not developed as it was not needed. Statistics are from start date, six months and we have not met one year yet, so as of June 30, 2013.

October 2012	(start month)	72 LIKES
March 2013	(6 months)	170 LIKES
June 2013	(9 months)	244 LIKES

Beneficiaries

The project benefited the entire Arizona nursery crop industry. This industry, according to the 2007 survey, has total sales of $644 million. The Arizona Nursery Association has a membership of just over 200 members and an estimated 60 Arizona growers and another 100 retail outlets. This project benefited all of them as well as the non-members growers and retail nurseries in the state of Arizona. Educating consumers of the environmental benefits to planting landscapes has resulted again in an increase in sales on the retail level which will in turn, increase Arizona grower sales. Because the grant met a need of each level of the Arizona industry as well as now other states and the general public, an actual number cannot be quantified. However, any increase in the education of consumers to the benefit of plants and trees will ultimately benefit the Arizona industry be increasing sales and competiveness of their products.

Lessons Learned

We learned that adding plant stakes to track where plants were planted was way too much of a daunting task and would probably have not be utilized by the general public. We also learned that a plant profiler was not able to be added to our Facebook page. Both of these seemed to be great ideas by the agency in the beginning however proved to not be achievable.

We also learned that decision by committee is still a lengthy process and reviewing and making changes in electronic media is more costly and time consuming that we originally anticipated.

We also learned that our campaign, Plant Something, is gaining momentum and is more popular than we ever could have imagined.

Contact Person

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Additional Information

We believe the Plant Something promotional campaign has increased awareness of the competitiveness and consumption of ornamental plants in Arizona and is now spreading to other states.

An Award of Merit was received from the Valley Forward Association in Arizona recognizing this promotion as a vital environmental enhancement to our state.

Copies of any and all promotional materials and radio advertisements are available upon request. Website is www.plant-something.org and Facebook page is under Plant Something.

Arizona Specialty Crop Trade-show Display

This project was completed on September 30, 2013

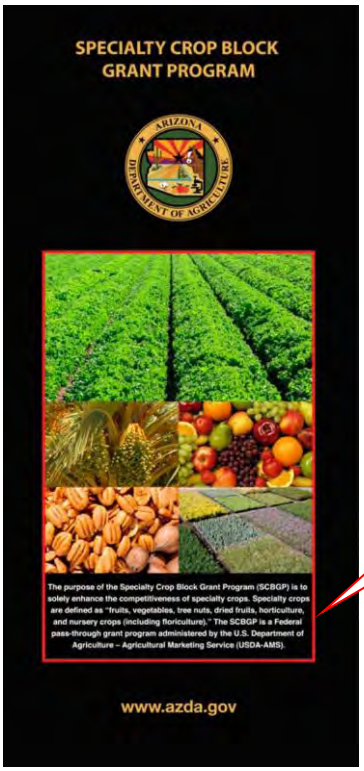
Project Summary

The Agricultural Consultation and Training (ACT) staff has the opportunity to attend multiple trade-show events and fairs each year to distribute information about the Arizona Specialty Crop Block Grant Program (SCBGP), talk with potential sub-grantees and promote consumer awareness about the benefits of locally grown specialty crops. A trade-show display specific to the SCBGP was needed to draw attention to the program and the opportunity for funding that would enhance the competitiveness of Arizona specialty crops.

ACT purchased a professionally designed display that could be used to draw attention at these events. The display was available for use by other specialty crop industry organizations, such as The Arizona Nursery Association, The Yuma Fresh Vegetable Association, the Arizona Farm Bureau and Western Growers.

Project Approach

In February of 2012, Skyline Display and Design was contacted to create the trade-show display, which is a retractable banner stand style. Skyline is the same company that designed and created the displays for the additional programs administered by ACT. Therefore, the base design was already in place for the display to coordinate with the other programs that are frequently displayed at the same events.



The purpose of the Specialty Crop Block Grant Program (SCBGP) is to solely enhance the competitiveness of specialty crops. Specialty crops are defined as "fruits, vegetables, tree nuts, dried fruits, horticulture, and nursery crops (including floriculture)." The SCBGP is a Federal pass-through grant program administered by the U.S. Department of Agriculture – Agricultural Marketing Service (USDA-AMS).

The banner stand was delivered in March of 2012 just in time to be displayed at the 2012 Southwest Ag Summit in Yuma, AZ. The following is a list of events that the display was utilized during the project period and approximate number of attendees:

Dates	Event	Approx. # of Attendees	
March 7-8, 2012	2012 SW Ag Summit	670	
August 30, 2012	Maricopa County Farm Bureau Annual Meeting	110	
November 8, 2012	AZ Farm Bureau Annual Meeting	225	
March 6-7, 2013	2013 SW Ag Summit	1,000	Plus
September 5, 2013	Maricopa County Farm Bureau Annual Meeting	100	Plus
Total		**2,105**	**Plus**

Regardless of the type of event, the display has only been used by ADA-ACT staff to promote the SCBGP and the opportunity for funding to enhance the competitiveness of Arizona specialty crops. No other specialty crop organizations have requested to use the display thus far.

Goals and Outcomes Achieved

The GOAL of this project was to purchase a professionally designed trade-show display and utilize the display at 4 to 6 events per year. A log was kept to track the usage of the display by the ACT staff and other specialty crop organizations.

The number of events held per year was lower than originally anticipated. There were only 5 events total for the 3-year period compared to the goal of 4 to 6 events per year, or a total of at least 12 events. Due to the delay in creating and receiving the display, it was not utilized in the first year.

The number of events per year may be lower, but the display will continue to be used for several years in the future. At a cost of less than $1,400, the display will continue to be a good investment for the program.

Beneficiaries

Potential beneficiaries of this project included more than 2,105 attendees at the various events. The number of attendees who actually benefited from seeing the display and learning about the SCBGP is unknown. The ADA-ACT staff also benefited by having an easy tool to draw attention to the program. The benefit of this project will continue over several years as the display is utilized at future events. Although the original intent was to make the display available to other specialty crop organizations, it is not likely that they will request to use the display.

Lessons Learned

This project was delayed due to the potential “re-branding” of the Agricultural Consultation and Training (ACT) Division’s graphic displays, which would have incorporated the display for specialty crops and the SCBGP. Due to budgetary concerns the “re-branding” of ACT’s graphic

displays did not take place. Due to this delay, the display was not available to use until the second year of the 3-year period. This proved to be a lesson in timing and meeting the overall goals and objectives of the project.

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Enhancing Vegetable IPM in Arizona

This project was completed on September 30, 2013

Project Summary

Arizona growers are one of the leading producers of fresh-market vegetables in the U.S., producing vegetables and melons on 134,000 acres at an estimated value of over $900 million annually. However, vegetable cropping systems in Arizona are pest-intensive and growers annually spend millions of dollars battling a multitude of insect pests, weeds and plant diseases. Furthermore, new pest problems periodically challenge the industry causing unwanted economic losses. Because of the high crop of these values and consumer demands for aesthetically appealing and pesticide-free produce, Arizona vegetable growers are forced to use IPM tactics that are both effective and safe. UA Extension Specialists and Research Scientists have been working with local growers for years in developing useful information that assist them in their pest management activities and their endeavors to satisfy consumer and regulatory demands.

Continual maintenance of existing IPM programs and implementation of new IPM strategies is essential for sustaining economically and environmentally sound production of vegetable crops in Arizona. Cost-effective adoption of new reduced-risk control technologies by growers and PCAs will require a significant knowledge base of pest biology, ecology, impact and management. Because "All IPM is local", the knowledge base necessary for training young PCAs and implementing new IPM approaches must be developed specifically for desert growing conditions in Arizona. Presently, information on vegetable IPM in Arizona has resulted almost exclusively through the efforts of several University of Arizona Cooperative Extension specialists and agents who have developed objective, research-based IPM information on insects, weeds and plant diseases. Although individual research programs are adequately supported from local and national grant funding, resources to sufficiently support IPM educational programs for desert vegetable crops are becoming increasingly scarce. The objectives of this project were to synergize and enhance an unbiased, science-based multidisciplinary IPM outreach program that emphasizes the development, validation, and delivery of timely and relevant information and technologies to growers and PCAs for managing pests in Arizona vegetable and melon crops that 1) reduces reliance on broadly-toxic pesticides without sacrificing yield, quality and profitability, and 2) concurrently minimizes dietary and environmental risks.

Project Approach

The objectives of this three year were achieved by strategically investing in an extension educator to assist team members in delivering and demonstrating IPM in local high value,

vegetable production systems. A similar project was funded in 2009 for 1 year by the SCBGP to provide support for an extension educator. The extension educator, Mr. Marco Pena, was hired in late November 2009 where he initiated and continues to participate in a number of project activities in association with the 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 Vegetable IPM Team has been engaged was in the implementation and maintenance of an innovative outreach system for delivering timely and relevant information to our varied stakeholders and beneficiaries through our Vegetable IPM Updates. During this project the Vegetable IPM Team has delivered over 75 bi-weekly updates that provided new and useful information to vegetable growers and PCAs with the assistance of our extension educator. These email messages contained information on insect, weed, disease management along with market information that are presently important in Arizona. Each update contained at least one electronic .pdf document available on our website that contains research information addressing a recent 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 Arizona Vegetable IPM team members have set up and participated 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 area-wide whitefly and virus management. In 2013, an area-wide pheromone trapping network was established where real-time information on trap captures are provided via our email updates. The Vegetable Team, 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 annually 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 various aspects of vegetable IPM. These videos and others 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. 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 achieved this goal by producing and delivering numerous educational materials, workshops, meetings, and grower demonstrations. A total of 69 continuing education units (CEUs) were provided by the team during this project with attendance at these meeting ranging from 27 to over 300 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 36 months. When we initiated the project in January 2010, our list serve contained 172 emails addresses. At the completion of the project, the email listserve contained 499 addresses who receive our bi-weekly update. This list continues to grow. Based on the overwhelming increase in subscriptions and users of our IPM information, we estimate that IPM awareness and usage by stakeholders has clearly increased by more than 30%. In addition, upon request from a popular regional publication, our IPM Veg updates are published bi-weekly on their website which caters to stakeholders throughout the western US: the Western Farm Press, http://westernfarmpress.com. This publications reaches 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 been measuring this outcome though the Insect, Disease, and Weed Losses Workshops described above. To date we have collected baseline data (2004-2010) on sampling, pesticide usage, threshold usage and profitability that will allow us to measure changes in grower behaviors in the IPM tactics they adopt. During this project we have continued to collect data on sampling, IPM tactics and pesticide usage. The data collected specifically shows that PCAs are now scouting at higher intensity levels, where field visits increased 10% per week since 2010. Also the usage of economic decisions levels has increased through the awareness of insect, weed and disease pressure. PCAs reduced the number of spray applications by almost 15% in 2013. Perhaps most important has been the steady increase in the use of "soft" reduced-risk pesticides. For the first time, PCAs are not treated a greater number of lettuce acres with soft chemistry rather than the broad spectrum OP/carbamate chemistries.

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 listserve for our VEG IPM updates, which increase 2-fold during the project. We have only had two individuals cancel their subscription in 3 years. 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 a large regional agricultural publication also requested to use our updates indicates the value in the outcomes of this project. Based on the updates alone, we estimate that well over 500 stakeholders in Arizona, (and likely another 500 in California) have benefitted from this project.

The economic impacts of this project are difficult to measure at this time, but our quantification through our Insect, Disease, and Weed Losses Workshops has shown a definite measure in behavior which has certainly resulted in economic and environmental improvements. Direct benefits to the stakeholder are best explained through our results from the Workshops over the past 3 years that show a trend in the consistent reduction in total pesticide usage in crops like lettuce, and in particular, organophosphate pesticide usage by stakeholders. This also occurred with an increased usage of soft, reduced risk chemistry which has a significantly reduced risk in mammalian and environmental toxicity. Furthermore, these surveys indicate that PCAs are

scouting more, with an increased consideration of pest biology/ecology when making IPM decisions.

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.

Contact Person

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Additional Information

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

Evaluating New Repellants for Bird Management

This project was completed on June 30, 2013

Project Summary

The experiments investigated the potential use of 5 existing compounds (methyl anthranilate [Trade Name, Migrate], methiocarb [Trade Name, Mesurol], plant extracts and oils [Trade Name, Flock Buster], anthraquinone [Trade Name, Avipel], and fipronil [Trade Name, MaxForce]) as potential bird repellents for lettuce seedling protection. The experiments were conducted to determine the efficacy of over-sprays and seed coatings in protecting germinating seed and seedlings of lettuce, broccoli, and cauliflower, during the period of stand establishment. The effort was highlighted by the quantification of repellent residues on the surface of leaves to further define the nature of the repellent relative residual levels on mature lettuce leaves. Overall, Mesurol used as a treated deterrent before lettuce seedling emergence, significantly reduced seedling consumption by 43% relative to untreated controls. All other repellents surveyed in this study did not effectively deter birds from damaging young lettuce seedlings. Essentially, there is potential for Mesurol to be successful in the fresh cut produce industry when used as a treated cracked corn deterrent application and will reduce the probability of feeding damage by birds.

Project Approach

Birds commonly cause damage to newly planted seeds, germinating seeds, or emerging seedlings of crops in many agronomic and horticultural crops in Arizona. Birds such as horned larks, sparrows, blackbirds, starlings, and mourning doves feed on newly seeded vegetable crops causing major crop damage resulting in significant economic losses by producers. Newly planted vegetable crops are often the only source of food in the desert and birds migrate to fields

to nibble, chew, or destroy the emerging seedlings of lettuces, cole crops, onions, and melons. The work initially focused on the evaluation of bird repellents on lettuce seedlings using caged bird studies. Later, repellents were evaluated in field conditions. This approach involved identifying lettuce fields while they were undergoing bird damage, where applications of the repellent were made during the onset of damage, and then monitoring subsequent bird feeding. Chemical residuals on lettuce leaves were also performed via HPLC to determine concentrations and longevity.

Cage Trials

Laboratory experiments compared the consumption of lettuce seed treated with potential repellent compounds either alone or in mixtures. Locally trapped birds were identified and held in captivity in a roofed outdoor aviary at least 2-days prior to testing and were fed maintenance food and untreated pelleted lettuce seed or lettuce seedlings. The 2-day period was shown to condition the birds for consuming lettuce. Birds with the highest average lettuce consumption during the pretreatment period were randomly assigned to a test group and were offered a 50:50 mixture of untreated grain and either treated or untreated lettuce. Seed consumption was used to determine the effectiveness of the treatments.

Additional tests were conducted to determine the effectiveness of the 5 chemical compounds as over-sprays on sprouting lettuce seedlings. After a 2-day pretreatment period, birds were offered flats containing 3-day old lettuce seedlings over-sprayed with methyl anthranilate (60 kg/ha), methiocarb (4 kg/ha), acetophenone (6 kg/ha), anthraquinone (4 kg/ha), or fipronil (4 kg/ha). During a 2-day post treatment period lettuce seedling damage was assessed for chemical effectiveness.

Field Trials

We evaluated the effectiveness of the 5 compounds for reducing damage by local bird populations to lettuce seedlings in field studies conducted during years 2 and 3. Two lettuce fields will be selected in the Yuma and Maricopa areas that typically receive damage. In each field, study plots were established to evaluate the test chemicals when lettuce seedlings were about 1 and 0.5 cm height, respectively. Six enclosures were established in each of two newly sprouted lettuce fields. Birds (6) were placed in each enclosure. Half of the enclosures were used as controls where lettuce seedlings were not treated. The lettuce seedlings in the other enclosures (treatments) were treated with bird repellents, at rates described above.

Analytical Quantification

High-pressure liquid chromatography (HPLC) was applied for the analytical separation and quantification of the concentrations of bird repellent residues on the surface of treated leaf tissue. Previous workers have determined the quantification protocols by means of HPLC for all 6 of the compounds involved in this study. Briefly, either, alone or in combinations, methanol, acetonitrile, water, or acetone extracts of repellent treated leaves were evaporated to dryness and reconstituted in acetonitrile–water (80/20, v/v, 500 µl). An aliquot of the extract was assayed by HPLC with UV detection at wavelengths between 250 and 350 nm using a gradient solvent delivery system.

Goals and Outcomes Achieved

1. We rank the overall effectiveness of 5, most common, bird repellents (GOAL) available for specialty crops within two representative geographical Arizona locations (TARGET) in Figure 1. As no such ranking of bird repellents is currently available (BENCHMARK), this project provided the first unbiased collection of rankings for chemical bird repellents in Arizona (PERFORMANCE MEASURE).

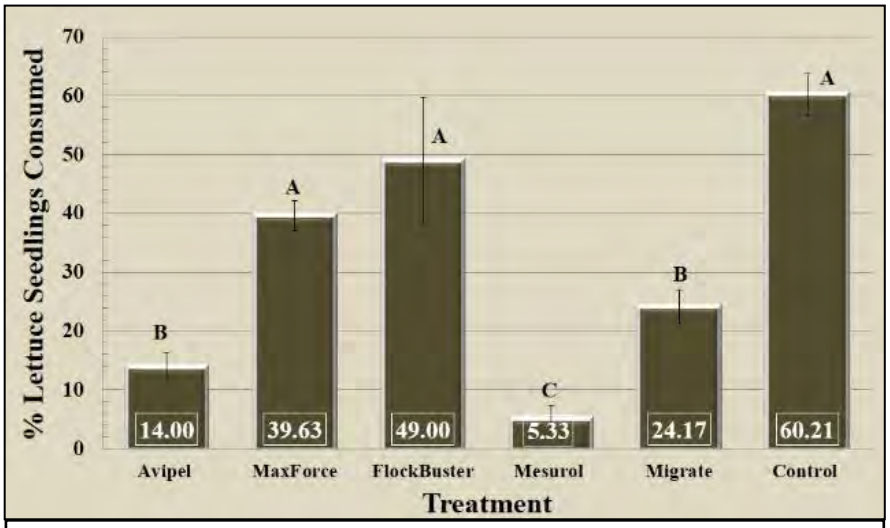

Figure 1. Ranking of chemical bird repellent effectiveness in lettuce seedlings using repellent treated cracked corn as a bird predation deterrent.

2. Indoor enclosure and field studies suggest that Mesurol (methiocarb) treated pelleted lettuce seed with the bird repellent is not effective in preventing bird predation on germinating lettuce seedlings. However, when methiocarb was applied as a cracked corn treated deterrent application (Fig. 2), significant decreases in seedling consumption were observed compared to direct application to the seed surface. In all lettuce seedlings grown in the presence with Mesurol treated cracked corn, consumption was reduced by a factor of up to 10 when compared to untreated checks. Anthraquinone and anthranilate were found to have intermediate effectiveness in deterring birds from damaging lettuce seedlings, while fipronil and organic oils and extracts were found to be not effective in mediating lettuce seedling damage.

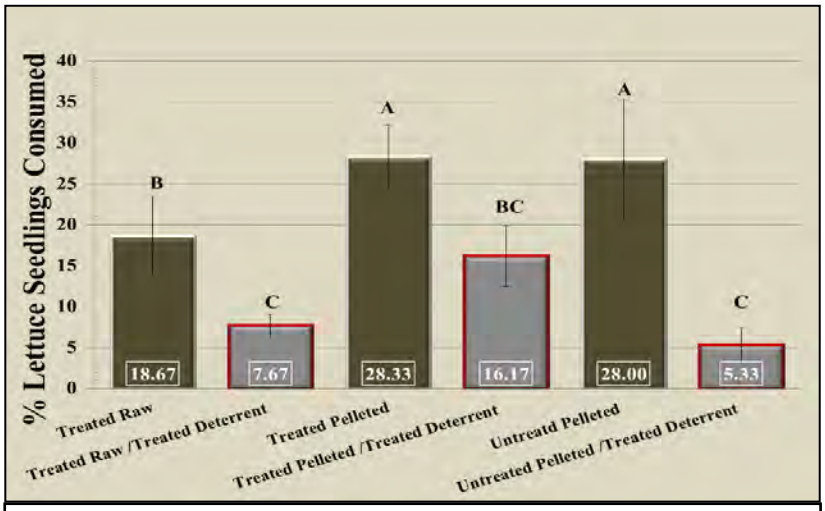

Figure 2. The effects of using Mesurol treated cracked corn as a bird predation deterrent. In either treated raw lettuce seed, treated pelleted lettuce seed, or untreated lettuce seed, repellent treated cracked corn aides in minimizing the effects of bird damage in lettuce seedlings.

3. The timing of repellent system application is a factor when deciding on when to conduct bird damage intervention as shown in Figure 3. It appears that applications of treated deterrent at planting are the most effect method of minimizing damage associated with bird visitation to fields. An approximate, two fold reduction in seedling damage was found when repellents were applied at planting relative to making repellent applications after germination (Fig. 3).

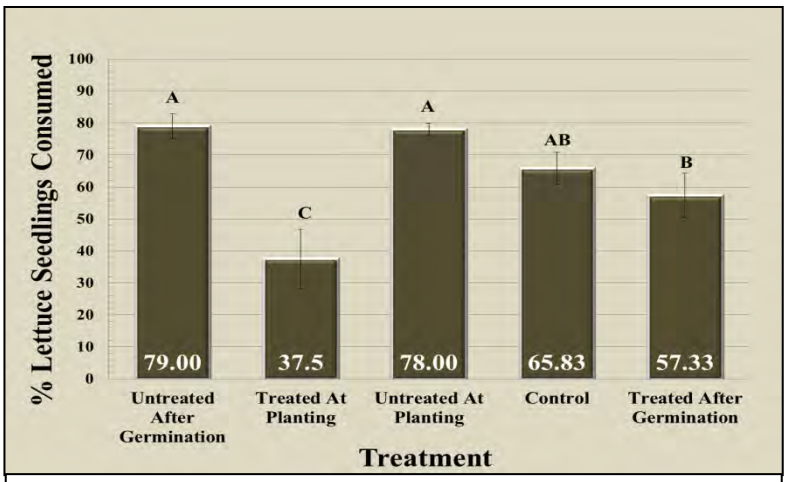

Figure 3. Relative effectiveness of Mesurol applications to cracked corn as a means of minimizing bird predation on lettuce seedlings.

4. Chemical residue of bird repellents on the surface of lettuce leaves was evaluated via HPLC analysis. Since the most effective use of bird repellents on lettuce was determined to be in conjunction with repellent treated cracked corn, it was not expected to find detect repellent residues on lettuce leaf surfaces. Figure 4 shows the absence of repellent residues on mature lettuce leaves as a result of their use in field grown lettuce.

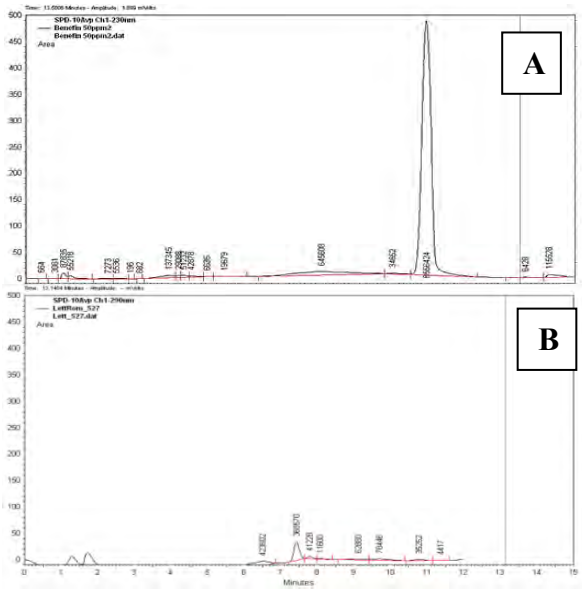

Figure 4. Example of repellent residue on the surface of mature lettuce leaves following repellent applications. Note the presence of Mesurol in repellent spiked lettuce leaves (A) relative to field applied Mesurol (B) using a cracked corn deterrent system.

Beneficiaries

It has been over 10 years since any significant work has been done in the area of bird management in Arizona specialty crops (BENCHMARK). Thus, to disseminate this new knowledge and key recommendations, research findings were presented to over 450 growers (GOAL) at the 2011 (80), and 2012 (85) pre- and post-season vegetable and cotton workshops in Yuma, the 2011 Desert Ag Conference in Casa Grande (78), and integrated pest management

workshops in central and western Arizona (84), the 2011 and 2013 American Society for Horticultural Science Annual Conference (168) and the 2012 SW Ag Summit in Yuma (105). The success of the project was measured by attendance (PERFORMANCE MEASURE) at these meetings and overall adoption of the guidelines. Currently, two Yuma county lettuce producers will be incorporating these recommendations in a selected number of lettuce fields in the fall of 2013.

Lessons Learned

Birds commonly cause damage to newly planted seeds, germinating seeds, or emerging seedlings of crops in many agronomic and horticultural crops causing economic loss. In Arizona, a variety of vegetables are grown throughout the year with planting occurring from the early fall (July to September for fall melons and leafy vegetables) through the winter (October to December for early spring vegetables) and into early spring (February to March for late spring vegetables and melons). Hybrid vegetables, including lettuce, are often planted to a stand and when bird damage occurs, quality and yield of the harvestable crop are significantly reduced. The experiment investigated the potential use of nine compounds, such as Mesurol 50% (Gowan Company, Yuma, AZ) as potential bird repellents for lettuce seedling protection. The experiments conducted, evaluated and determined the efficacy of over-sprays, seed coatings, and treated deterrent applications in protecting germinating seed and seedlings of lettuce during the period of stand establishment. Untreated cage studies determined that the rate of seedling consumption after 2 consecutive days was 26%. During a similar time frame, cage studies using Mesurol as a treated deterrent application using raw lettuce seed showed significant reductions in lettuce seedling consumption. When Mesurol was applied as a treated deterrent application (Fig. 5), significant decreases in seedling consumption were observed when compared to the repellent being directly applied to the surface of the lettuce seed before planting. In all deterrent treated lettuce seedlings, lettuce consumption was reduced by a factor of between 2 and 5 when compared to non-deterrent treated lettuce. In addition to conducting caged studies, the research protocols were developed using Mesurol in a field trial. Results showed that Mesurol used as a treated deterrent before lettuce seedling emergence, significantly reduced seedling consumption by 29% relative to untreated controls. Determining the chemical residuals in lettuce seedlings via High Pressure Liquid Chromatography was used to evaluate the effectiveness and field longevity of the repellents and was determined that residual chemical were not detectable in repellent treated lettuce. This project addresses some of the technical issues relating to the efficacy of chemical repellents and suggests future avenues of research that would improve the ability to develop effective chemical repellents for specialty crops in Arizona.

Figure 5. Mesurol treated and untreated cracked corn.

Contact

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Improve Management Efficiency Using Crop Models

This project was completed on September 30, 2013

Project Summary

Winter vegetable production contributes over $500 million annually to Arizona's economy. Accurate prediction of crop growth stage, harvest date, and yield can help growers in planning fertilizer application, arranging labor for thinning and harvest, and coordinating with their marketing sectors. The objectives of this proposal was to provide management recommendations for vegetable growers using remote sensing and crop growth models. Soil and crop growth data from growers' field in Yuma and west Phoenix area as well as at Maricopa Ag Center were taken in the first and second year of the project. The data were analyzed and used as parameters to calibrate and validate crop growth models. The models can be used to predict crop growth to assist growers to improve their management efficiency and crop yields. A crop yield map can also be generated when image and remote sensing data of the whole field is available.

Project Approach

Soil and plant growth data were collected from growers' fields in Yuma and west Phoenix area in the first year. These data, along with plant growth data from a field experiment at Maricopa Ag Center in the second year, were used to build and calibrate DSSAT crop growth models. At each field of lettuce, broccoli, cabbage, and carrot crops, pre-plant soil samples were taken at different depths (0-5, 5-15, 15-30, 30-45, 45-60, and 60-90 cm) from each plot for soil texture and nitrogen analysis. In the first year, plant samples were taken every 10 days for growth analysis and model calibration. Remote sensing images was collected on each plant sampling date using modified cameras with removed infrared filters. At harvest, crop yield in each plot was measured.

The DSSAT model was calibrated using soil data and plant growth and development information. Simulation results were compared to plant growth samples to calibrate and validate the model for each crop. After the model validation, historical weather information from the previous years can be used to predict crop growth and yield in the current growing season.

At each site, five soil samples (each with 3 2.5-inch soil cores at different depth) were collected from each field and mixed for analysis for the field. The soil samples were analyzed for soil texture (sand, silt, and clay), organic carbon, bulk density, drainage rate, and Albedo rate at each depth. The soil data that was incorporated into the DSSAT model are below:

```
*AZPX201001  WANG      C      210 AZ CLAY
@SITE        COUNTRY          LAT    LONG SCS FAMILY
  IB           USA            -99    -99     CLAY
@ SCOM SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
  -99    .2      6    .14     1     1     1   -99   -99   -99
@  SLB  SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC  SADC
    5   -99   .201   .352   .499  1.00   .84  1.45   .58  57.9  30.2   -99   -99   -99   -99   -99   -99
   15   -99   .196   .349   .498  1.00   .95  1.45   .58  56.3  31.4   -99   -99   -99   -99   -99   -99
   30   -99   .191   .346   .500  1.00   .92  1.45   .58  55.0  33.8   -99   -99   -99   -99   -99   -99
   45   -99   .197   .349   .497  .638   .94  1.57   .17  56.6  30.2   -99   -99   -99   -99   -99   -99
   60   -99   .166   .325   .475  .407   .82  1.57   .17  45.0  37.8   -99   -99   -99   -99   -99   -99
   90   -99   .191   .326   .469  .165   .77  1.57   .17  52.6  23.0   -99   -99   -99   -99   -99   -99
  210   -99   .191   .326   .469  .005   .77  1.57   .17  52.6  23.0   -99   -99   -99   -99   -99   -99
```

Soil data from other sites were also taken with same measurements as above:

```
*AZPX201002  WANG      CL     210 AZ CLAY LOAM
*AZPX201003  WANG        L    210 AZ LOAM
*AZYU201004 WANG L 210 AZ LOAM
```

```
*AZYU201005  WANG      SL     210 AZ SANDY LOAM
*AZPX201106  WANG      SL     210 AZ SANDY LOAM
*AZPX201007  WANG      CL     210 AZ CLAY LOAM
*AZYU201008  WANG      CL     210 AZ CLAY LOAM
*AZPX201009  WANG      SL     210 AZ SANDY LOAM
*AZPX201010  WANG      L      210 AZ LOAM
*AZMC201101            CL     210 TRIX CLAY LOAM
```

Plant growth (leaf, stem, reproductive structures, and crop yield), phenology, and management data were also incorporated in the data. Here is the plant file for Cabbage in DSSAT model.

```
*EXP.DETAILS: AZPX1001CB WANG VEGETABLES CABBAGE

*GENERAL
@PEOPLE
-99
@ADDRESS
-99
@SITE
-99
@ PAREA  PRNO  PLEN  PLDR  PLSP  PLAY HAREA  HRNO  HLEN  HARM.......
   -99    2   -99   -99   102   -99   -99   -99   -99   -99

*TREATMENTS                        -------------FACTOR LEVELS------------
@N R O C TNAME.................... CU FL SA IC MP MI MF MR MC MT ME MH SM
 1 1 1 0 Sim1                       1 1 0 0 1 0 0 0 0 0 0 0 1
 2 1 1 0 Sim2                       1 1 0 0 2 0 0 0 0 0 0 0 1
 3 1 1 0 Sim3                       1 1 0 0 3 0 0 0 0 0 0 0 1
 4 1 1 0 Sim4                       1 1 0 0 4 0 0 0 0 0 0 0 1
 5 1 1 0 Sim5                       1 1 0 0 5 0 0 0 0 0 0 0 1
 6 1 1 0 Sim6                       1 2 0 0 1 0 0 0 0 0 0 0 1
 7 1 1 0 Sim7                       1 2 0 0 2 0 0 0 0 0 0 0 1
 8 1 1 0 Sim8                       1 2 0 0 3 0 0 0 0 0 0 0 1
 9 1 1 0 Sim9                       1 2 0 0 4 0 0 0 0 0 0 0 1
10 1 1 0 Sim10                      1 2 0 0 5 0 0 0 0 0 0 0 1
11 1 1 0 Sim11                      2 1 0 0 1 0 0 0 0 0 0 0 1
12 1 1 0 Sim12                      2 1 0 0 2 0 0 0 0 0 0 0 1
13 1 1 0 Sim13                      2 1 0 0 3 0 0 0 0 0 0 0 1
14 1 1 0 Sim14                      2 1 0 0 4 0 0 0 0 0 0 0 1
15 1 1 0 Sim15                      2 1 0 0 5 0 0 0 0 0 0 0 1
16 1 1 0 Sim16                      2 2 0 0 1 0 0 0 0 0 0 0 1
17 1 1 0 Sim17                      2 2 0 0 2 0 0 0 0 0 0 0 1
18 1 1 0 Sim18                      2 2 0 0 3 0 0 0 0 0 0 0 1
19 1 1 0 Sim19                      2 2 0 0 4 0 0 0 0 0 0 0 1
20 1 1 0 Sim20                      2 2 0 0 5 0 0 0 0 0 0 0 1
21 1 1 0 Sim21                      1 3 0 0 1 0 0 0 0 0 0 0 1
22 1 1 0 Sim22                      1 3 0 0 2 0 0 0 0 0 0 0 1
23 1 1 0 Sim23                      1 3 0 0 3 0 0 0 0 0 0 0 1
24 1 1 0 Sim24                      1 3 0 0 4 0 0 0 0 0 0 0 1
25 1 1 0 Sim25                      1 3 0 0 5 0 0 0 0 0 0 0 1
26 1 1 0 Sim26                      2 3 0 0 1 0 0 0 0 0 0 0 1
27 1 1 0 Sim27                      2 3 0 0 2 0 0 0 0 0 0 0 1
28 1 1 0 Sim28                      2 3 0 0 3 0 0 0 0 0 0 0 1
29 1 1 0 Sim29                      2 3 0 0 4 0 0 0 0 0 0 0 1
30 1 1 0 Sim30                      2 3 0 0 5 0 0 0 0 0 0 0 1

*CULTIVARS
@C CR INGENO CNAME
 1 CB 990001 Tastie   4
 2 CB 990002 CG       4

*FIELDS
@L ID_FIELD WSTA.... FLSA FLOB FLDT FLDD FLDS FLST SLTX SLDP ID_SOIL   FLNAME
 1 PHX10CAB PHGR1001  -99  -99 DR000  -99  -99  -99 L     -99 AZPX201003 PHX10CAB
 2 PHXCAB10 PHGR1001  -99  -99 DR000  -99  -99  -99 SL    -99 AZPX201009 PHXCAB112010
 3 XXXXXXX3 PHGR1001  -99  -99 DR000  -99  -99  -99 CL   210 AZPX201007 PHX10BRC
@L ..........XCRD ........YCRD ......ELEV ............AREA .SLEN .FLWR .SLAS FLHST FHDUR
 1        -99       -99       -99        -99  -99  -99  -99  -99  -99
 2        -99       -99       -99        -99  -99  -99  -99  -99  -99
 3        -99       -99       -99        -99  -99  -99  -99  -99  -99

*SOIL ANALYSIS
@A SADAT .SMHB SMPX SMKE SANAME
 1 10258  -99  -99  -99 -99
@A .SABL  SADM SAOC SANT SAPHW SAPHB  SAPX  SAKE  SASC
 1   15  -99  -99  -99  -99  -99  -99  -99  -99

*INITIAL CONDITIONS
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
 1    CB 10258  -99  -99    1    1  -99  -99  -99  -99  -99  -99 -99
@C .ICBL  SH2O SNH4  SNO3
 1   5...227   .1   .7
 1  15...204   .1   .7
 1  30...221   .1   .7
 1  45...23    .1   .7
 1  60...223   .1   .7
 1  90...195   .1   .7
 1  210...195  .1   .7

*PLANTING DETAILS
@P PDATE EDATE  PPOP  PPOE  PLME  PLDS  PLRS  PLRD  PLDP  PLWT  PAGE  PENV  PLPH  SPRL                PLNAME
 1 11015  -99    5     5     S     R    25   -99   1.3   -99   -99   -99   -99   -99
 2 10349  -99    5     5     S     R    25   -99   1.3   -99   -99   -99   -99   -99          December Planting Date
 3 10319  -99    5     5     S     R    25   -99   1.3   -99   -99   -99   -99   -99          November Planting Date
 4 10288  -99    5     5     S     R    25   -99   1.3   -99   -99   -99   -99   -99          October Planting Date
 5 10258  -99    5     5     S     R    25   -99   1.3   -99   -99   -99   -99   -99          September Planting Date

*IRRIGATION AND WATER MANAGEMENT
@I.EFIR, IDEP  ITHR  IEPT  IOFF  IAME  IAMT IRNAME
 1   1   30   50  100 GS000 IR001   10 -99
@I IDATE  IROP IRVAL
 1 10015  -99  -99

*FERTILIZERS (INORGANIC)
@F FDATE FMCD FACD FDEP FAMN FAMP FAMK FAMC FAMO FOCD FERNAME
 1 10258  -99  -99  -99  -99  -99  -99  -99  -99  -99  -99 -99

*RESIDUES AND ORGANIC FERTILIZER
@R RDATE RCOD RAMT RESN RESP RESK RINP RDEP RMET RENAME
 1 10258  -99  -99  -99  -99  -99  -99  -99  -99  -99 -99

*TILLAGE AND ROTATIONS
@T TDATE TIMPL TIDEP TNAME
 1 10258  -99  -99 -99

*ENVIRONMENT MODIFICATIONS
@E ODATE EDAY ERAD EMAX EMIN ERAIN ECO2 EDEW EWIND ENVNAME
 1 10258 A  0 A  0 A  0 A  0 A 0.0 0 A  0 A  0 A  0

*HARVEST DETAILS
@H HDATE .HSTG  HCOM HSIZE  HPC  HBPC HNAME
 1   70 GS000    C  -99  -99  -99 Cabbage

*SIMULATION CONTROLS
@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
 1 GE           1    1    S 10244 2150 DEFAULT SIMULATION CONTR CROPRO
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES CHEM  TILL   CO2
 1 OP           N    N    Y    N    N    N    N    Y    M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 1 ME           M    M    E    R    S    L    R    1    G    S    2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 1 MA           R    R    R    R    M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 1 OU           N    Y    Y    1    Y    Y    Y    Y    Y    N    Y    N    Y

@ AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PHOL PHOU PHOD PSTMX PSTMN
 1 PL          10001 10001  40  100   30   40   10
@N IRRIGATION  IMDER ITHRL ITHRU IROFF IMETH IRAMT IREFF
 1 IR             30   50  100 GS000 IR001   10    1
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
 1 NI             30   50   25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
 1 RE            100    1   20
@N HARVEST     HFRST HLAST HPCNP HPCNR
 1 HA              0 01001  100    0
```

Weather data from each site were also included in the model:

```
*WEATHER DATA : Phoenix Greenway

@ INSI      LAT     LONG  ELEV   TAV   AMP REFHT WNDHT
  PHGR   33.621 -112.108   401  21.9  10.5   2.0   3.0
@DATE  SRAD  TMAX  TMIN  RAIN  DEWP  RHUM
 10001  12.3  20.4   4.3   0.0  60.5  47.9
 10002  12.7  20.5   5.0   0.0  60.5  60.2
 10003  12.9  22.8   2.9   0.0  51.8  71.4
 10004  12.5  23.1   5.7   0.0  69.1  42.7
 10005  13.1  22.6   5.0   0.0  51.8  56.4
....
....
```

In addition, spectral data were also taken from each site at each sampling date using spectral equipment as well as regular cameras and cameras with different wavelength filters. Below is the example of some sensing indices at two sampling dates at one site:

Table 1. Spectral indices from one site (using two sampling dates as examples)

Date	File	Spot	Reading	NDVI V1	NDVI(Circle)=(820-670/(820+670) V2	RNDVI(GSkr) V3	GNDVI(Git) V4	GNDVI(Amber)=(880-590/880+590) V5
Nov30-10	SPEC.001	1	1	0.881634	0.882727	0.881126	0.79131	0.842229
Nov30-10	SPEC.006	2	1	0.891345	0.892361	0.890679	0.806918	0.856458
Nov30-10	SPEC.011	3	1	0.890354	0.891258	0.889608	0.802452	0.853356
Nov30-10	SPEC.016	4	1	0.884592	0.885555	0.883834	0.797034	0.847264
Nov30-10	SPEC.021	5	1	0.889416	0.890616	0.889097	0.799696	0.850869
Dec7-10	SPEC.001	1	1	0.920892	0.922995	0.921754	0.849454	0.892332
Dec7-10	SPEC.006	2	1	0.908423	0.910349	0.908741	0.830942	0.876689
Dec7-10	SPEC.011	3	1	0.905455	0.907447	0.90587	0.825348	0.873005
Dec7-10	SPEC.016	4	1	0.900822	0.902961	0.901395	0.821444	0.86926
Dec7-10	SPEC.021	5	1	0.91004	0.912042	0.910492	0.836118	0.880971

Goals and Outcomes Achieved

We measured soil conditions at different crops in multiple fields in Phoenix and Yuma areas. At each field, the growth trends of biomass, leaf area, leaf weight, and stem weight of each crop in each planting at each location were measured (Figure 1). Images and remote sensing data were also taken at each sampling location. Using the soil and plant growth data, we developed computer growth models that can be used to predict crop growth and help grower to manage their fields (Figure 2). The crop growth model can be implemented by extension personnel to produce crop advisory bulletins for vegetable growers in Arizona to inform them about crop development status, potential harvest date, and yield predictions. In the future, the models can also be used to produce yield map for a large field if aerial maps are available.

A graduate student was also trained on DSSAT crop growth model. The student worked with University of Arizona and USDA-ARS scientists on data collection and crop growth model development.

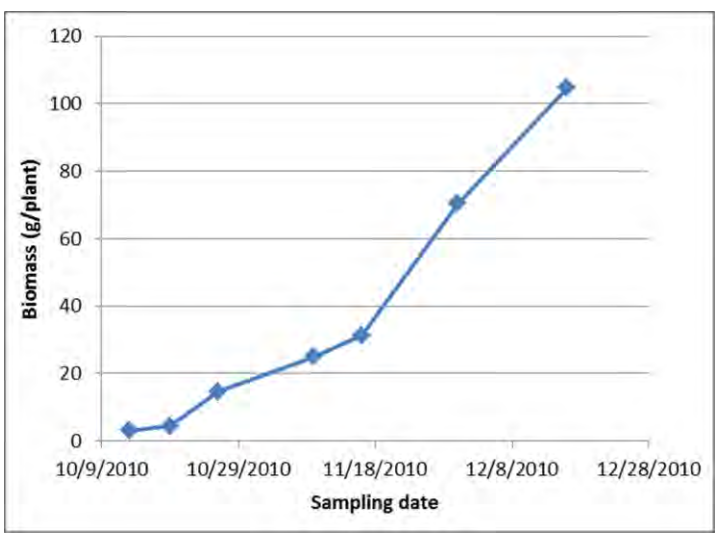

Figure 1. Biomass growth trends of first broccoli planting in Phoenix area in 2010. The similar data were measured for two plantings in each of Yuma and Phoenix location for lettuce, broccoli, cabbage (only Phoenix location) and carrot (only Phoenix location). At the same time, leaf area, leaf weight, and stem weight (if applicable) were also measured.

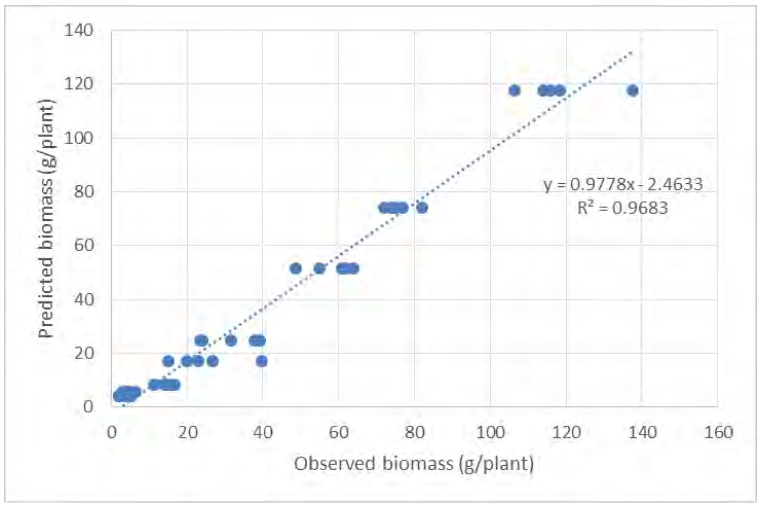

Figure 2. Cabbage observed biomass from the field and predicted biomass by models in one of the planting in Phoenix area in 2010.

The two workshops at each location were not held due to the PI leaving the University of Arizona in May, 2013.

Beneficiaries

This project developed crop growth models from measurements in growers' field and experiments at research centers. The models can be used to develop a decision support system to improve management efficiency for several vegetable crops. The information can be used to produce biweekly crop advisory bulletins for growers to use in their crop management schemes.

These crop models increased the knowledge and advanced the understanding on vegetable crop modeling by researchers. The county agents and specialists in Arizona are aware of the model development and usefulness. The results were shared with only a few growers (most are the owners and managers of the farm where the data were taken). Currently there are no growers using these models in their decision-making process. However, the effectiveness of the models is proven and they will benefit growers if the Extension section is continued.

Lessons Learned

After validation, crop models can be used to predict biomass growth and to develop a decision support system to improve management efficiency for several vegetable crops. However, the proposed biweekly crop advisory bulletins for growers were not produced due to a job change of the PI. Future work can continue to improve the models and develop Extension materials for growers in Arizona.

Contact

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Improving Arizona Tree Crop Weed Management

This project was completed on September 30, 2013

Project Summary

Weeds are consistently a top concern for agricultural producers and are a significant problem in Arizona's irrigated orchards. During the last two decades, Arizona orchard managers have sprayed glyphosate, a postemergence herbicide (e.g., Roundup branded products), on orchard floors multiple times per year (typically 4 to as many as 8 times). This overreliance on a single postemergence herbicide mode of action is not sustainable and has resulted in the selection of glyphosate tolerant weed species on orchard floors (e.g., jungle rice, little mallow, spurred anoda and others). It also has increased the risk of selecting for herbicide resistant weed species. This is now of particular concern because glyphosate resistant Palmer amaranth was discovered in Buckeye, Arizona in July 2012.

Including one annual preemergence herbicide application in an orchard weed management program reduces the density of weeds that emerge and must be sprayed with a postemergence herbicide. It also introduces a different herbicide mode of action which reduces the selection pressure for herbicide resistant weeds. Previous research in Arizona found that using a dinitroaniline herbicide in citrus and pecan orchards could result in one less postemergence herbicide application per year. Unfortunately, the effectiveness of commonly used dinitroaniline herbicides (e.g., oryzalin and pendimethalin) are reduced by rapid anaerobic degradation in water-saturated orchard soils (Probst et al., 1975).

A dilemma for orchard managers is that weeds are distributed heterogeneously in time and space (i.e., weed distributions are patchy or clumped). Growers typically spray postemergence herbicides on the entire orchard floor when weedy plant cover is generally less than 10% (ideally when weeds are small). This wastes herbicide because a lot of bare ground is sprayed. Currently, growers who use preemergence herbicides to reduce overall weed density cannot capture an economic benefit from the reduced density by not spraying bare ground. This is because manual spot-spraying is slow, labor intensive and costly and because a commercially available light-activated, automatic spot spray system, the WeedSeeker, has performance limitations and is expensive. The WeedSeeker system can detect the presence or absence of green plants and make a spray or no spray decision on the go as the sprayer travels through the orchard. It has an internal modulated light source that illuminates the ground and an optical detector that measures the red light at 670 nm (R) and near infrared light at 750 nm (NIR) reflected by soil and green plant surfaces and calculates the ratio of reflected near infrared (NIR) and red (R) light. The NIR:R ratios for bare soil range between 1:1 to 1.5:1 and NIR:R ratios for green plants range between 6:1 to 15:1 (Biller, 1998). When the WeedSeeker system measures a NIR:R ratio greater than the background NIR:R ratio reflected from soil indicating the presence of a green plant, a solenoid valve is opened and herbicide solution is sprayed. Previous research with a WeedSeeker sprayer in Arizona found that the amount of glyphosate sprayed was reduced 36 to

66% in irrigated Arizona citrus and pecan orchards. However, the efficiency of the WeedSeeker system was reduced by the problem of false positives (i.e., spraying bare ground) caused by changes in the light reflectance characteristics of the soil (i.e., the background reflectance). False positives typically occurred in transitions between wet and dry soil, light and dark areas and in areas with varying amounts of organic debris on the surface.

This project was **timely** and **important** because of the encroaching problem of herbicide resistant weeds and the availability of two new preemergence herbicides with new modes of action that will be registered and available to tree crop producers by winter 2010. In small plot testing these products, penoxsulam (from Dow AgroSciences) and indaziflam (from Bayer CropScience), provided superior long lasting control of common annual weeds in Arizona compared to existing herbicide chemistry. These new herbicides used in conjunction with glyphosate or an alternative such as Rely (glufosinate) have the potential to reduce the number of passes across the orchard floor for weed control in Arizona tree crops. This would potentially could save growers over 0.5 million dollars per year in weed control costs and reduce the risk of selecting for herbicide resistant weed species in orchards. This project was also timely because of the recent creation of a research and extension program in Precision Agriculture at the University of Arizona by Dr. Pedro Andrade-Sanchez. His program will provide the necessary equipment and expertise to address the short-comings of existing selective spot-spraying technology. Specifically we will measure the reflectance characteristics of Arizona orchard floor soils under a variety of conditions. We hope to find a better suite of light wavelengths or combinations of them that can be used to improve light-activated automatic spot sprayer technology.

Specifically the **objectives** of this project were to 1) test and demonstrate improved weed control strategies using newly registered preemergence and postemergence herbicides in pecan orchards and assess their usefulness for reducing the risk of selecting for herbicide resistant weeds in Arizona orchards, 2) evaluate the field performance of existing technology used for selective spraying, and 3) characterize the spectral response of orchard soils under a variety of conditions and propose the basic framework of an improved spraying system with a sensor-based control mechanism for selective spraying and recording geo-referenced locations of weed patches.

Project Approach

Project PI McCloskey finalized the preemergence herbicide treatments in discussions with growers and representatives of agricultural chemical companies and obtained in-kind donations of the herbicides used in this project (Prowl H_2O, Pindar GT, Chateau, Alion, Rely 280 and glyphosate herbicide). The preemergence herbicide treatments were:

1) Prowl H_2O @ 3 qt/A in spring, 2 qt/A in late June,
2) Prowl H_2O + Chateau @ 3 qt/A + 6 oz/A, respectively,
3) Pindar GT @ 3 pt/A,
4) Alion @ 7 fl oz/A and,
5) Postemergence herbicide (usually glyphosate) only comparison treatment.

6) Note: at Chase Farms, treatment 5 was Goal Tender @ 3 pt/A + Chateau @ 6 oz/A; treatment 6 was the control or postermergence herbicide only comparison treatment.

Using this basic treatment outline, Project PI McCloskey established replicated, large-plot experiments at three cooperating orchards: Red Rock Pecans (Red Rock, AZ), Green Valley Pecans (Sahuarita, AZ) and Chase Farms (Kansas Settlement, AZ south of Willcox, AZ). The experiments were replicated three times. The tree spacing was 30 feet between trees in the row and between the tree rows with a row length of about 1,200 feet at Red Rock Pecans (see Quarterly Reports for experiment diagrams showing plot layout). A similar arrangement was used to establish the experiment at Green Valley Pecans in field 63 where the tree rows were 60 feet apart (40 feet of each panel is irrigated and was sprayed with herbicides) and 30 or 60 feet between trees in a row; tree row length ranged between 660 and 900 feet. The Chase Farms tree spacing was the same as at Red Rock; 30 feet between trees in the row and between the tree rows with a row length of about 1,200 feet, however, the plots were 600 feet long so that there were two plots per row. At both Red Rock and Chase Farms, the entire 30 feet panel between tree rows by the length of the rows (i.e., the "panels") were treated with herbicide. At Green Valley Pecans, only 40 feet of the 60 foot width of the panels were treated with herbicide (i.e., the 20 feet adjacent to the tree row on each side of the panel leaving 20 feet in the middle that was not treated with herbicide; this area was not irrigated by the grower).

Each spring after growers had completed tillage operations, PI McCloskey and his staff used a tractor mounted sprayer to apply the preemergence herbicide treatments. At various times during the year, postemergence herbicides were applied using the same sprayer to manage weed populations in the orchard experiments. The field operations conducted at Red Rock Pecans, Green Valley Pecans and Chase Farms are presented in **Appendix I**. Unless otherwise noted, all postemergence herbicide treatments at all three orchards included ammonium sulfate at 1% v/v as a spray adjuvant to enhance herbicide absorption. The glyphosate formulations used in these experiments all contained surfactants.

Weed populations were measured by placing a 0.5 m^2 frame on the ground and taking a photograph every 75 feet in two lines per panel (i.e., space between tree rows) at Green Valley Pecans and Chase Farms. Where noted in Tables 1 to 6, photographs were taken with the camera mounted on a pole rather than photographing 0.5 m^2 frame on ground. The photographs were analyzed using the American Phytopathological software, Access 2.0, to calculate percentage of green pixels in the photographs and this was assumed to be percent ground cover. The area in each image was also determined so that the actual area of weed cover could also be determined. Similarly at Red Rock Pecans, weed populations were measured with 0.5 m^2 frame as described above but the weeds were counted by species rather than photographed due to the lower density of weeds present at this site. At various times, PI McCloskey and staff visually estimated percent weed control in each of the preemergence herbicide treatments relative to the untreated (with preemergence herbicide) control plots. After weed populations were assessed, all treatments were sprayed with postemergence herbicide to keep the weeds in the orchard under control for our grower cooperators.

The experiments established and maintained by PI McCloskey were used by PI Andrade-Sanchez along with adjacent fields at these locations at multiple times to measure the temperature and reflectance at various wavelengths of light including far-red light of weeds and soils in the orchards.

Results – Weed management with preemergence herbicides

The basic procedure used to collect weed control data was to subsample the plots multiple times using a 0.5 m^2 frame. After weed counts or subsample pictures were collected, all treatment plots were sprayed to kill all weeds (see **Appendix I**) so that weeds present at later dates were different plants than those counted or photographed earlier. It should be noted that the Alion treatment was not applied at the same time as the other initial preemergence herbicide treatments because Alion was not registered until after the experiments were started.

At Red Rock Pecans, the weed densities were relatively low so we were able to count weeds by species in each subsample on many occasions. However, because the densities were low at Red Rock and to summarize the data, either total weed counts or separate monocots and dicots totals are shown for selected dates in 2011 (Tables 1) and 2012 (Tables 2a and 2b). In 2011 a little more than a month after the spring preemergence herbicide treatments were applied, all of the preemergence herbicide treatments except Alion (which was not applied) had substantially lower weed densities than the treatment with no preemergence herbicide (No PREE). In mid-August 2011 about 4 months after the preemergence herbicide applications, the weed density in the No PREE was still much greater than in plots treated with preemergence herbicide although weed density increased modestly from the April 2011 assessment. By November 2011, the Prowl+Chateau treatment and the sequential Prowl treatment were similar to the No PREE treatment indicating that by 7 months the residual amounts of herbicide in the soil did not provide any significant weed control. In contrast, the Pindar and Alion treatments still suppressed weed emergence compared to the No PREE treatment.

Table 1. Weed counts collected at Red Rock Pecans at representative times in 2011. Data were transformed prior to statistical analysis; data are untransformed treatment means. Means within a column followed by the same letter are not significantly different.

Treatment	Rate (Product/A)	PREE Applied (Date)	Total Weed Density (plants m^{-2})		
			5/10/2011	8/15/2011	11/18/2011
Prowl H_2O Prowl H_2O	3 qt/A 2 qt/A	4/4/2011 6/21/2011	0.24 b	1.6 b	7.6 ab
Prowl H2O Chateau	3 qt/A 6 oz/A	4/4/2011	0.0 b	2.4 b	9.8 a
Pindar GT	3 pt/A	4/4/2011	0.04 b	0.68 b	4.0 b
Alion	5 fl oz/A	6/21/2011	1.9 b	0.72 b	3.4 b
No PREE			11 a	10.2 b	7.8 ab

Table 2a. Weed population data collected at Red Rock Pecans on July 26 and August 31 in 2012. Percent weed ground cover was determined photographically from photographs of 0.5 m^2 subplots. Percent weed control was visually estimated. Data were transformed prior to statistical analysis; data are untransformed treatment means. Means within a column followed by the same letter are not significantly different.

Treatment	Rate (Product/A)	PREE Applied (Date)	Weed Ground Cover (%)	Percent Weed Control (%)	Percent Weed Control (%)
			7/26/2012	7/26/2012	8/31/2012
Prowl H_2O Prowl H_2O	3 qt/A 2 qt/A	6/15/2012 Not applied	0.40 b	100 a	88 ab
Prowl H2O Chateau	3 qt/A 6 oz/A	6/15/2012	0.47 b	99 a	97 a
Pindar GT	3 pt/A	6/15/2012	0.34 b	99 a	99 a
Alion	5 fl oz/A	Not applied	0.59 b	95 a	89 ab
No PREE			3.54 a	78 a	74 b

Table 2b. End of season weed population data collected at Red Rock Pecans in late October 2012. All weeds in a panel were counted; monocots (grasses) and dicots (broadleaves) were counted separately and then added to obtain total weed counts. Data were transformed prior to statistical analysis; data are untransformed treatment means. Means within a column followed by the same letter are not significantly different.

Treatment	Rate (Product/A)	PREE Applied (Date)	Monocot Weeds (#/0.826 A)	Dicot Weeds (#/0.826 A)	Total Weeds (plants m^{-2})
			10/24/2012	10/24/2012	10/24/2012
Prowl H_2O Prowl H_2O	3 qt/A 2 qt/A	6/15/2012 Not applied	56 a	91 a	0.08 a
Prowl H2O Chateau	3 qt/A 6 oz/A	6/15/2012	60 a	132 a	0.06 a
Pindar GT	3 pt/A	6/15/2012	6 b	7.5 b	0.005 b
Alion	5 fl oz/A	Not applied	67 a	71 a	0.05 a
No PREE			157 a	134 a	0.11 a

Due to late spring rainfall and grower delays in conducting winter tillage operations, the preemergence herbicide treatments were applied later in 2012 compared to 2011 at Red Rock Pecans. The preemergence herbicide treatments were applied to the same plots in the two years of the study so the impact of repeated herbicide treatments on weed populations could be assessed. A few trees in the Alion treatment showed evidence of injury in winter 2011-2012 which was even more evident after bud-break in spring 2012. New leaves turned chlorotic after emerging and then rapidly desiccated. After conversing with the grower cooperator, the decision was made not reapply the Alion treatment in June 2012. The effectiveness of Alion in suppressing weed emergence was demonstrated in the percent weed ground cover data collected in July and August of 2012 more than 1 year after the herbicide was originally applied.

In general the weed densities at Red Rock Pecans were significantly lower and fewer postemergence spray operations were needed for weed control in 2012; four postemergence applications were made in 2011 compared to three applications in 2012. The reduction in weed density is reflected in the comparison of end of season weed densities measured in November 2011 versus October 2012 with the latter having 10 to 50 fold reduction in weed emergence in

the preemergence herbicide treatments and a 10 fold reduction in the No PREE treatment. Thus, using a weed management strategy that minimizes seed production and includes a preemergence herbicide can reduce weed densities; the number of herbicide applications needed annually and associated costs (labor, equipment, herbicide, adjuvants) in pecans.

Green Valley had weed population levels that were extremely high; weed species densities in the 0.5 m^2 subsamples were so high that we were not able to count individual plants. There was strong emergence of new weeds through the spring and summer and in 2011 the preemergence herbicides did not appear to have a substantial effect on emergence with possible exception of Alion late in the year (but see comment above about application timing above) (Table 3). As the experiment at Green Valley progressed in 2012, two problems became evident that affected spray operations and the ability to detect differences between treatments. First, with summer rainfall and normal irrigation scheduling by the grower, most of the plots in replication 3 and part of plot 205 remained continuously wet with standing water such that tadpoles developed into frogs. We were not able to drive equipment through these plots so the planned sequential application of Prowl H_2O in treatment 1 was not applied in 2012. The percent ground cover that was visually estimated on 6/8/2012 was highly variable due to the very high emergence of purple nutsedge on the south side of the tree rows but not the north side (Table 3 and 4). None of the preemergence herbicides used in this experiment significantly suppressed purple nutsedge emergence from tubers so it was difficult to detect differences between treatments with respect to other weed species. Thus, it was difficult to draw conclusions from the data collected at this site although the plots treated with Alion in both 2011 and 2012 had fewer weeds at the end of both seasons compared to the other treatments.

The density of weeds at Chase Farms was higher than at Red Rock so photographs of 0.5 m^2 subsamples were analyzed to determine percent weed cover rather than counting weeds but the densities were not as high as at Green Valley. About 2 months after the initial preemergence herbicide applications in early May 2011, the treatments that received preemergence herbicide had substantially fewer weeds than the No PREE treatment except the Alion treatment that was not sprayed until June 27, 2011. On July 8, 2011 the sequential Prowl treatment was applied tank mixed with glyphosate, Alion was sprayed tank-mixed with Rely and glyphosate was sprayed on the No PREE treatment. The other treatments were not sprayed because few weeds were present in those treatments. Thus, it was not surprising that the sequential Prowl H_2O and the Alion treatments had the lowest weed cover on 8/30/2011 compared to the preemergence herbicide treatments that were not sprayed on 7/8/2011 (Table 5). The No PREE treatment still had substantial weed cover despite being sprayed twice with glyphosate. Weed cover was fairly low in all treatments at the end of the season following the 9/1/11 maintenance glyphosate application and there were no significant differences between treatments in weed cover. Note however that the Alion treatment was not sprayed on 9/1 because there were no weeds in this treatment and this was still the case in early November 2011.

Table 3. Percent ground cover of weeds (a mixture of monocot and dicot species) at Green Valley Pecans (Sahuarita, AZ) at representative times in 2011. Data were transformed prior to statistical analysis; data are untransformed treatment means. Means within a column followed by the same letter are not significantly different.

Treatment	Rate (Product/A)	PREE Applied (Date)	Percent Weed Ground Cover (%)			
			5/4/2011	5/23/2011	7/13/2011	10/4/2011
Prowl H_2O Prowl H_2O	3 qt/A 2 qt/A	4/11/2011 6/27/2011	3.4 b	7.8 a	5.9 a	20 a
Prowl H2O Chateau	3 qt/A 6 oz/A	4/11/2011	2.4 b	2.9 a	14.0 a	30 a
Pindar GT	3 pt/A	4/11/2011	2.9 b	5.8 a	6.4 a	20 a
Alion	5 fl oz/A	6/27/2011	8.4 b	4.2 a	7.0 a	3.4 b
No PREE			8.2 a	5.9 a	6.2 a	24 a

Table 4. Percent ground cover of weeds (a mixture of monocot and dicot species) at Green Valley Pecans (Sahuarita, AZ) at representative times in 2012. Data of 6/8 and 9/1 were visually estimated. WeedSeeker sprayer output was measured on 9/1 and photographic analysis was used to determine percent weed ground cover on 9/24/2012. Data were transformed prior to statistical analysis; data are untransformed treatment means. Means within a column followed by the same letter are not significantly different.

Treatment	Rate (Product/A)	PREE Applied (Date)	Percent Weed Ground Cover (%)	Percent Weed Control (%)	Gallons Sprayed per Acre	Percent Weed Ground Cover (%)
			6/8/2012	9/1/2012	9/1/2012	9/24/2012
Prowl H_2O Prowl H_2O	3 qt/A 2 qt/A	4/27/2012 Not applied	.55 a	65 b	1.89 a	3.5 ab
Prowl H2O Chateau	3 qt/A 6 oz/A	4/27/2012	.0023 a	81.3 ab	1.32 a	4.6 ab
Pindar GT	3 pt/A	4/27/2012	45.75 a	57.5 b	1.54 a	4.1 ab
Alion	5 fl oz/A	4/27/2012	.004 a	96.5 a	1.45 a	2.5 b
No PREE			49.167 a	70 b	1.65 a	5 a

Table 5. Percent ground cover of weeds (a mixture of monocot and dicot species) at Chase Farms (Kansas Settlement, AZ) at representative times in 2011. Data were transformed prior to statistical analysis; data are untransformed treatment means. Means within a column followed by the same letter are not significantly different.

Treatment	Rate (Product/A)	PREE Applied (Date)	Percent Weed Ground Cover (%)		
			7/8/2011	8/30/2011	11/4/2011
Prowl H_2O Prowl H_2O	3 qt/A 2 qt/A	5/13/2011 7/8/2011	1.6 b	1.5 bc	0.5 ab
Prowl H2O Chateau	3 qt/A 6 oz/A	5/13/2011	1.1 b	5.8 abc	0.4 ab
Pindar GT	3 pt/A	5/13/2011	0.4 b	12.5 ab	0.3 ab
Pindar GT	3 pt/A	5/13/2011	0.8 b	3.3 abc	0.4 ab

Treatment	Rate (Product/A)	PREE Applied (Date)	Percent Weed Ground Cover (%)		
			7/8/2011	8/30/2011	11/4/2011
Chateau	6 oz/A				
Alion	5 fl oz/A	7/8/2011	8.9 a	0.05 c	0.0 b
No PREE			8.2 a	9.4 a	0.7 a

Table 6. Percent ground cover of weeds (a mixture of monocot and dicot species) at Chase Farms (Kansas Settlement, AZ) in 2012. Percent weed control was visually estimated. Percent weed ground cover data was from photographic analysis. On 10/10/2012, weeds in 0.5 m^2 subplots were counted and photographed to also determine percent weed ground cover. Data were transformed prior to statistical analysis; data are untransformed treatment means. Means within a column followed by the same letter are not significantly different.

Treatment	Rate (Product/A)	PREE Applied (Date)	Percent Weed Control (%)	Percent Weed Ground Cover (%)	Weed Counts per Plot
			7/26/2012	10/10/2012	10/10/2012
Prowl H_2O Prowl H_2O	3 qt/A 2 qt/A	5/10/2012 8/2/2012	9.1 a	6.0 a	23.4 a
Prowl H_2O Chateau	3 qt/A 6 oz/A	5/10/2012	9.2 a	3.4 b	17.1 ab
Pindar GT	3 pt/A	5/10/2012	9.8 a	1.6 bc	2.9 bc
Goal Tender Chateau	1.5 lb/A 6 oz/A	5/10/2012	9.4 a	1.0 bc	6.3 bc
Alion	5 fl oz/A	5/10/2012	9.8 a	0.0 c	0.0 c
No PREE			9.1 a	6.8 a	41.2 a

The preemergence herbicide treatments at Chase Farms were sprayed on May 10th in 2012 (the No PREE treatment was sprayed with glyphosate) and the resulting weed control (7/26/2013) early in the season was excellent. By the end of the 2012 season, weed densities were fairly low throughout the season as shown by the percent weed ground cover and weed counts measured on 10/10/2012 (Table 6). Only two postemergence glyphosate maintenance applications were required during the 2012 season compared to 3 in season glyphosate maintenance applications in 2011. Judging from the end of season data at Green Valley Pecans, the best preemergence herbicide treatments were Alion and Pindar GT followed by the Goal Tender+Chateau treatment (which was not included in the other two experiments). Unfortunately, at Chase Farms in a field near our preemergence herbicide experiment, some young trees in the 3 to 7 year old age class exhibited leaves that turned chlorotic and rapidly desiccated. This injury resulted in severe injury and defoliation of entire trees in some cases. This project helped identify the problem of Alion movement or leaching into tree root zones (which also occurred in a few orchards not part of this study) and contributed towards the suspension the Alion registration for pecans in the state of Arizona.

The weed population data collected in 2012, particularly at Red Rock Pecans and Chase Farms, showed that early in the season (i.e., in the first several months after preemergence herbicide

applications) all of the preemergence herbicide treatments substantially reduced weed populations compared to the total postemergence weed control program (i.e., glyphosate). The latter treatment served as our standard practice comparison treatment. By the end of the second season of use, Alion and Pindar GT were the most effective preemergence herbicide treatments. An unforeseen and unexpected result was observed in the Alion treatments at Red Rock and at Chase Farms (at this location in an adjacent field treated with Alion) in 2012. Some young trees in the 3 to 7 year age class exhibited leaves that turned chlorotic and rapidly desiccated. This injury in some trees resulted in severe injury and defoliation of entire trees. This project helped identify the problem (which also occurred in a few orchards not part of this study) and contributed towards the suspension the Alion registration for pecans in the state of Arizona.
The data collected show that preemergence herbicide can reduce the number of glyphosate applications per year and save Arizona tree crop producers money. Furthermore, preemergence herbicide use adds additional herbicide modes-of-action and helps decrease the risk of developing herbicide resistant weed populations. Further work has the potential to result in additional savings to tree crop producers if a commercially effective automatic spot sprayer can be developed and brought to market. The analysis of the spectral data we collected as discussed below will help lead the way to such commercialization.

Field deployment of electronic instrumentation in orchard environments

Technical details of electronic instrumentation and field vehicles used in this project have been reported throughout the duration of this grant. Field work was planned and executed to achieve successful continuous data acquisition from mobile platforms in orchard environments. This project provided an ample set of conditions to characterize the spectral and thermal response of typical pecan orchard floors in Arizona. Field deployment of electronic sensing instrumentation in pecan orchards was greatly enhanced with the addition of a Global Position System (GPS) equipped with an advanced algorithm that allowed position tracking under the dense canopy conditions of Pecan orchards.

This project supported the creation of a data set that contains the multispectral response in the visible and near infra-red regions (460–880 nm) of the most common weeds found in Arizona orchards. This data set was complemented with spectral characterization of the orchard floor which results from the combined effect of vegetation residues, soil surface disruption by tillage operations, and moisture content. These data provided a framework for the analysis of Weed-seeker performance reported on January 31, 2013. These field trials were designed to test the ability of the sensor system to detect vegetation from a moving platform, in this case a utility vehicle fitted with spraying equipment, under varying soil moisture and surface roughness conditions, ambient light intensity, and weed pressure. The main objective of these tests was to determine the sensitivity of the Weed-seeker background settings. The results of these tests show that weed detection performance of the existing Weed-seeker system can be improved with the implementation of a system for real-time adjustment of background sensitivity.

Second phase of field deployment of weed detection instrumentation in orchard environments consisted of experimental work designed to establish a relationship between the extent of weed infestation and the spectral response of this vegetation (i.e. weeds) in the orchard floor. Active-light instrumentation was used in this experiment to generate information normalized with a vegetation index (NDVI). These tests were designed to capture the spatial variability of orchard floor attributes and therefore were carried out in a large-scale setting for subsequent mapping

using Geographic Information Systems (GIS) software. Results confirmed the proportional relationship between sensor spectral signal (light reflectance) and the extent of weed population. Moreover, we used these findings to test the feasibility of the sensor system to be used for continuous, objective assessment of the efficacy of weed management treatment in experimental plots of this project. The distribution of NDVI values in these experimental plots are consistent with the observations of weed control efficacy performed with other methods.

As seen in the quarterly reports, this project generated large data sets of spectral and thermal information at different spatial and temporal scales. This wealth of information will enable us to perform analyses to model different ways to detect weeds on the orchard floor and to adjust the detection system to account for a changing background. NDVI is a measure of light reflectance that is largely unaffected by changing background, therefore we will continue using it and developing applications for orchard floors in Arizona. Further refinement of modeling work to improve weed detection in orchard settings will include the addition of floor temperature information and alternative spectral-based indices of vegetation and plant activity.

Goals and Outcomes Achieved

Grower Presentations: PI McCloskey made presentations to growers at Annual Pecan Growers Association Meetings held in Tucson, AZ on September 13, 2013 (*Pecan Weed Management and Herbicide Resistant Weeds*), on September 21, 2012 (*Pecan Herbicide Update – 2012*) and September 16, 2011 (*Pecan Herbicide Research and Sprayer Demonstration*). A major focus of these presentations has been the results of our preemergence herbicide studies and the value of adding additional herbicide modes of action to weed management programs to avoid developing herbicide resistant weed populations. At these APGA meetings we reach greater than 80% of pecan growers In addition, PI McCloskey made a presentation to pecan growers at the Western Pecan Growers Association Meeting in Las Cruces, NM on March 4, 2013 (*Recognizing and Diagnosing Herbicide Injury Symptoms*). The injury caused by Alion, one of the preemergence herbicides in our pecan studies, was a major focus of this presentation along with information on the effectiveness of alternative preemergence herbicides (many of which were also in our studies). Lastly, PI McCloskey also made presentations to pistachio growers at their annual meeting in Willcox, AZ on March 30, 2012 (*Pistachio Weed Management*) and to citrus growers in Yuma County on April 25, 2013 (*Weed Control in Citrus and Date Orchards – 2013*) where the value of using preemergence herbicides in weed control programs was discussed. We had hoped to be able to conduct grower surveys at some of these meetings but found that the conference organizers were not able to accommodate the time required to conduct such a survey. We are pursuing initiating a telephone survey at this year's (i.e., 2014) APGA meeting but this will take time to accomplish. We also did not achieve acceptable performance with the WeedSeeker sprayer units and thus we did not present this work to growers. In fact, our research results indicated that better technology and measurement of NDVI is required to make light-activated spot-spray systems feasible for growers by reducing false positives and improving weed detection (as discussed earlier in this report).

Extension Publication: The publication of the Extension document has been delayed in order to accommodate two very important changes that occurred in 2012-2013. The first of these was the discovery of the unanticipated leaching or movement of Alion into pecan tree root zones and the subsequent injury this caused to pecans, particularly to trees in the 3 to 7 year old age range. The second development was the discovery of a population of Palmer amaranth (*Amaranthus*

Palmeri) that was resistant to glyphosate herbicides (Roundup brands and other generic labels). Further greenhouse experiments conducted in 2013 found that this population was also resistant to pyrithobac-Na (trade name Staple). This information is now being incorporated into the Extension bulletin for pecan and pistachio producers. A draft document has been written and will be submitted to the peer-review process shortly.

The activities that were proposed for this project are listed in Table 7. We did in fact request a no-cost extension of the project in order to continue obtaining light reflectance and temperature data from orchard floors. All of the proposed activities in Table 7 were successfully conducted over the course of the project with one exception. The operations focused on weed management are listed in the **Appendix I** and the light reflectance and temperature data collected are chronicled and illustrated in our cumulative progress report. The publication of the Extension document has been delayed in order to accommodate two very important changes that occurred in 2012-2013. The first of these was the discovery of the unanticipated leaching or movement of Alion into pecan tree root zones and the subsequent injury this caused to pecans, particularly to trees in the 3 to 7 year old age range. The second development was the discovery of a population of Palmer amaranth (*Amaranthus Palmeri*) that was resistant to glyphosate herbicides (Roundup brands and other generic labels). Further greenhouse experiments conducted in 2013 found that this population was also resistant to pyrithobac-Na (trade name Staple). This information is now being incorporated into the Extension bulletin for pecan and pistachio producers. A draft document has been written and will be submitted to the peer-review process after the first of the year.

Table 7. The activities that were proposed to be performed as a part of this project as tabulated in the grant proposal.

Project Activity	Who's Responsible	Timeline
Establish study sites	McCloskey & Andrade	December 2010 to January 2011
Apply preemergence herbicides	McCloskey	Spring 2011 & Spring 2012*
Spray postemergence herbicides	McCloskey & Andrade	Spring through fall 2011 & 2012*
Measure light reflectance	Andrade	Spring through fall 2011 & 2012*
Presentation to pecan growers	McCloskey & Andrade	September 2011 & 2012
Presentation to citrus growers	McCloskey & Andrade	Fall 2011 & 2012
Extension Bulletin	McCloskey	December 2012*
Data summary/technical reports	McCloskey & Andrade	Jan 2012 & 2013*
Final Report	McCloskey & Andrade	January 2013*

*Note: in the event that additional time is needed to analyze and summarize the project results at the end of 2012, a no-cost extension will be requested to complete work.

Beneficiaries and Lessons Learned

The pecan and pistachio nut crop and citrus producers in Arizona, the crop and pest control advisors and the agricultural chemical companies including local, national and international firms that support these tree crop producers were the direct primary beneficiaries of this project. Specifically, there were 3 direct beneficiaries; the pecan growers who collaborated with us and provided pecan orchards where we conducted the research. PI McCloskey's presentations on the value of preemergence herbicides in tree nut weed management programs reached greater than 80% of pecan and pistachio growers and their field men at the annual Arizona Pecan Growers

Association meeting. There are about 10 to 12 Pistachio producers (many with multiple owners) primarily located in Cochise County. There are about 25 to 30 pecan producers, several which are quite large, mainly in Pinal, Pima and Cochise Counties. There are also a couple of dozen citrus (primarily) lemon producers in Yuma County that could potentially benefit from this project but in recent years due to poor economic conditions there has been very little use of preemergence herbicides in lemon orchards. Weed control has been accomplished mechanically. Anecdotally, PI McCloskey has observed increased preemergence herbicide use in the last three years in tree nut crops and has answered many questions regarding preemergence herbicides and problems encountered with Alion herbicide use. The way these producers benefitted from this project are discussed the paragraphs below.

The knowledge gained regarding the performance of preemergence herbicides under Arizona conditions allows more efficient weed management in tree crops and more importantly has led to greater diversification of herbicide modes of action. This is especially important now that glyphosate and ALS herbicide resistant Palmer amaranth is present in Arizona because glyphosate has been the backbone of tree crop weed management programs for nearly two decades. Now growers have better guidance for make choices that diversify their weed management programs using preemergence herbicides and reduce their reliance on glyphosate. This project was also involved in the initial use of Alion in pecan orchards following registration and trees in our large plot experiments were some of the first injured by this herbicide. PI McCloskey and other University of Arizona researchers cooperated with Bayer Crop Sciences to support growers dealing with this issue. This effort led to the suspension of Alion's registration and use in Arizona and New Mexico. More generally, all agricultural producers in regions including tree crops benefit from more diversified and efficient weed management that limits the spread of herbicide resistant weeds and the reduces the selection pressure that drives the evolution of herbicide resistant weeds.

The direct results of this project are a reduction in number of postemergence herbicide applications required to control weeds in Arizona's tree crops. With continued preemergence herbicide use, this is potentially two or more postemergence herbicide spray operations but to some degree the cost savings are offset by the use of more expensive and effective preemergence herbicides. The reduction of weed densities and soil seed banks are tangible benefits that have the potential to save tree crop producers millions of dollars in weed control costs. The project PIs are using the spectral data collected by this project to model different weed detection methods that will result in better automatic spot spray systems. These systems will allow growers to capture more economic benefit from the use of preemergence herbicides that reduce weed densities.

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Maximizing Control of Lettuce Drop

This project was completed on September 30, 2013

Project Summary

Lettuce drop, caused by the fungal pathogens *Sclerotinia minor* and *Sclerotinia sclerotiorum*, causes annual and at times extensive losses for Arizona lettuce growers. Preventative application of fungicides is a fundamental component of an integrated disease management system for this disease. With fungicides and application methods currently used, significant crop losses continue to occur. Previous field trials conducted over several years revealed a maximum level of lettuce drop control of about 50%, using currently available fungicides and application methods. The proposed research will focus on two areas to achieve this project's objective of optimizing lettuce growers' ability to control lettuce drop. First of all, the baseline efficacy of several new fungicides and biofungicides in development will be determined and compared to existing products. Secondly, application parameters will be evaluated to maximize disease control efficiency, such as comparing physical incorporation of products into the soil versus soil surface application and evaluating the value of two compared to one application of tested fungicides.

Project Approach

Lettuce drop, caused by the fungal pathogens *Sclerotinia minor* and *Sclerotinia sclerotiorum*, is an annual concern to Arizona lettuce producers. As with most diseases caused by fungi, disease severity and resultant crop losses are dependent on environmental conditions. Unlike many plant diseases caused by fungi, all lettuce plants infected with lettuce drop die, so plant loss is directly related to disease incidence. Management strategies for lettuce drop are heavily reliant upon preventative applications of conventional fungicides, such as Endura (boscalid) and Rovral (iprodione), and for those that choose to use them, products containing biologically active ingredients, such as Contans (*Coniothyrium minitans*). The labels for these products usually recommend two applications to the surface of the bed for optimum disease control. *Sclerotinia minor* and *S. sclerotiorum* reside in the soil and efforts to achieve consistently high levels of lettuce drop control have been elusive. In field trials conducted from 2001 through 2006, the average reduction of dead lettuce plants in plots treated with two applications of Endura, Rovral and Contans in plots infested with *S. minor* was 53, 35 and 32%, respectively, and in plots infested with *S. sclerotiorum* was 33, 38 and 52%, respectively. Can we do better than this apparent ceiling of just over 50% control? Preliminary results from 2007 and 2008 field trials suggest that the answer is yes. For example, a single application of Omega (fluazinam), a new fungicide not yet registered on lettuce, resulted in disease control levels of 79 and 72% in plots infested with *S. minor* and *S. sclerotiorum*, respectively. Also, physical incorporation of Endura into beds reduced the incidence of disease caused by *S. minor* and *S. sclerotiorum* by 69 and 66%, respectively, compared to a 61 and 55% reduction in disease when applied to the soil surface without incorporation. These results suggest that fungicides other than those currently registered as well as application methods other than the traditional initial application to the soil surface following thinning may provide the means to achieve levels of lettuce drop control well above the current level of approximately 50%. Furthermore, the value of one versus two preventative applications of fungicides needs to be documented, so that growers can make informed cost/benefit analyses concerning fungicide inputs.

Research goal #1 (Baseline fungicide efficacy studies). Fungicides are an integral component of a lettuce drop disease management system. The relative efficacy of registered products, such as the conventional products Endura (boscalid) and Rovral (iprodione) as well as the biofungicide Contans (*Coniothyrium minitans*), has been documented in past field trials. Several new fungicides, such as Cannonball (fludioxonil), Fontelis (penthiopyrad), and Omega (fluazinam), as well as some biofungicides such as Actinovate (*Streptomyces lydicus*) and SoilGard (*Gliocladium virens*) were in development at the beginning of this project and have now become available to lettuce growers. In three yearly field trials, the efficacy of these products as management tools for lettuce drop was compared to fungicides previously evaluated. In each trial, lettuce was seeded on raised beds in early November. After thinning in early December, plots were infested with sclerotia of *Sclerotinia minor* or *S. sclerotiorum*, then treated with one of the fungicides to be studied. A second application of all products except Omega was made approximately 2-weeks later. The number of dead plants caused by the pathogens in each plot was recorded when the lettuce crop was mature in early March. Results from these three trials are summarized in Table 1.

Table 1. Effectiveness of fungicides applied to soil in reducing the death rate of lettuce plants grown in plots infested with *Sclerotinia minor* or *S. sclerotiorum*.

Fungicide brand name [1]	**Active ingredient**	**Percent reduction in dead plants in presence of [2]**	
		S. minor	***S. sclerotiorum***
Endura	Boscalid	51 a[3]	41 bc
Omega	Fluazinam	42 ab	44 b
Rovral	Iprodione	37 ab	37 bc
Actinovate	*Streptomyces lydicus*	36 b	26 cd
Fontelis	Penthiopyrad	33 b	15 d
Contans	*Coniothyrium minitans*	31 b	64 a
Cannonball	Fludioxonil	28 b	27 cd
SoilGard	*Gliocladium virens*	28 b	46 b

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 lettuce plants compared to those in plots that were not treated. Each value is derived from three field trials conducted in 2010, 2011, and 2012. The mean proportion of lettuce plants that died in nontreated plots was 53 and 73% in the presence of *S. minor* and *S. sclerotiorum*, respectively.

3. Values in each column followed by a different letter are significantly different ($P = 0.05$) according to Fisher's protected least significant difference test.

In these three field trials, Endura, Omega, and Rovral provided the most effective control of lettuce drop caused by *S. minor*. On the other hand, Contans was most efficacious in the presence of *S. sclerotiorum*. The likelihood of dealing with *S. minor* or *S. sclerotiorum* can sometimes be predetermined by time and location of planting in Arizona. In this situation, choosing the best fungicides to manage each probable pathogen would be possible. However, lettuce growers more often do not know what species of *Sclerotinia* they will be dealing with, so consistent effectiveness against both pathogens would be important. In this case, Endura,

Omega, or Rovral would be good choice as these products provided effective control of disease caused by either species of *Sclerotinia.*

A laboratory study also was performed to determine the ability of selected fungicides to suppress growth of *Sclerotinia minor* and *S. sclerotiorum* when present in potato dextrose agar within petri dishes at concentrations of 0.01, 0.1, and 1.0µg/ml. Each treatment, including the nontreated control, was replicated five times and the entire experiment was conducted twice. The mean percent reduction in mycelial growth for each pathogen in both trials is shown in Table 2.

Table 2. Inhibition of mycelial growth of *Sclerotinia minor* and *S. sclerotiorum* by different concentrations of fungicides within potato dextrose agar in petri dishes.

Fungicide	**Concentration (µg/ml)**	**Percent inhibition of mycelial growth** [1]	
		S. minor	***S. sclerotiorum***
Cannonball	0.01	96	90
	0.1	100	88
	1.0	98	70
Endura	0.01	36	38
	0.1	68	64
	1.0	82	82
Fontelis	0.01	32	20
	0.1	70	30
	1.0	83	76
Omega	0.01	84	82
	0.1	92	93
	1.0	96	96
Rovral	0.01	22	30
	0.1	81	59
	1.0	99	95

1. Percent reduction in mycelial growth compared to that in agar not containing a fungicide. Each value is derived from five replicate petri plates in each of two runs of the experiment. The mean growth of mycelium in potato dextrose agar without fungicides was 44 and 56 mm for *S. minor* and *S. sclerotiorum*, respectively.

These laboratory studies were performed to compare the inhibitory potential of fungicides, especially at a low concentration (0.01 µg/ml), to performance of fungicides in the field. If field performance could be predicted by laboratory tests, initial screening of new chemistries for disease management efficacy could be performed rapidly and effectively before moving on to field evaluation. However, for the fungicides tested, the laboratory data did not consistently correlate with field performance. For example, Cannonball and Omega were both highly

inhibitory to mycelial growth of both *S. minor* and *S. sclerotiorum* at the lowest tested concentration in the laboratory study; however, field performance of Omega was much better than Cannonball.

Research goal #2 (Maximizing application efficiency). In addition to determining the comparative efficacy of tested products for control of lettuce drop in the field, the frequency and method of fungicide application were evaluated in our quest to maximize fungicide efficacy and efficiency. Experiments conducted to address these questions are listed below. These experiments were in the same field trials conducted in 2010, 2011, and 2012 that contained the fungicide efficacy treatments described earlier. Since Endura and Rovral were the most commonly used fungicides at the beginning of this research effort, one or both of these products were used in the experiments described below.

1. **Efficacy of one compared to two applications of a fungicide.** After thinning, sclerotia of each species of *Sclerotinia* were spread onto the soil surface of plots. The efficacy of one application of Endura or Rovral (after thinning) was compared to two applications of each product (after thinning and 2-weeks later). Results are shown in Table 3.

Table 3. Effect of one compared to two applications of Endura or Rovral on reduction of dead lettuce plants caused by *Sclerotinia minor* or *S. sclerotiorum*.

Fungicide[1]	Pathogen	Percent reduction of dead plants[2]		
		One application	Two applications	*P* value[3]
Endura	*S. minor*	40	48	0.26
	S. sclerotiorum	26	40	0.09
Rovral	*S. minor*	22	34	0.24
	S. sclerotiorum	46	46	0.96

1. The amount of each product applied was the highest amount stated on the label

2. Percent reduction in dead lettuce plants compared to those in plots that were not treated. Each value is derived from three field trials conducted in 2010, 2011, and 2012. The mean proportion of lettuce plants that died in nontreated plots was 53 and 73% in the presence of *S. minor* and *S. sclerotiorum*, respectively.

3. Values in each row are considered to be significantly different if $P \leq 0.05$ according to the t-test.

Disease control tended to increase when comparing one to two applications of Endura when *S. minor* and *S. sclerotiorum* were present as well as for Rovral when *S. minor* was present. However, these trends were not statistically significant, likely due in part to the inherent variability in disease incidence among the three trials and replicate plots within each trial.

2. **Comparison of soil surface application of fungicide followed by physical incorporation of treated soil into the bed to the traditional soil surface application without incorporation.** After thinning, sclerotia of each pathogen were spread onto the soil surface of plots. Two applications of Endura or Rovral (after thinning and 2-weeks later) were made to the bed surface following by cultivation of the bed to distribute treated surface soil to a depth of 1-inch in the bed. This treatment was compared to the standard application to the bed surface at the same time but without incorporation. Data for these trials are presented in Table 4.

Table 4. Comparison of soil surface application of fungicide followed by physical incorporation of treated soil into the bed to the traditional soil surface application without incorporation.

Fungicide[1]	Pathogen	Percent reduction of dead plants[2]		
		Not incorporated	Incorporated	*P* value[3]
Endura	*S. minor*	48	39	0.21
	S. sclerotiorum	40	38	0.77
Rovral	*S. minor*	35	37	0.80
	S. sclerotiorum	46	55	0.30

1. The amount of each product applied was the highest amount stated on the label

2. Percent reduction in dead lettuce plants compared to those in plots that were not treated. Each value is derived from three field trials conducted in 2010, 2011, and 2012. The mean proportion of lettuce plants that died in nontreated plots was 53 and 73% in the presence of *S. minor* and *S. sclerotiorum*, respectively.

3. Values in each row are considered to be significantly different if $P \leq 0.05$ according to the t-test.

The data suggest that there was no significant benefit of incorporating Endura or Rovral into soil after application to the bed surface compared to the standard practice of applying these fungicides to the bed surface without further action. Both Endura and Rovral are generally immobile once applied to soil. The physical movement of soil particles containing the fungicides into the soil profile did not result in enhanced reduction of Sclerotinia drop.

3. **Effectiveness of first application of Endura at seeding compared to the customary first application after thinning**. After lettuce seed was planted, sclerotia of each *Sclerotinia* species were spread onto the soil surface of plots. Endura was applied to plots at this time and once again after thinning. The comparison or customary treatment was to apply sclerotia

to the soil surface of plots after thinning. Endura was applied to these plots after thinning and distribution of sclerotia and once again 2-weeks later. Results of these experiments are found in Table 5.

Table 5. Effect of first application of Endura at seeding compared to first application after thinning on reduction of dead lettuce plants caused by *Sclerotinia minor* or *S. sclerotiorum*.

Fungicide[1]	Pathogen	Percent reduction of dead plants[2]		
		First app. after seeding	First app. after thinning	*P* value[3]
Endura	*S. minor*	43	51	0.17
	S. sclerotiorum	52	36	0.04

1. The amount of each product applied was the highest amount stated on the label

2. Percent reduction in dead lettuce plants compared to those in plots that were not treated. Each value is derived from three field trials conducted in 2010, 2011, and 2012. The mean proportion of lettuce plants that died in nontreated plots was 53 and 73% in the presence of *S. minor* and *S. sclerotiorum*, respectively.

3. Values in each row are considered to be significantly different if $P \leq 0.05$ according to the t-test.

The percent reduction of dead lettuce plants tended to be greater when Endura was first applied after thinning compared to at seeding in plots containing *S. minor*; however, this difference was not statistically significant. On the other hand, the first application of Endura at seeding was significantly better than first application after thinning in plots containing *S. sclerotiorum*.

Goals and Outcomes Achieved

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

Performance (research) goals

1. **Baseline fungicide efficacy studies.** Three field fungicide evaluation trials were conducted from 2010 to 2012 to evaluate eight different fungicides for their comparative ability to reduce the incidence of lettuce drop caused by *Sclerotinia minor* and *S. sclerotiorum.*

2. **Maximizing application efficiency**. The frequency and method of fungicide application may have a bearing on product efficacy. Experiments were conducted to address the following questions: 1) comparative efficacy of one compared to two applications of a fungicide, 2) comparison of soil surface application of fungicide followed by physical incorporation of treated soil into the bed to traditional soil surface application without

incorporation, and 3) comparing efficacy of first application of Endura at seeding to the customary first application after lettuce thinning. At the beginning of this research effort, Endura and Rovral were the most commonly used fungicides; one or both of these products were evaluated in this set of field experiments conducted from 2010 to 2012.

Measurable outcomes

Two distinct, quantifiable, and measurable outcomes **(goals)** were proposed for this project: 1) **increased disease management efficiency** and 2) **increased use of effective biofungicides** for disease management. These are discussed in more detail below.

1. **Increased disease management efficiency.** This **goal** is achieved by using data derived from project experiments to develop disease management strategies incorporating the most effective fungicides and methods of application to maximize disease control and optimize cost efficiency. Annual surveys of growers and Pest Control Advisors quantify losses due to lettuce drop and provide data on the quantity and identity of each fungicide used to manage this disease. Surveys before and during the time this research project was being executed provide baseline information on the quantity and identity of fungicides used and serve as a **benchmark**. The final findings of this research project will be disseminated to growers, Pest Control Advisors, and other interested personnel within the Arizona lettuce production community **(target)**. Data related to the quantity and identity of fungicide used to manage lettuce drop gleaned from future surveys will serve as a **performance measure** to monitor adoption of research findings by lettuce growers and others in the lettuce production community.

   Endura, Omega, and Rovral provided the highest level of protection from lettuce drop among tested fungicides when the soil contained *Sclerotinia minor*. On the other hand, Contans was most efficacious in the presence of *S. sclerotiorum*. The time and location of planting can sometimes help lettuce growers in Arizona predict the likelihood of having to deal with *S. minor* or *S. sclerotiorum*. In these situations, choosing the best fungicides to manage each probable pathogen would be feasible. However, usually growers cannot predict what species of *Sclerotinia* they will be dealing with, so consistent effectiveness against both pathogens would be important in these situations. In this case, Endura, Omega, or Rovral would be good choices as these products provided effective control of disease caused by either species of *Sclerotinia.*

   Experiments evaluating the frequency and method of fungicide application did not reveal any dramatic increases in disease control over that achieved by using standard application methods. The efficacy of two compared to one application of Endura or Rovral was not statistically different, although disease control usually tended to increase when comparing one to two applications of each fungicide. Fungicide labels allow two applications; however, many growers in Arizona will make one rather than two applications as a cost saving measure. Data from this research supports these growers' decisions. Physical incorporation of treated soil after application to the soil surface did not significantly improve disease control over the standard practice of applying these fungicides to the bed surface without further action. Both Endura and Rovral are generally immobile once applied to soil. The physical movement of soil particles containing the fungicides into the soil profile did not

result in enhanced reduction of lettuce drop. First application of Endura at seeding was statistically superior to first application at thinning in soil infested with *S. sclerotiorum*, but not in soil infested with *S. minor*.

The results of these studies did not reveal an application method that was statistically superior to standard application methods for growers having to contend with both *Sclerotnia* pathogens. Of all the issues examined in this research project that might have had a significant effect on fungicide performance in the field, the most important factor seems to be the innate ability of a particular active ingredient to suppress pathogen activity in the field and thus reduce disease severity.

2. **Increased use of effective biofungicides.** This **goal** is supported by using data derived from biofungicide field efficacy trials performed for three years during the course of this project. As for the first goal described earlier, the annual surveys before and during the time this research project was being conducted provide baseline information and serve as a **benchmark**. The data concerning effectiveness of tested biofungicides in reducing the severity of lettuce drop derived from this research project will be disseminated to interested personnel within the Arizona lettuce production community **(target)**. Data related to the quantity and identity of fungicides used to manage lettuce drop gleaned from future surveys will serve as a **performance measure** to monitor use of biofungicides for management of lettuce drop.

   Biofungicides evaluated in this research project included Contans, Actinovate, and SoilGard. In the presence of *S. sclerotiorum*, Contans provided the highest level of disease control among all products tested, including the other biofungicides and conventional chemistries. SoilGard was less effective than Contans, but equal to or better than the remaining products tested. Actinovate was the least effective biofungicide in plots containing *S. sclerotiorum*. In soil containing *S. minor*, Actinovate, Contans, and SoilGard controlled lettuce drop as well as all other tested materials except Endura, which provided the highest level of disease control in the presence of this pathogen.

   Field trials in this study as well as additional earlier experiments have demonstrated the ability of Contans to provide exceptional control of lettuce drop caused by *S. sclerotiorum* and moderate disease control when disease is caused by *S. minor*. In spite of these experimental results, recent fungicide use surveys reveal little or no use of this product in Arizona lettuce production fields. Possible reasons for this lack of use may include inadequate promotion by distributors, potential storage and application issues (product must be stored in a freezer prior to mixing and application to maintain potency), and availability of competitive effective conventional fungicides. Perceived inferiority of biofungicides when compared to conventional fungicides may impact widespread use of Actinovate and SoilGard as well. Actinovate, Contans, and SoilGard will have a fit in organic lettuce production fields, where competition from conventional fungicides is eliminated. Proper marketing in addition to ongoing educational efforts to showcase the benefits of these biofungicides as disease management tools should increase their use in conventional lettuce production fields as well.

Adoption of recommendations resulting from this project will be monitored by annual surveys of growers and Pest Control Advisors to quantify losses due to Sclerotinia drop of lettuce and to determine the quantity and identity of each fungicide used. Such data are already collected as part of an annual survey of losses due to diseases, insects, and weeds in lettuce production fields. This annual survey usually is conducted in late spring.

In addition to this survey, product sales data and pesticide use data submitted to the Arizona Department of Agriculture will be used to quantify the stated measurable outcomes.

Knowledge gained from this research will be disseminated to growers, agrochemical industry representatives, and other interested stakeholders through vigorous and extensive educational efforts, including grower meetings, publications, and other means of communication. Information from this research was delivered to 50 clientele attending the Preseason Vegetable Workshop held in Yuma in August, 2013 as well as through online Vegetable IPM Updates. Also, data will be published in a 2014 Plant Disease Management Report, which will reach a worldwide audience. The knowledge generated from this research will continue to be disseminated through future grower meetings and publications and other forms of communication as well.

Beneficiaries

The data derived from the completion of this project will directly benefit lettuce growers in Arizona. Lettuce production in Arizona is second only to California in acreage and crop value. In 2012, approximately 64,300 acres of lettuce were grown in Arizona with a value of $423,578,000. Lettuce production is a significant component of Arizona agriculture. Lettuce drop caused by *Sclerotinia minor* and *S. sclerotiorum* can have a significant negative impact on lettuce growers' income. Using the stated crop value figure, a 1% total crop loss due to Sclerotinia lettuce drop would translate to an economic loss over $4,000 000. Losses can exceed this level in heavy disease years. The information on comparative efficacy of fungicides and application methods generated by this research project will be disseminated through vigorous and extensive educational efforts, including grower and Pest Control Advisor meetings, publications, and other means of communication. Through these efforts, lettuce growers throughout the nation and the world will have access to this information as well.

The actual data demonstrating the comparative efficacy of fungicides and application methods has been presented earlier in this report. The potential economic impact of this project will be reflected in more efficient and potentially cost effective management of Sclerotinia lettuce drop.

Beneficiaries of the knowledge generated by this project include lettuce growers, Pest Control Advisors and in a broader sense all those associated with the production, harvest, and consumption of lettuce, in addition to personnel directly involved with management of Sclerotinia drop. The number of these beneficiaries is considerable but difficult to quantify. Benefits include management of Sclerotinia drop with the most effective fungicides applied at the most efficient rate, which in turn facilities the use of the least amount of fungicides to achieve the best level of disease control, benefitting consumers and the environment.

Lessons Learned

1. The ability of certain fungicides to control lettuce drop caused by *Sclerotinia minor* can differ significantly from disease control when lettuce is exposed to *S. sclerotiorum.*
2. Of all the issues examined in this research project that might have had a significant effect on fungicide performance in the field, the most important factor apparently is the innate ability of a particular active ingredient to suppress pathogen activity in the field and thus reduce disease severity.
3. Detecting statistically significant differences in fungicide efficacy among tested products and in methods of fungicide application was hindered by the inherent variability in lettuce drop severity present in field trials. This variability existed between replicates within a trial as well as between individual trials in spite of efforts to minimize its effects through experiment design and execution.

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Pesticide Information Empowers Progressive Vegetable Industry

This project was completed on September 30, 2013

Project Summary

Background: The Arizona Pest Management Center (APMC), in collaboration with the Arizona Department of Agriculture and a stakeholder advisory committee, has constructed a historical research database of historical and ongoing agricultural pesticide use records based on uses reported by growers to the state (on form L-1080). **These data continue to be available through the APMC to support education, research, registration, and other information needs of the vegetable industry.** This database, funded in part by previous Specialty Crop Block Grants heavily leveraged with other resources, is useful for analyzing long-term pesticide use trends and benchmarking practices to measure progress and change in the agriculture industry. For example, our data show dramatic declines over time in the use of broad-spectrum insecticides in Arizona lettuce and other specialty crops. The data also support Extension education efforts, pesticide registration needs, responding to federal pesticide information requests with accurate use data to support industry needs, and to support applications for research grants that may benefit the vegetable industry. The objectives of this project were (1) to maintain data entry, availability and accuracy of AZ pesticide use data; (2) to increase the usefulness of the database by integrating data from annual lettuce and melon pest losses surveys of Pest Control Advisors (PCAs); and (3) to mine data and interact with stakeholders to address research, education and registration needs to support vegetable crops production in Arizona.

Project Approach

Brief Summary of Activities:

- **The APMC Pesticide Use Database Advisory Committee (formed in 2008) met in 2 locations annually throughout the grant term.** Our committee includes 24 (non-UA) members of the agricultural sector, including growers, PCAs, custom applicators, chemical manufacturers, state regulatory officials, and representatives of Western Growers Association, Yuma Fresh Vegetable Association, Arizona Farm Bureau and Arizona Crop

Protection Association. At the request of the committee, we added representatives from CDMS and Agrian, two companies that provide 1080 services to Arizona clients. Each meeting has included updates from project PIs on research projects and detailed discussions on topics including protecting privacy, improving data accuracy, developing technical reports, reviewing pesticide data requests, and appropriate uses of the data. A summary of pesticide use data requests is provided to participants at each meeting. ***Our Advisory Committee is central to our function and use of these data, which we maintain belong to the Arizona producers, PCAs and applicators, who provided to the state.***

- **We have maintained a close relationship with partners at Arizona Department of Agriculture Environmental Services Division (ADA-ESD) throughout this project.** The APMC Pesticide Use Database was in place at the beginning of this project. Our goal is to improve accuracy of data and maintain access the most current data possible. Through this grant, we provided $39,624 in contract funds to ADA-ESD, which was used to support roughly 50% of 1080 data entry and quality control costs in that unit. Beyond this, frequent email and telephone communication and less frequent but regular meetings with Jack Peterson, Gary Christian and David Hall of ADA helped to improve data and data processing tasks at ADA and UA. In 2011, Wayne Dixon examined the data entry program used by ADA-ESD personnel to enter 1080 data and identified a number of programming solutions to limit errors and improve the quality of the data.
- Early on, our Arizona Pest Management Center (APMC) database was set up with the ability to link to the ADA database to download and integrate newly entered 1080 data as needed. **Throughout this project term we have improved the quality and usefulness of data** by adding a series of data checks and correction steps into the ADA-import process, improving the back-end structure of our database, and integrating additional useful data fields (e.g., EPA pesticide data, longitude & latitude, maximum and seasonal product rates, and fields used to calculate pounds of active ingredient applied).
- **One of the most significant advancements made through this project has been the development and expansion of our Research Interface**, a computer program created by Wayne Dixon that allows secure desktop access, searching, summing, and outputting from the APMC database only for project PIs and only when onsite at the Maricopa Agricultural Center. This program has grown and evolved and integrated many improvements throughout this project.
- **Throughout the term of this grant we have invested a large portion of resources into data evaluation and correction for specialty crops pesticide use data**. A range of fields has been evaluated across several crops with the largest investment in lettuce (lettuce data work was supported in part through a separate SCBG). It is important to note that the database contains nearly 1 million (~970,000) application records (1.3 million rows of data) across over 575,000 L-1080 forms. Over 100 separate fields are maintained, each subject to potential errors through data entry, poor hand writing on forms, or post-processing errors. While they represent a small portion of the data, they require a major time investment to ensure data accuracy. This effort is ongoing beyond this project, though great progress has been made. Significantly, ADA-ESD has provided us with scans of actual 1080 forms from 2007 – current, and many of these have been integrated into our research interface, which allows us to evaluate and correct potential errors in the data more quickly.
- From the start of this project, pesticide use data have been available upon request to support the information needs of specialty crop producers and other stakeholders. However, during the term of this grant, **at the urging of our stakeholder advisory committee, we have**

formalized procedural guidelines for processing of data requests. These guidelines require the review and approval of a stakeholder subcommittee for pesticide data requests from agencies (except federal pesticide information requests), organizations, companies and private parties. Requests from UA researchers and Extension personnel used for research, education and outreach are exempted from this requirement.

- **3 Lettuce Pest Losses workshops and 2 Melon Pest Losses workshops were held by John Palumbo during the term of this grant**. Data were collected from PCAs on estimated yield losses, pesticide use and control costs due to key insect, weed and disease pests. This activity, while funded through separate USDA-NIFA Western IPM Center grants, facilitated the development of pest losses data that were integrated into the APMC database under Objective 2.
- We set up a database to track pesticide information requests to the database. We have used data from this system on quarterly reports.
- We integrated Crop Pest Losses annual data summaries for Lettuce and Melons (2004 – 2010) into the Research Interface program and now have the capacity to summarize, subset or query these data in tandem with the Pesticide Use Database.

Significant Results, Accomplishments, Recommendations & Conclusions:

- A major outcome of this project has been **improved quality and accuracy of the Arizona pesticide use data** and more timely availability of the most recent data submitted to ADA.
- **The open dialog surrounding these data and involving broad grower, PCA, industry and regulatory stakeholders through our Pesticide Use Database Advisory Committee have had many benefits for all stakeholders involved.** For example, a data request from John Palumbo in 2011, we discovered that the bagrada bug, a new invasive pest of cole crops, was not listed as a target pest in the database. We worked with ADA to add bagrada bug to their list of pests for data entry and also discussed this issue with our advisory committee. As a result, several registrants started listing bagrada bug on their product labels, which now allows PCAs to start list this pest it on 1080 forms. This ability to respond to a new pest and work quickly to enable proper reporting is a great outcome of this project and the advisory committee. This will allow us to track this important new pest and the impact it has on pesticide use in cole crops.
- Because of investments made in this project, we have been able to document and present **long-term use trends (1991 – 2011) in lettuce that showed an 88% reduction in pounds of active ingredient applied for broad-spectrum insecticides and a 69% reduction in number of sprays**. At the same time, data reveal increased adoption of reduced-risk chemistry with fewer environmental or human health concerns. These data, which demonstrate the progress and success of the AZ lettuce industry have been presented at numerous Extension meetings in Arizona and California and to scientific peers and regulators at national and international conferences, including:
    - USDA National Institute for Food and Agriculture session held at the 7th International IPM Symposium in Memphis, TN on March 28, 2012. This presentation (available at http://ag.arizona.edu/crops/presentations/2012/12MemphisNIFA-EIPMvFc.pdf) includes significant impacts of IPM adoption of reduced risk pest management on pesticide use in lettuce. This session reached about 40 key stakeholders nationwide including USDA representative, EPA representatives, land grant university researchers and extension personnel and others. Subsequently, USDA-NIFA published a summary of extended abstracts from the session, available at

http://www.ncipmc.org/resources/ncripm_grants_publications/NIFA_IPM_Programs.pdf (pp. 19-21).

- We presented a poster based on lettuce and cotton long-term pesticide use trends at the 7th International IPM Symposium in Memphis, TN. The poster documents very large decreases in broad spectrum insecticide use in lettuce and includes new information on that reduction expressed in terms of "pounds on the ground" as well as annual sprays. 635 international IPM scientists from 36 countries attended the symposium. http://ag.arizona.edu/crops/presentations/2012/12MemphisAPMCdataPoster.pdf

Significant Contributions and Roles of Project Partners:

- **Dr. Al Fournier**, IPM Program Manager with the APMC at UA and lead PI for this project, supervised the management of the APMC Pesticide Use Database, including supervision of Wayne Dixon; coordinated activities and communications with the APMC Pesticide Use Database advisory committee; interacted with Dixon, Extension Specialists and stakeholders to review and correct data errors; communicated with ADA-ESD partners; supervised the development of data outputs including federal pesticide information requests, research requests and requests from industry and others; and presented information from the database to stakeholders and scientific peers, including aggregated data that highlight pesticide use trends of the lettuce industry.
- **Wayne Dixon,** Assistant in Extension for IPM Assessment and Database Specialist for the APMC, helped to develop, improve, expand and refine the APMC Pesticide Use Database; evaluated and corrected data; integrated new information and tables needed to support various projects and data requests; developed data outputs and presented to the Advisory Committee.
- **Peter Ellsworth**, Director of the APMC, IPM Specialist and State Pesticide Coordinator, supported database activities as needed, including review of data and identification of data anomalies; often fielded data requests from stakeholders; developed graphical representations of data for use in presentations; and presented data to Extension clientele, PCAs, growers, regulators and other stakeholders.
- **APMC Pesticide Use Database Advisory Committee.** The committee members have provided invaluable input and feedback throughout this project on a number of 1080 data issues.
- **ADA-Environmental Services Division Partners**. Jack Peterson provide input on pesticide use data and database issues at Advisory Committee meetings and separate project meetings, often leading to changes in the ADA database or procedures. Gary Christian manages 1080 data entry and personnel responsible for data quality issues. He was always available to answer questions or check data on the ADA side to help us resolve issues, and also participate in the Advisory Committee. David Hall, an Information Technology Specialist with ADA handled technical issues related to the ADA 1080 database, our access to it, and issues affecting data quality. He came to serve on the Advisory Committee starting in 2011.

Goals and Outcomes Achieved

Outcome 1: *Availability of current 1080 data (GOAL) will be measured by documenting the range of dates of available 1080s at the time of each quarterly report (PERFORMANCE MEASURE), with the TARGET goal of ≤ 30-d time lag following application. The BENCHMARK measure will be the available range of 1080 data (by date and number of 1080s represented) at the start of the 3-year project.*

This outcome was achieved in 7 out of 12 quarters of the project, during which the lag time was generally around 15 days. The mean for all quarters was 36.25 days. At the start of this project (BENCHMARK) there was a 90-day lag between our databases. This lag continued for the first 2 quarters of the project, after which, ADA-ESD "caught up" on 1080 data entry. **Because of potential lag time in submission of 1080 forms to ADA, at their best pace of data processing, we were able to maintain data in our database of applications as recent as 2 weeks old.** This was the best-case scenario. Because personnel resources dedicated to 1080 data entry ebbed and flowed during the 3-year project, there was fluctuation in available data time lag. This was due to gaps between temp personnel that occurred and also influenced by the busy fall licensing season, when it was often hard for them to keep up. Overall, we are very pleased with this result.

Outcome 2: *Integration of vegetable CPL data into the database (GOAL) will be measured by the documented completion of this task (PERFORMANCE MEASURE), with the TARGET of having all current data (2004–2010) integrated and available by the end of Y1. This data is not currently available through the database (BENCHMARK). The value of the expanded database to stakeholders will be measured by documenting annual data requests related to specialty crops (PERFORMANCE MEASURE) and estimating the impact of these requests on industry practices and profit based on user input.*

This outcome was achieved. Although we did not meet our goal of having Crop Pest Losses data integrated into our database by the end of year 1, we did achieve this goal by the end of the project. Technically, the data reside within 2 separate tables in the database, and are accessible through the Research Interface. Our thanks to John Palumbo for developing and providing the data summaries and making this information available to stakeholders. We have documented annual data requests to the database throughout this project, and made summaries available at our Pesticide Use Database Advisory Committee meetings. Over the course of this project, we have fielded 22 research requests, 10 federal requests related to pesticide registration or re-registration issues, and 3 requests from external stakeholders for pesticide use data. Research requests typically come from UA researchers or collaborators and nearly always result in one or several "outputs" such as Extension presentations to growers, Extension publications or journal articles, presentations or posters to scientific peers, etc. Federal information requests are related to registration issues and the database provides a valuable resource for responding with *real use data* that help us defend important uses for vegetable and other agricultural markets. Examples include reports developed on buprofezin use and malathion use, including data on uses in desert vegetables.

Outcome 3: *In 2009, UA researchers were involved in 6 funded federal grants for $311,600 related to vegetable crop pest management issues (BENCHMARK). We will document federal grants with UA faculty participation funded annually for vegetable crop pest management (PERFORMANCE MEASURE) using a UA Cooperative Extension database. Our TARGET is an increase of 10% over benchmark in Y1, 20% in Y2, and 40% in Y3 (cumulatively, about $1.15mil.).*

This objective was met. We calculated federally funded grants related to vegetable pest management (not all specialty crops) with UA researchers as PIs using the UA Analytics financial data system. The full project amount was credited in the initial year a project was

funded, even for multi-year grants. All federal competitive grants, exclusive of the Specialty Crop Block Grant Program, were included for UA researchers known to work with vegetable crop pest management. A portion of USDA-NIFA Extension IPM Coordination and Support funding that directly supports our Vegetable IPM Team (Palumbo, Matheron, Tickes and Pena) was included for all years, as was funding from USDA-NIFA that supports Vegetable Pest Losses surveys and federal pesticide information requests. As the table shows, we achieved a 14% increase in 2010 (target = 10%), a 16% increase in 2011 (target = 20%), and a 71% increase in 2010 (target = 40%). Total funding for 22 projects during the grant term was $1.25 million (target = $1.15 million).

Year	**2009**	**2010**	**2011**	**2013**
Projects	6	7	8	7
Funding	$311,600	$354,726	$361,448	$533,948
% change from 2009	**Baseline**	13.8%	16.0%	71.4%

Beneficiaries

This project benefited Arizona specialty crop producers (175), in particular lettuce and melon producers (74), marketers (12) and crop protection personnel (220), as well as researchers (20), ADA, and specialty crops consumers (millions). The data retained in the APMC Pesticide Use Database and the data outputs and summaries included in presentations, publications and reports enable stakeholders to clearly document improvements toward economic and environmental goals of integrated pest management. For example, we have documented an **88% reduction in pounds of active ingredient applied for broad-spectrum insecticides and a 69% reduction in number of sprays in lettuce in 2011 versus 1991. The available data allow vegetable stakeholders and researchers to identify and quickly respond to emerging pest issues** (e.g., data were used to support 2 USDA-NIFA research grants totaling over $300,000 to develop effective management for bagrada bug in cole crops); and **to defend useful products when labels are threatened** (e.g., buprofezin use in melons, lettuce, citrus and other crops). The vegetable industry has also benefited from $1.25 million in federal grants related to vegetable pest management that were in part supported and justified through availability of these data. Potential economic impact of these benefits far exceeds $1 million.

Lessons Learned

- Our valuable partnership with growers, PCAs, industry representatives, regulators and agricultural associations through our ongoing Pesticide Use Database Advisory Committee is invaluable to the success of this project. Member participation and input on important issues has remained strong. The ideas and concerns brought forward within the group are taken seriously and have at times accelerated achievement of important outcomes (e.g., getting bagrada bug added to pesticide labels) and at other times modified our approaches and even slowed achievement of some specific goals. For example, production of a “synthesis report” or publication that highlights much of the fantastic progress of the vegetable industry with respect to reductions in pesticide use has not been completed within the timeframe of this project. (Although some of this data has been presented and published in Extension publications and other outputs – some listed under “Additional Information”.) Discussed at length at several advisory meetings, members have expressed concerns about the possible misuse of the data or misinterpretation by interest groups. Also, we have shifted back and

forth regarding the specifics of the document's contents. Nonetheless, in our 2013 meetings, we have identified a process and a group of participating reviewers and are proceeding with this goal.

- Through this project we have improved our relationship and efficiency in interacting with ADA-ESD in the transfer of 1080 data and attending to data correction and integrity issues. We may have been a bit naïve in our goal of maintaining our database consistently no more than 30 days behind application of pesticides. We learned that this is achievable at times, but not consistently, due to work flow issues within ADA-ESD, including annual licensing obligations in an under-staffed office. We are pleased with our average data lag time of around 36 days.

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Additional Information

We believe that the benefits derived from these data help enhance the competitiveness of the Arizona Specialty crops industry by improving our ability to respond to federal pesticide information requests related to registration review with *real user data* that demonstrate the value and need of key chemistries to our crop production system (e.g., buprofezin). Our responses are further improved through direct stakeholder input (often members of our advisory committee) that addresses the specific roles and value of these chemistries. Loss of these active ingredients can be costly to the industry, as pest managers shift practices and attempt to compensate, sometimes at increased cost of control or with potentially costly yield impacts. Another benefit of these data is their use in justification of grant proposals, through documentation of a pest management need (for example, by documenting an increase in broad spectrum insecticide use targeting the new invasive pest bagrada bug, Palumbo helped justify new research to develop effective control approaches). We have not measured specialty crop consumption in this project.

Partial list of Publications, Reports & Presentations
(Made possible by availability of AZ pesticide use data)

Ellsworth, P.C., A. Fournier, W. Dixon & J. Palumbo. 2012. Buprofezin Use In Arizona. University of Arizona, Arizona Pest Management Center.
http://ag.arizona.edu/apmc/docs/12EPABuprofezinUseInArizonavF.pdf

Fournier, A., Ellsworth, P.C. & W. Dixon. 2013. Malathion Use in the Desert Southwest. University of Arizona, Arizona Pest Management Center.
http://ag.arizona.edu/apmc/docs/APMC_Malathion_Request_May2013.pdf

Fournier, A., Ellsworth, P.C., W. Dixon, J, Palumbo & J. Peterson. 2012. 22 years of agricultural pesticide use data reveal dramatic reduction in broad-spectrum insecticides. University of Arizona Cooperative Extension. 7th International IPM Symposium, TN. March 27, 2012. (Poster) http://ag.arizona.edu/crops/presentations/2012/12MemphisAPMCdataPoster.pdf

Ellsworth, P.C., A. Fournier, W. Dixon, J.C. Palumbo, K. Umeda and J. Peterson. 2012. Enhancing Capacity for IPM Practice and Assessment in Arizona. An extended abstract for NIFA IPM Programs: Legacy and Impacts Mini-Symposium, 7th International IPM Symposium, Memphis, TN, March 27-29, 2012. pp. 19-21. (Invited presentation) http://www.ncipmc.org/resources/ncripm_grants_publications/NIFA IPM Programs.pdf

Palumbo, J.C. 2013. Impact of the Bagrada Bug on Desert Cole Crops from 2010 - 2012: A Survey of PCA and Growers. Vegetable IPM Update Vol. 4, No. 10. 8pp. University of Arizona Cooperative Extension. https://extension.arizona.edu/sites/extension.arizona.edu/files/resourcefile/resource/marcop/052913%20Bagrada%20Bug%20Survey_2013_Report.pdf

Wang, G. 2011. Cotton response to plant distribution pattern at low population. Cotton Research & Outreach Report, 2010-2011. University of Arizona Cooperative Extension. Publication no. az1548a. p 1-5. http://cals.arizona.edu/pubs/crops/az1548/az1548a.pdf

Presentations:

March 2011. Arizona Pesticide Use Data: A Resource for the Vegetable Crops Industry. Southwest Agriculture Summit, Yuma, AZ. 150 participants. 1 ADA CEU, 1 CDPR CEU.

May 2011. Arizona Pest Management Center / Extension IPM Update and Funding Request. UA College of Agriculture and Life Sciences, Executive Council Meeting. Tucson, AZ. 6 participants. *Data used to support request for leveraged funding for Extension IPM.*

1/30/12. Fournier A., P. C. Ellsworth, W. Dixon, J. Peterson & J. Palumbo. Specialty Crop Block Grant Progress Report: Pesticide Information Empowers Progressive Vegetable Industry. Maricopa, AZ.

5/3/12. Fournier A., Ellsworth P. C., W. Dixon & J. Palumbo. Pesticide Use Data: Documenting the Change of an Industry. Desert Ag Conference, Casa Grande, AZ. 15 participants. 1 ADA CEU, 1 CDPR CEU.

8/30/12. Fournier A., P.C. Ellsworth, W. Dixon, P. Jepson, M. Guzy. Historical Pesticide Use in AZ Lettuce. Preseason Vegetable Workshop. Yuma Ag Center, Yuma, AZ. 41 participants. 1 ADA CEU, 1 CDPR CEU.

12/19/12. Fournier, A. & Ellsworth P. C. 2012. Investing in IPM Assessment. Western IPM Center, IPM Adoption Dynamics and Impact Assessment Work Group meeting. Davis, CA. 12 participants. (Invited presentation)

03/06/2013. Jepson P., M. Guzy, W. Dixon, Fournier, A., P.C. Ellsworth, J. Palumbo. Pesticide Use in Arizona Lettuce: Understanding and Reducing Risk. Southwest Ag Summit, Yuma, AZ. 100 participants. 1 AZ CEU, 1 CA CEU, 1 CCA CEU.

03/07/2013. Jepson P., M. Guzy, W. Dixon, Fournier, A., P.C. Ellsworth, J. Palumbo. Lettuce IPM Workshop: Better IPM, Better Pesticides, Better Environment for Lettuce Production. Southwest Ag Summit, Yuma, AZ. 50 participants. 2 AZ CEUs, 2 CA CEUs, 2 CCA CEU.

08 - 09/2013. Ellsworth, P.C., J. Palumbo, Y. Carrière, Fournier, A., W. Dixon. Appropriate Use of Your Data? Mapping Chemical Use Patterns. Arizona Pest Management Center Pesticide Use Database Advisory Committee, Yuma & Maricopa, AZ August – September 2013.

09 - 10/2013. Ellsworth, P.C., J. Palumbo, Y. Carrière, Fournier, A., W. Dixon. Chemical Use Data & Resistance. Useful? Fall Extension Workshop, Parker, Coolidge, and Marana, AZ. September - October 2013.

Season-long Sprinkler Irrigation for Vegetables

This project was completed on September 30, 2013

All figures and tables referred to in this report are located in Appendix J in the order that they appear.

Project Summary

Solid set sprinkler systems are commonly used to irrigate crops worldwide. In the Yuma area, solid set sprinkler systems are increasingly used for season long vegetable production. Existing systems were primarily designed to provide supplementary irrigation (mainly for environmental control purposes) during the early part of the vegetable growing season. However, with season long sprinkler operation, the objective of irrigation is not only providing adequate water supply for environmental modification for the first few weeks of stand establishment, but also applying it efficiently and uniformly. Hence, the performance of sprinkler systems designed primarily for supplementary irrigation may need to be evaluated in light of the requirements of season long use. In the current study (which has both field and modeling components), irrigation performance is evaluated in terms of irrigation application uniformity.

A typical field-scale solid set sprinkler system in the Yuma area consists of an open pipeline network of aluminum pipes, commonly obtaining its supply from a lined field supply canal (Figure 1). Water is pumped (often using centrifugal pumps) from the canal into a main with equally spaced multiple outlets, each supplying irrigation water to a lateral. Valves are used to control the supply to individual laterals. Each lateral is fitted with regularly spaced riser pipes supporting a sprinkler head, which distributes water over the irrigated field in the form of precipitation. There are two types of field layout configurations typically used in the Yuma area. The most common one consists of a mainline installed across the head end of the field supplying irrigation water to a line of laterals installed on one side of the main, described here as a system with single-line laterals layout configuration (Figure 2a). Another widely used field layout consists of a mainline installed in between two adjacent irrigated fields, or somewhere within an irrigated field, and supplies irrigation water to two sets of laterals, each installed on either side of the main (Figure 2b). Such a system is referred here as one having double-line laterals layout configuration. With this layout each set of laterals irrigate either a fraction of the field or each of the adjacent fields, as the case may be. In the irrigated fields of the Yuma Valley, land surface slopes are typically flat; hence they have negligible effect on system hydraulics. Soils in the area are relatively heavy (with texture varying from the silt loam to silt clay range) and sprinkler

irrigation is often light and frequent, which is well suited to the relatively shallow rooted high value vegetable crops grown in these fields

Field-scale sprinkler irrigation system uniformity can be evaluated through on-site evaluations. A commonly used field technique for the evaluation of a solid set sprinkler irrigation system application rates and distribution uniformity involves the installation of a test-plot between two adjacent laterals with overlapping sprinkler application patterns (Martin et al., 2007a; Keller and Bliesner, 1990; Cuenca, 1989). Typically, a test-plot consists of a rectangular area, with dimensions equal to sprinkler and lateral spacing, and is populated with an array of rain gages arranged in grid squares. In some of the field evaluations, pertinent meteorological data (mainly wind speed and direction) can be measured at regular time intervals. At the end of a field evaluation, precipitation depths collected in each of the rain gages in a test-plot are recorded and used in test-plot scale uniformity calculation. Test-plot scale irrigation uniformity evaluations can be replicated over an irrigated field, to take into account the effects of spatially variable factors on irrigation uniformity, based on which field-scale uniformity can be estimated.

In this study, field evaluations were conducted in grower's farms in the Yuma area. The field-scale sprinkler systems used in these evaluations have single-line laterals layout configurations. During the field evaluations, plot scale uniformity tests were performed at preset locations in the irrigated field. The test-plot scale application uniformities were scaled up to field-level through averaging. The results of the field studies show that measured field-scale irrigation uniformities are high (with field-scale Christiansen's uniformity coefficient, UCC, of about 0.75 and 0.90 and low-quarter distribution uniformity, DU_{lq}, of 0.69 and 0.85). These values are in the moderately high to higher end of the range recommended for solid set sprinkler system design (Keller et al., 1980). The field evaluations were conducted under low wind speed conditions (with average wind speeds during the field tests not exceeding 1.8m/s). In an earlier study conducted in a different sprinkler irrigated farm, similarly high field-scale irrigation uniformity was obtained: UCC = 0.85 and DU_{lq} = 0.78. Additional sprinkler irrigation system field evaluations were conducted in the Maricopa Agricultural Center of the University of Arizona. The sprinkler system used in this study has a double-line lateral layout configuration. Five field evaluations were conducted under comparable hydraulic and ambient weather conditions (wind speed ≤2.5m/s). Test-plot scale UCC and DU_{lq} values vary between 0.75 to 0.92 and 0.69 to 0.88, respectively; with field-scale average UCC of 0.86 and DU_{lq} of 0.78. The Maricopa study was conducted in an experimental sprinkler system specifically set up for the study described here and it is smaller than a typical field-scale sprinkler system in the Yuma Valley. Hence, the results described here are significant only to the extent that sprinkler systems with sufficiently large lateral and mainline diameters, to keep energy loss to a minimum, can attain high levels of irrigation uniformity provided the system is well maintained, properly installed, operated under low wind speed conditions, and application rate is sufficiently small to make sure that there is no surface runoff. In addition, hydraulic evaluations (consisting of pressure head and discharge measurements along laterals) were conducted as part of these studies. The hydraulic data was primarily used for evaluation of a field-scale sprinkler irrigation hydraulic model, developed as part of the current study, but it also provided a qualitative measure of the effects of system hydraulics on application uniformity.

Field studies can provide a more realistic evaluation of irrigation performance. However, mathematical models can offer a much more flexible and inexpensive alternative for developing

optimal sprinkler irrigation system design recommendations. Flow in a field-scale solid set agricultural sprinkler system can be considered steady without loss of generality. Hence, pressure head and discharge distribution along a lateral or mainline can be modeled through the application of the energy conservation and continuity equations for steady incompressible flow (Granger, 1995; Larock et al., 2000; Miller, 2009). Because of limitations in computational resources, in the past analytical solutions of these equations derived based on a set of simplifying assumptions were commonly used in the hydraulic analysis of sprinkler systems. Christiansen (1942) approximated the friction head loss in a sprinkler lateral as the product of the friction head loss in an equivalent flow through pipe (computed with a suitable friction head loss equation) and a friction reduction factor. Various improvements and enhancements have been proposed to the basic approach of Christiansen to allow for increased flexibility in terms of the location of the first sprinkler with respect to the lateral inlet, provisions for computing friction head loss in tapered laterals, and in lateral with residual outflow (Jensen and Fartini, 1957; Keller and Bliesner, 1990; Anwar, 1999; Vallesquino and Escamilla, 2002; Yitayew, 2009). Current advances in computing allow the implementation of numerical procedures, not limited by many of the assumptions listed above, to describe the field-scale hydraulics of sprinkler systems. Considering sprinkler laterals and mains as manifolds (pipes with multiple outlets of known hydraulic characteristics), a rigorous and flexible formulation of the field-scale sprinkler system hydraulic problem can be obtained by coupling the energy equation for each lateral/main segment with the continuity equation at a node. The resulting set of equations is then solved iteratively starting from the distal end sprinkler/mainline outlet and moving sequentially upstream along the lateral/mainline (e.g., Larock et al., 2000; Miller, 2009). An appropriate interpolation scheme can then be used as an interface to couple the numerical solutions of the lateral and mainline hydraulic equations.

Mathematical models of sprinkler irrigation system networks exist (e.g., de Andrade and Allen, 1999; AEI Software, 2011). These models have the capability to simulate the hydraulic characteristics of a field-scale sprinkler system. However, their emphasis is on hydraulic analysis of large scale pressurized agricultural water distribution networks. A model for the optimal design and management of field-scale sprinkler irrigation system requires the coupling of a rigorous field-scale hydraulic model with a droplet-dynamics submodule (for computing the pattern of precipitation around a sprinkler, e.g., Playan et al., 2009) and a soil hydraulic model (for simulating subsequent infiltration and soil water flow processes, e.g., Simunek et al., 2009). The development of a computationally efficient and robust model with such a capability remains a challenge.

As a step toward the development of a fully coupled field-scale sprinkler irrigation model, a rigorous and flexible mathematical model for the hydraulic characterization, simulation, and design of a field-scale solid set sprinkler system is developed. The basic numerical algorithms used for modeling the hydraulics of a field-scale solid set sprinkler system with single-line laterals layout configuration were developed and evaluated though comparison with field data. Further development and enhancement of the hydraulic model has been performed with additional funding.

The model can be used to conduct hydraulic analysis of field-scale sprinkler systems with uniform or spatially variable hydraulic, geometric, and topographic characteristics. Because of the scope of the study, currently model development is limited to field-scale hydraulics.

However, the objective is to eventually couple the hydraulic model with soil water flow and droplet dynamics models, thereby developing a modeling capability for a complete characterization of the field-scale irrigation performance of a solid set sprinkler system. With support from the USBR, a follow up study aimed at developing a droplet dynamics model capable of simulating precipitation patterns around a single sprinkler and exploring possibilities for coupling it with the field-scale hydraulic model is being undertaken.

The component of the mathematical model, developed for hydraulic analysis of field-scale sprinkler systems with single-line laterals layout configuration, was evaluated with field data as part of a previous study. The results of the study showed that model predictions compare well with field data, suggesting that the numerical algorithms of the hydraulic model for systems with single-line laterals is accurate. In this study, a limited evaluation of the model functionality developed for the hydraulic analysis of systems with double-line lateral layout configuration has been conducted through comparison of model output with field data. The results show that the performance of the model is satisfactory. In addition, the model is used to evaluate the hydraulic characteristics of the sprinkler system used in the field study. It is also used to evaluate the sensitivity of the hydraulics of the system to changes in hydraulic, geometric, and topographic variables. Example simulations highlighting the practical application of the model in the hydraulic analysis of field-scale sprinkler systems with spatially variable geometric and topographic characteristics are presented.

Project Approach

Field Studies

Irrigation evaluations were conducted in growers' fields in the Yuma area in 2010 to 2012. The soils of the evaluation farms can be described as silty clay loam. The field sprinkler systems used in these evaluations have single-line laterals field layout configuration (Figure 2a). One of the irrigation evaluations described in this report were conducted in a sprinkler system consisting of 14 laterals set at a regular spacing of 35 ft. Each lateral was 1290 ft long and has 43 sprinklers installed at a spacing of 30 ft. The mainline is 595 ft long, with the upstream most lateral set at 140 ft distance from the system inlet. Hence, the effective irrigated area of the farm is 14.7acre. The second field-scale sprinkler system described, consists of 36 laterals installed along a mainline of 1244 ft length. However, the field evaluation covers only the upper 609 ft long section of the mainline, in which 18 laterals are installed at a regular spacing of 35 ft (with the first lateral set at a distance of 14 ft from the mainline inlet). Each lateral is 1530 ft long and has 51 sprinklers set at a regular spacing of 30 ft. The area of the field covered by the irrigation evaluation is 21.6acers.

Additional irrigation evaluations were conducted in a sprinkler irrigated field in the research farm of the Maricopa Agricultural Center of the University of Arizona in the summer of 2012. The main objective of this study is to conduct hydraulic evaluations of a field-scale sprinkler system with double-line laterals layout configuration (Figure 2b). However, alongside the hydraulic measurements, irrigation uniformity evaluations were also conducted. The soils of the test farm can be characterized as loam. As shown in Figure 3, the sprinkler system used in this study has a double-line laterals layout configuration. The irrigated field has a rectangular shape and it is 210 ft wide and 1260.2 ft long, covering an area of 6.15acre. The water source is a lined field supply canal running along the edge of the field and water was pumped (with a centrifugal pump) from the canal into a mainline. The mainline runs across the shortest dimension of the

field, dividing the field into two equal halves of each 210 ft width and 630 ft (Figure 3). The mainline, which spans the width of the field (210 ft), is comprised of 152.4mm diameter aluminum pipe sections with six water off-take nodes, each supplying water to a pair of laterals running perpendicular to the main. The upstream end off-take node is set at 10.0ft from the pump and the remaining five off-take nodes were set at an equal distance of 40 ft. Each lateral consists of 630 ft long aluminum pipe with a constant diameter of 76.2mm and has twenty-one sprinklers set at a regular spacing of 9.14m. The sprinklers used in this study are a mix of Rain Bird 14J model (a predecessor of the Rain Bird 14VH model), nozzle size 7/64″ and WeatherTec 10-20 model with a nozzle size 7/64″. The head discharge characteristics of these two types of sprinklers is essentially the same with a maximum error of less than 0.5%. Hence, in subsequent analysis WeatherTec 10-20 sprinkler with nozzle size of 7/64″ (*WeatherTec Corporation: http://www.weathertec.com*) is used.

Topographic survey was conducted covering the entire field with a bench mark set at an elevation of 328.08ft (100.0m) from an assumed datum. Based on which the average longitudinal slope (slope along the longest dimension of the field) is computed as 0.01% and the cross-slope (slope along the shortest field-dimension) is determined to be 0.03%. Note that topography of the field is such that the even-numbered laterals run up the slope, hence they have a 0.01% slope and the odd-numbered laterals have a -0.01% slope. The mainline runs down slope, hence has a -0.03% slope.

Layout of an irrigation uniformity test-plot and measurements

The layout of rain gages in the irrigation uniformity test-plots used in the Yuma Valley and Maricopa studies are depicted in Figures 4a and 4b, respectively. In the Yuma Valley study each test-plot is setup in between two adjacent laterals, and circumscribed by four sprinklers, covering a rectangular area measuring 30.0ft along the laterals (sprinkler spacing along laterals) and 35 ft in a direction normal to the laterals. In the field study conducted in the Maricopa Agricultural Center each test-plot covers an area of 30ft (sprinkler spacing along laterals) by 40ft (spacing between laterals). The type of rain gage used in this study is a 10″ long tapered (conical) rain gage that can measure 1.0-140.0 mm depth of precipitation with a measurement precision of 1.0mm. Each rain gage is mounted on a plastic stake provided by the manufacturer and is fastened to a wooden post providing it sufficient clearance from the ground (preventing splash from entering the rain gages) when installed in a test-plot. During an irrigation evaluation three test-plots distributed over the irrigated field, each representing an equal fraction of the total area of the field, were installed.

Depending on the degree of overlap between adjacent sprinklers, which varies with time in any given irrigation event, a rain gage in a test-plot receives precipitation from a number of sprinklers. Typically, the precipitation depths collected in each rain gage are recorded manually immediately following the end of a test irrigation event. However, when it is inconvenient to do so and when the time that precipitation readings were taken and the time an irrigation evaluation event ended is different, and then evaporation data from a control rain gage is used to correct the measured precipitation depths. In the Yuma Valley studies weather data (mainly wind speed) was measured with a nearby micro-meteorological station. In the Maricopa studies, weather data from a nearby AZMET (the Arizona meteorological network) station for the duration of the irrigation evaluation event was downloaded from AZMET website *http://ag.arizona.edu/azmet/*). The data used in this study contains a record of the hourly average wind speed and direction.

Hydraulic (discharge and pressure head) measurements

In the field studies, hydraulic (pressure head and discharge) measurements were made along the main and laterals. The flow meter used to measure lateral discharges in the current study is a propeller meter that can measure discharges of up to 250.0 GPM with a measurement precision of 10.0 GPM. It also has a totalizer with a digital display. Pressure gages that can measure a maximum pressure head of 70.0m water column (100.0psi) with measurement precision of 1.4m (2.0psi) was used to measure pressure head along laterals.

Prior to each test irrigation event, five or four pressure gages were installed along selected laterals and flow meters were installed at a point just upstream of the first sprinkler from the inlet end of each of the laterals. In addition, as described above, topographic survey was conducted in the irrigated field to determine average slopes along the mainline and the laterals. The measured pressure heads and elevations at the computational nodes along the laterals will be used to compute hydraulic grade lines. The hydraulic model will then be evaluated by comparing the simulated and measured hydraulic grade lines along the laterals and lateral inlet discharges.

Irrigation uniformity equations

Sprinkler field tests are used to determine application uniformity at the scale of a test-plot. In the current study, irrigation uniformity is measured with two indices:

(*1)* Christiansen's uniformity coefficient, *UCC (-)*, a good measure of spatially distributed nonuniformity, is given as

$$UCC = 1.0 - \frac{\sum_{k=1}^{K} \left| d_k - d_{av} \right|}{\sum_{k=1}^{K} d_k} \qquad (1)$$

In Eq. 2, k = rain gage indices *(-)*, K = the total number of rain gages in a test-plot *(-)*, d_k = depth of water collected by individual rain gages *(mm)* and d_{av} = average depth collected over the test-plot *(mm),* and *(2)* the low-quarter distribution uniformity, DU_{lq}*(-)*, which is a good measure of localized significant negative deviations from the average depth

$$DU_{lq} = \frac{d_{lq}}{d_{av}} \qquad (2)$$

where d_{lq} = average of the lowest quarter depths *(mm)*.

In order to scale up the test-plot scale uniformity indices to field-scale, a simple averaging procedure is used. With this approach the test-plot scale uniformity (which also represents the application uniformity of the corresponding farm block) is computed with Eqs. 1 and 2. The field-scale uniformity indices are then computed as the weighted averages of the test-plot scale uniformity indices. The weighting coefficient for each test-plot is computed as the ratio of the area of the farm block that the test-plot represents to the total farm area.

The modeling work performed within the frame work of the study include: (1) The formulation and numerical solution of the hydraulic equations for a sprinkler system with double-line laterals layout configuration; (2) An interpolation scheme, based on cubic splines, was developed and

incorporated into the current version of the model as an interface for coupling the numerical solutions of the lateral and mainline hydraulic equations; (3) A one-dimensional optimization algorithm is developed and incorporated into the hydraulic simulation and design functionalities of the model; (4) Enhancements were made to earlier version of the model in order to accommodate field layouts with irregular boundaries (variable lateral lengths); and (5) A new functionality for computing test-plot scale and field-scale sprinkler irrigation uniformity from field data is developed.

Overall, current version of the model is capable of conducting hydraulic characterization, design, and simulation as well as field evaluation computations at a field-scale for systems with single-line laterals or double-line laterals layout configuration. A description of the model in terms of equations and solution algorithms, available functionalities, limitations, program components and organization, and issues related to the installation and running of the program is presented in a companion document. Evaluation of the model through comparison of its output with field measured hydraulic (discharge and pressure head) data and its application in the determination of the hydraulic characteristics of the field-scale solid set sprinkler system is presented in the following section.

Cooperator contributions

All the field evaluations and demonstrations conducted in the Yuma area were conducted in grower fields. The growers cooperated in the implementation of these experiment demonstrations and provided the infrastructure.

Goals and Outcomes Achieved

Evaluation example I (Yuma)*:* The first irrigation evaluation described was conducted in a grower's field with an effective irrigated area measuring 490 ft ×1290 ft. Irrigation duration was 7.0h. The wind speed during the irrigation evaluation vary in the range 0.0-3.7m/s with an average value of 1.8 m/s. Measured precipitation depths for each of the test-plots are summarized in Table 1. The collected depths vary from a minimum value of 7.0mm to a maximum of 81.0mm. The test-plot scale average depths vary from a minimum of 18.0mm for the middle test-plot to a maximum of 32.0mm for the upstream end test plot, with the average depth for the downstream end test-plot being 27.0mm (Table 1). Computed Christiansen's uniformity coefficient values are 0.78, 0.58, and 0.89 for the upstream end, middle, and downstream end test-plots, respectively. Distribution uniformity is 0.76 for the upstream end test-plot, 0.48 for the middle test-plot, and is 0.84 for the downstream end test-plot. The field-scale average UCC and DU_{lq} are 0.75 and 0.69, respectively. While the computed UCC and DU_{lq} for the upstream and downstream end test-plots can be considered high, the values for the middle test plot are low. In addition, it can be noted from the data for test-plot 2 (Table 1) that there is a spatial trend to the observed variation in precipitation depths within the test-plot, which is not noted in the other test-plots of the field. This suggests that factors other than wind might have been contributing to this. Perhaps some combination of such factors as sprinkler riser settings, the use of sprinklers with hydraulic characteristics significantly different from the design specification due to inadvertent mixing of sprinklers, the use of sprinklers with significantly modified hydraulic characteristics due to wear and tear or routine maintenance issues could account for this observation.

Evaluation example II (Yuma): The second irrigation field evaluation event described was conducted in a section of a grower's farm measuring 609 ft along the mainline and 1530 ft along the laterals. Each of the three irrigation uniformity evaluation test-plot has 49 rain gages arranged in grid squares (of 5ft×5ft), Figure 7a. The duration of the field evaluation was 7.0h. Table 2 summarizes the precipitation depths collected in each rain gage of the test-plots. They vary over a wide range, between a minimum of 13.0mm and a maximum of 28.0mm, with a field-scale average of 21.0mm. Although the data range suggests a fairly wide variation in the collected depths, as can be noted form Table 2 much of the data vary in a narrower band indicating higher field-scale irrigation uniformity. For each test-plot, the Christiansen's uniformity coefficient (UCC) and the low-quarter distribution uniformity (DU_{lq}) were computed with Eqs. 1 and 2 and are summarized in Table 2. The test-plot UCC values are 0.91, 0.91, and 0.87 for the upstream end, middle, and downstream end test-plots, respectively. Test-plot scale DU_{lq} varies in the range 0.84 to 0.88. The field-scale average UCC and DU_{lq} are 0.90 and 0.85, respectively. Note that the field-scale UCC is in the higher end of the recommended range for solid set sprinkler systems (Keller et al., 1980). In addition, the fact that the differences between the test-plot scale UCC and DU_{lq} values are relatively small indicate that the number of data points with extreme localized deviations from the average is small.

Maricopa evaluations Irrigation uniformity evaluations were conducted in the research farm of the Maricopa Agricultural Center of the University of Arizona. The layout of the sprinkler system used in the study is depicted in Figure 3. Three test-plots were installed distributed over the irrigated field, each representing an equal fraction of the irrigated field. A test-plot covers a rectangular area of 30.0ft×40.0ft, which is further discretized into 48 grid squares measuring 5ft×, at the center of each is placed a rain gage (Figure 4b). A total of five field evaluations were conducted with the same test-plot layout. The duration of the test irrigation event vary from 2.5h to 3.0h. The average wind speed over the duration of each of the irrigation evaluation events was less than 2.5m/s.

The precipitation depths collected during the first field evaluation event of the Maricopa study is summarized in Table 3. The average wind speed during the irrigation evaluation event is 2.2m/s and the duration of the irrigation event is 3.0h. The test-plot scale average depths collected vary in the narrow range of 9.9mm-11.1mm with a field-scale average of 10.5mm, suggesting a high field-scale irrigation uniformity. The test-plot scale uniformity indices vary in the range 0.87 to 0.90 for UCC and over a relatively wider interval of 0.77 to 0.86 for DU_{lq} (Table 3). Field-scale UCC and DUlq are 0.88 and 0.81, respectively.

Four additional field evaluations were conducted using the same test-plot layout (including the spatial distribution of test-plots over the irrigated field) and under comparable hydraulic and weather conditions. A summary of the test-plot scale and field-scale irrigation uniformity indices and the average precipitation depths collected are summarized in Table 4. The use of test-plot scale uniformity indices from different irrigation events to compute a field wide average irrigation uniformity (UCC and DU_{lq}) assumes that the hydraulic and weather conditions during the irrigation evaluation events did not show significant variation. The average wind speed is less than 2.5m/s, the total dynamic head at the sprinkler system inlet varies in a narrow range of 139.0m to 144.0m. Hence the irrigation evaluations can be considered comparable with regard to system hydraulics and weather. However, the durations of the last two irrigation evaluation events were 2.5h, while those of the first three events are 3.0h. Hence, instead of average depths

collected, the average application rate is computed as an indicator of the field wide average irrigation depth that can be applied by the sprinkler system, given the duration of an irrigation event.

As can be noted from Table 4, values of the test-plot scale uniformity indices are generally high and the field-scale averages (UCC of 0.86 and DU_{lq} of 0.78) are in the upper end of the recommended range for solid set sprinkler system. It can also be noted that uniformity estimates for the fourth field evaluation was relatively lower than those obtained for the rest of the evaluations. Although average wind speed is slightly higher during this irrigation event (2.5m/s), perhaps the effect of factors other than wind speed could be more significant.

The very high field-scale irrigation uniformity maintained over a series of irrigation events (Table 4) can be explained by the fact that the sprinkler system, described here, was specifically set up for research purpose and that care was exercised in ensuring proper installation and operation of the system. Considering this and the fact that the sprinkler system used in the study is smaller in size compared to a typical field sprinkler system in the Yuma Valley Irrigation District; the irrigation uniformity results obtained in the Maricopa study are significant only to the extent that a sprinkler system with sufficiently large lateral and mainline diameter (typical of sprinkler systems in the Yuma area) can attain high levels of irrigation uniformity provided the system is well maintained and is operated under low wind speed conditions.

Field measured hydraulic data

The hydraulic data presented here consists of pressure head and discharge measurements made in an experimental field-scale sprinkler system with double-line laterals layout configuration (Figure 3). As described above, the field evaluation was conducted at the Maricopa Agricultural Center of the University of Arizona and the primary objective was to collect hydraulic data for model evaluation purposes: verification of the component of the mathematical model developed for hydraulic analysis of sprinkler systems with double-line laterals layout configuration. A detailed description of the hydraulic, geometric, and topographic attributes of the sprinkler system used in the study is presented in the methodology section. Three sets of hydraulic data, labeled here as data sets I, II, and III, were collected during the field evaluations. All the data sets consist of measured pressure head profiles along the main. To be specific these measurements were made, on the laterals, at a distance of one sprinkler spacing from the main. In addition, data sets I, II, and III consist of measured pressure head profiles along laterals #4, #7, #9, respectively (Figure 3). Inlet discharges measured at the inlet of laterals #4 and #9 during two field evaluations events (Data sets I and III) were also used in the model evaluation.

The hydraulic, geometric, and topographic input data used for model evaluation is summarized in Table 5. The total dynamic head at the mainline inlet is computed as a function of measured elevation and pressure head and computed velocity head at the system inlet (based on pipe geometry and approximate flow rate derived as a function of measured lateral discharges). The friction calculation equation used in model evaluation is that of Darcy-Weisbach. The pipe absolute roughness given in Table 5 is obtained from Keller and Bliesner (1990) as a function of pipe material: aluminum pipe. Values of the local head loss coefficient for the branch and line-flow at the lateral-sprinkler riser pipe and mainline lateral junctions were also obtained from Keller and Bliesner (1990) as a function of pipe material, diameter, and type of pipe appurtenance.

Hydraulic modeling

A limited evaluation of the component of the model, developed for hydraulic analysis of a field-scale sprinkler system with double-line laterals layout configuration, is presented here. The model is then used to simulate the hydraulics of the field-scale sprinkler irrigation system used in the study. In addition, a discussion on the sensitivity of the sprinkler irrigation system hydraulics to changes in hydraulic, geometric, and topographic variables is presented. Hydraulic simulation examples are also presented in order to highlight the practical applications of the model.

Model evaluation with field data

Model evaluation is based on a comparison of measured and computed hydraulic grade line (HGL) along the main and laterals and lateral inlet discharges. Because discharge measurements were available only at the lateral inlets, computed energy grade lines (EGL) cannot be compared with measured data. However, velocity heads are very small (the maximum value occurring at the lateral inlet can be shown to be about 3.0cm, which is less than 0.1% of measured pressure heads) and as a result the difference between HGL and EGL is negligible. Therefore, a comparison of the measured and computed HGL and lateral inlet discharges was considered here as a satisfactory criteria for model evaluation.

A comparison of the simulated and measured HGL along the main and laterals for data sets I, II, and III are depicted in Figures 5a-5f. The results presented in Figures 8a-8f are computed based on simulations with values of system total dynamic head, imposed at the inlet, equal to 139.0m for data set I and 144.0m for data sets II and III. For all the three irrigation evaluations the measured HGL data closely matches the simulated values. For each irrigation evaluation, the minimum, maximum, and average relative difference between measured and computed pressure heads along the mainline and the laterals are summarized in Table 6. The error in pressure head prediction along the laterals vary between a minimum value of 0.31% for lateral #9 and a maximum value of 3.28% for lateral #7, with an overall average of 1.49% (Table 6). The error in the computed mainline pressure head vary in the range 0.32% to 11.59%, with an overall average value of 2.02% (Table 6). Lateral inlet discharge prediction errors vary between a minimum value of 9.9% at the inlet of lateral #4 (Data set I) and a maximum value of 14.9% at the inlet of lateral #9 (Data set I), Table 6. The overall average error in lateral inlet discharge prediction is 11.8%.

The results summarized in Figure 5 and Table 6 show that the hydraulic model predicted pressure head profiles along the laterals and the main accurately. On the other hand, model predicted lateral inlet discharges show larger error than pressure head estimates. However, considering the relatively low precision of the flow meter used in the study (10 GPM), it can be noted that some fraction of the error in lateral inlet discharge estimates (Table 6) can be accounted for by measurement error.

The fact that the simulation results were obtained without the need for model calibration (based only on a generic set of literature data for pipe absolute roughness and local loss coefficients) suggests that the computational algorithm implemented in the hydraulic model is accurate. Note that both the measured and computed pressure heads along the laterals and the mainline as well as the corresponding HGL's show very small spatial variation (Figure 5). The fact that the maximum slope of the computed energy grade lines (EGL's) and the maximum velocity head along the laterals are very small, about 0.5% and 3.0cm, respectively; shows that the lateral

diameter in the test farm (which is 76.2mm) is sufficiently large to keep the friction head loss, velocity head, and the local head losses along the laterals very small. Since elevation differences in the test-farm have negligible effect on pressure variation, the very small energy loss within the sprinkler system should imply a uniform sprinkler pressure head and hence discharge variation over the irrigated field. This implies that the relatively large pipe diameter, and the resultant hydraulics, is an important contributing factor to the high level of application uniformity observed during the test irrigation events. Although large diameter pipes have the added advantage of minimizing operational costs of the system; they will result in higher installation costs.

Field-scale hydraulic simulation

The field-scale sprinkler system used in the Maricopa field evaluation is described above and the system layout is depicted in Figure 6. Related geometric, hydraulic, and topographic data used in the field-scale hydraulic simulation is presented in Table 5.

The mathematical model developed as part of the current study generates various types of output data, including: hydraulic characteristics curves for each mainline outlet and for the system inlet, energy and hydraulic grade lines along the main and each of the laterals, discharges at each of the computational nodes along the main and the laterals, and sprinkler pressure heads and discharges. However, in subsequent discussion only a summary of the model outputs that have direct significance from irrigation management perspective are presented: the field-scale spatial distribution of sprinkler pressure heads and discharges and the corresponding system hydraulic characteristic curves. Although the total dynamic head for the three hydraulic evaluations vary from 139.0m to 144.0m, only a simulation of the irrigation evaluation events with a total dynamic head of 144.0m is presented in subsequent discussion.

The spatial distribution of sprinkler pressure heads and discharges obtained through hydraulic simulation are summarized in Figures 6a and 6b, respectively. The two halves of the sprinkler system considered here are identical in terms of their geometric and pipe hydraulic characteristics, but are slightly different in the lateral slopes, with laterals irrigating one-half of the field installed on a surface with a slope of -0.01% and the other half installed on a slope of 0.01% (Table 5). However, the effects of the difference in slope on the sprinkler pressure head range, the locations in the field of the maximum and minimum pressure heads, and the spatial distribution of pressure head are negligible; hence for practical purposes the pressure head and discharge distribution patterns in one half of the field can be considered mirror images of those of the other half and vice-versa. Subsequent discussion will, therefore, focus on describing the pressure head and discharge distribution patterns for one-half of the field, implying that about the same inferences and observations can be made for the other half as well.

Considering either half of the field, it can be noted that the maximum sprinkler pressure head (43.5m) and maximum discharge (0.1715L/s or 2.719GPM) occur at the system inlet and the minimum pressure head (42.1m) and the minimum sprinkler discharge (0.1685L/s or 2.671GPM) occur near the field corner opposite to the inlet. The field-scale average sprinkler pressure head (considering the same fraction of the irrigated field) and discharge is about 42.5m and 0.1694L/s (2.686GPM), respectively. The range of sprinkler pressure head and discharge variation over the irrigate field is 3.5% and 1.7% of the average, respectively. Considering an average pressure head close to the design pressure head, the result suggests that the field-scale sprinkler pressure

head (and hence discharge) variations are well within the recommended range for satisfactory sprinkler irrigation system uniformity.

The spatial distribution of sprinkler pressure head over the upper quarter of the field (hydraulically speaking) shows the highest degree of sensitivity to distance, from sprinkler system inlet, along both coordinate axes (parallel and normal to the main), Figure 6a. Note that this is typical of a field-scale sprinkler system with level or nearly level field surface and spatially invariant lateral diameter, common in the Yuma area. On the other hand, in the lowest quarter of the field, pressure head and discharge variation exhibits the least sensitivity to distance measured from the system inlet. However, in the other two quarters of the field, sprinkler pressure heads and discharges show appreciable levels of sensitivity to distance in only one direction (in a direction parallel or perpendicular) to the laterals.

The lateral inlet discharges vary between 3.55L/s (56.3GPM) to 3.58L/s (56.7GPM). The system discharge is 42.69L/s (676.8GPM) with a total dynamic head of 144.0m, which is specified at the input (Table 5). The system discharge is almost equally divided between the two halves of the irrigated field, this is due to the fact that the hydraulic and geometric characteristics of the two subsystems are nearly identical and that the differences in land slope is negligible to have a significant effect on the hydraulics of the sprinkler system.

Sensitivity analysis

The preceding section presents the most significant model output (from irrigation management perspective) obtained through hydraulic simulation of the field-scale sprinkler system used in the current study. An analysis of the sensitivity of the hydraulics of a field-scale sprinkler system with single-line lateral layout configuration to changes in total dynamic head, lateral diameter, lateral slope, and pipe absolute roughness was performed. The most important result was that given the pipe diameters that are in common use in the Yuma Valley Irrigation District, system hydraulics is dominated by pipe diameter and it exhibits little sensitivity to significant variations in land surface slope and pipe absolute roughness. This suggests that the hydraulic design of the field-scale sprinkler system considered in the study is robust. In the current analysis, the sensitivity of the hydraulics of a sprinkler system with double-line laterals layout configuration to changes in the total dynamic, lateral diameter, lateral slope, and pipe absolute roughness is evaluated. A one-dimensional sensitivity analysis was conducted, in which at any one time the value of only one variable is varied and all other factors are kept constant at the level used in the field-scale hydraulic simulation of the sprinkler system (Table 5).

Total dynamic head at the system inlet

In order to evaluate the effects, of variation in the total dynamic head, on the field-scale spatial distribution of sprinkler pressure head and discharge; the total dynamic head was varied in the range 134.0m to 154.0m in increments of 10.0m. Note that 144.0m is the total dynamic head used in the actual system in two of the field evaluations (Table 5). The resulting spatial distribution of pressure head is depicted in Figures 7a-7c and sprinkler discharges are shown in Figures 7d-7f. Overall, the locations of the maximum and minimum sprinkler pressure heads and discharges within the irrigated field, the spatial variation patterns for both the sprinkler pressure heads and discharges, as well as the ranges of variation of sprinkler pressure head and discharge expressed as a percent of the field-scale averages show no sensitivity to changes in the total dynamic head at the system inlet. However, the actual values of the sprinkler pressure heads and

discharges show significant levels of sensitivity to changes in total dynamic head. The field-wide average sprinkler pressure head for a total dynamic head of 134.0m is 32.9m (Figure 7a). This is appreciably lower than the field-scale average pressure head values of 42.5m and 52.1m for systems with total dynamic head of 144.0m and 154.0m, respectively (Figures 7b and 7c).

As would be expected the sensitivity of sprinkler discharges to changes in total dynamic head is less pronounced than pressure heads, nonetheless, significant. Overall the absolute values of sprinkler pressure heads and discharges are increasing functions of changes in total dynamic head. The practical implication of this result is that maintaining the accuracy of pump pressure gages and/or flow meters is important for satisfactory irrigation system management.

Lateral diameter

The results of field-scale hydraulic simulation presented in the preceding section show that the diameter of the field-scale sprinkler system used in the study (76.2mm) is already sufficiently large to keep energy loss within the laterals very small. Hence, the hydraulics of the sprinkler system should not show any appreciable levels of sensitivity to further increases in lateral diameter. In subsequent analyses, only commercially available aluminum pipes with diameters smaller than 76.2mm (3.0”) are considered. Figures 8a-8f depict the simulated spatial distribution of field-scale sprinkler pressure heads and discharges for lateral diameters of 44.45mm (1.75”) and 50.8mm (2.0”) along with those simulated for a lateral diameter of 76.2mm (3.0”). As can be noted from Figures 8a-8f, changes in lateral diameter have a significant effect on the pattern of distribution of sprinkler pressure heads and discharges as well as on their ranges of variation. However, variations in lateral diameter do not affect the location of the maximum and minimum sprinkler pressure head and discharge in the field. As lateral diameter is reduced from 76.2mm to 50.8mm the range of variation of the field-scale sprinkler pressure head increased from 1.5m to 5.6m. Further decrease in lateral diameter to 44.45mm results in a significant increase in the range of variation of the field-scale sprinkler pressure head to 9.4m. Figures 8a-8c also depict that as the lateral diameter is reduced from 76.2mm to 50.8mm and then 44.45mm, the sprinkler discharge contours become nearly parallel to the mainline, the implication being the spatial distribution of sprinkler discharges become increasingly dominated by lateral diameters. In light of the significance of pipe diameter on friction and local head losses, the observed level of sensitivity of field-scale spatial distribution of pressure heads and discharges is consistent with hydraulic theory.

Although the location of the minimum and the maximum sprinkler discharges within the irrigated field is unaffected by changes in lateral diameter, the spatial distribution patterns of sprinkler discharges and their ranges of variation exhibit significant sensitivity to lateral diameter (Figures 8d-8f). In a manner similar to what has been observed in relation to sprinkler pressure heads (Figures 8a-8c), as the lateral diameter is reduced, the field-scale distribution of sprinkler discharges become increasingly dominated by the effects of lateral diameter.

Lateral slope

In order to evaluate the effects of changes in lateral slope on the spatial distribution and range of variation of sprinkler pressure heads and discharges simulation is conducted for two additional scenarios: one in which the field surface has a constant longitudinal slope (slope in the direction parallel to the laterals) of 0.1% and another one of 0.3%. Note that this implies one half of the field is irrigated with laterals running uphill with a slope of 0.1% or 0.3% and the other half is

irrigated by laterals with a longitudinal slope of -0.1% and -0.3%. Although irrigated fields with 0.1% slope are common in the Yuma Valley, the large slope of 0.3% is used because of its theoretical appeal. The sprinkler pressure head and discharge distribution resulting from a relatively steep negative slope (considering one-half of the field irrigated) is unique and lends itself to qualitative verification based on intuitive hydraulic reasoning.

Simulated pressure head and discharge distributions for a field surface with longitudinal slopes of 0.01% (actual system used in the field study, Table 5), 0.1%, and 0.3% are depicted in Figure 9a-9f. Considering the scenarios with longitudinal slopes of 0.01% and 0.1%, the location of the maximum and minimum sprinkler pressure heads within the irrigated field are essentially the same. However, the pressure head contours for the field with a longitudinal slope of 0.1% are slightly shifted to the right compared to that for a field with a 0.01% slope (Figure 9b). On the other hand, when the longitudinal slope of the field is increased to 0.3%, in the part the irrigated field where laterals run uphill, the locations of the maximum and the minimum sprinkler pressure heads within the field remain essentially unchanged (compared to the scenarios with longitudinal slopes of 0.01% and 0.1%, Figure 9a and 9b). However, the range of variation of the field-scale sprinkler pressure head is larger for 0.3% slope, reflecting the effect of increased lateral slope on pressure head. Considering the part of the irrigated field with a lateral slope of -0.3%, the sprinkler pressure head decreases over the upper 110.0m length of the field and then increases in the field segment downstream (Figure 9c). While the maximum sprinkler pressure head occurs at the system inlet, the minimum pressure head occurs along the distal end lateral at about 110.0m from its inlet end. The observed pattern of sprinkler pressure head distribution can be explained by the interactive effects of lateral slope and energy loss due to friction and local losses along laterals.

The effect of lateral slope on the spatial distribution pattern of sprinkler discharges and the location of the maximum and minimum sprinkler discharges is about the same as that observed above in relation to sprinkler pressure heads (Figures 9d-9f). As will be shown in Figure 11, the system characteristics curve does not show appreciable sensitivity to changes in lateral slope within the range considered in the current study. Overall, the results indicate that the system hydraulic characteristics show very little sensitivity to significant changes in field slope, which confirms the preceding observation that the hydraulics of the field-sprinkler system used in the study is dominated by the relatively large pipe (mainline and lateral) diameters. Note that this is typical for sprinkler systems in the Yuma Area.

Pipe absolute roughness

The friction head loss computed as a function of pipe absolute roughness of 0.127 (value recommended for aluminum pipes, Table 5) is very small. Hence, the hydraulics of the sprinkler system used in the field evaluation (Figure 6) should be virtually insensitive to lower values of pipe absolute roughness. In the current study, the field-scale spatial distribution of sprinkler pressure heads and discharges were evaluated only with respect to pipe absolute roughness values that are significantly larger than 0.127: 0.254 and 0.381, representing a 200% and 300% increases, respectively.

As can be noted from Figures 10a-10f, increasing pipe absolute roughness by 300% from 0.127 to 0.381 has virtually no effect on the location of the maximum and minimum sprinkler pressure heads and discharges within the field and also in the patterns of the sprinkler pressure head

contours. This is consistent with the fact that the changes in absolute roughness affect the entire sprinkler system network uniformly. As would be expected the increase in pipe absolute roughness resulted in a slight increase in the rate with which sprinkler pressure heads and corresponding discharges decrease with distance from the system inlet (Figures 10a-10f). Nonetheless, the changes in sprinkler pressure head and discharge are very small compared to the respective increase in pipe absolute roughness. Again the main reason for this is that the relatively large pipe diameter dominates the sprinkler system hydraulics. The effect of pipe diameter compared to hydraulic roughness characteristics of the pipe can be readily evident by examining the energy equation which shows that pipe diameter has a strong nonlinear effect on the energy equation compared to hydraulic roughness which has a much milder nonlinear effect compared to pipe diameter. As can be noted from Figure 11, the system hydraulic characteristics curve did not show appreciable sensitivity to changes in absolute roughness. This is consistent with preceding observation that the sprinkler pressure head was only slightly affected by changes in absolute roughness (Figure 10a-10c). Overall, the results suggest that the hydraulic characteristics of the sprinkler system considered here are virtually insensitive to significant changes in pipe hydraulic resistance properties.

Sensitivity of sprinkler system hydraulic characteristics: The sensitivity of the sprinkler system hydraulic characteristics to changes in lateral diameter, pipe absolute roughness, and lateral slope is summarized in Figure 11. Consistent with the preceding discussion, the sprinkler system hydraulic characteristics shows little sensitivity to significant changes in laterals slope and pipe absolute roughness. However, the hydraulic characteristics curve of a sprinkler system with lateral diameter of 50.8mm shows that for a given discharge at the system inlet, Q_s, the corresponding total dynamic head, H_s, is appreciably higher than the total dynamic head for a sprinkler system with lateral diameter of 76.2mm. Further reduction in lateral diameter to 44.45mm results in a system hydraulic characteristics curve that is significantly higher than that obtained for lateral diameters of 76.2mm and appreciably higher than that obtained for a lateral with a diameter of 50.8mm. Note that these results are consistent with intuitive hydraulic reasoning and observations noted above with regard to the sensitivity of sprinkler pressure and discharge to lateral diameter. As can be noted from Figure 11, if all the geometric, hydraulic, and topographic attributes of the sprinkler system is kept constant (at the level given in Table 5) and only the lateral diameter is varied, then the system with the smallest lateral diameter requires the largest total dynamic head (and power) to deliver a given discharge.

Model applications

With the aim of highlighting the practical application of the model, described here, in the context of sprinkler systems with variable topographic and geometric characteristics, results of field-scale hydraulic simulations for systems with both single-line and double-line laterals is presented in Figure 12. The input data sets used in the simulation example are summarized in Table 5. A summary of the hydraulic simulation outputs with direct significance in terms of their effect on irrigation uniformity is presented and discussed in subsequent sections.

Single-line laterals

The irrigated field considered in this example has a rectangular shape with a width of 149.4m and a length of 374.8m (Table 5 and Figures 12a and 12b). The field has no cross-slope. Note that the term cross-slope here refers to the land surface slope in a direction parallel to the shorter side of the field. Longitudinally (referring to the direction parallel to the longer field dimension),

the field is comprised of three parcels (shown in Figures 12a and 12b separated by dashed lines) each with a constant slope yet different from an adjacent parcel: the upper 128.0m reach of the field has a uniform slope of -0.3%; the middle section of the field (spanning between 128.0m and 256.0m) is level; and the lower section of the field (between 256.0m and 374.7m) has a slope of 0.5% (Table 5). The sprinkler irrigation system considered here consists of a 149.4m long mainline installed across the head end of the irrigated field with a constant elevation of 100.0m (0.0% slope). It is comprised of 203.2mm diameter aluminum pipe sections with an absolute (equivalent sand grain) roughness of 0.127mm. The mainline has fourteen off-take nodes set at a regular spacing of 9.14m, each supplying water to 374.8m long laterals. Since the laterals run normal to the mainline, following the spatial variation of the longitudinal slope of the field, each lateral has three distinct segments with different slopes. All the laterals are comprised of aluminum pipe sections with 76.2mm diameter and the same hydraulic resistance characteristic as the mainline. Each lateral has 41 sprinklers installed at regular spacing of 9.14m. The local head loss coefficients and the parameters of the sprinkler pressure head-discharge function are also summarized in Table 5.

The simulated spatial distribution of sprinkler pressure heads and discharges for the example with single-line laterals are summarized in Figures 12a and 12b, respectively. As can be noted from Figure 12a, the maximum sprinkler pressure head occurs at the inlet end of the sprinkler system (57.2m) and the minimum occurs at the field corner opposite the system inlet (53.9m). The range of field-wide pressure head variation is 5.9% of the field-scale average (55.1m). Considering the standard recommendations for sprinkler lateral and mainline design (Keller and Bleisner, 1990; Martin et al., 2007b), this represents a highly uniform field-scale pressure head distribution.

Considering the direction parallel to the main (Figure 12a), the sprinkler pressure head distribution over the upper half of the field (hydraulically speaking) shows appreciable levels of sensitivity to distance from the system inlet along both coordinate axes: parallel and normal to the mainline. However, as one moves further away from the inlet in a direction normal to the laterals, the contours tend to be parallel to the mainline. The implication is that in the lower half of the field sprinkler pressure head shows little variation with distance in a direction normal to the laterals, but exhibit appreciable sensitivity with distance in a direction parallel to the laterals. In addition, it can be noted that the pressure had contours within each of the field parcels show discernibly different curvature patterns as influenced by the changes in longitudinal field slope (Figure 12a). The contours in the region close to the upper boundary of each parcel tend to cluster more closely relative to the contours in the lower sections of, the same field parcel and, the parcel upstream. The implication is that within a field parcel, sprinkler pressure head decreases at a decreasing rate as one moves downstream along the laterals, but then the rate of decrease in sprinkler pressure head increases as one crosses into the field parcel downstream. Note that this is due to the interactive effects, of the field topographic configuration considered here and the decrease in discharge along a lateral, on the pressure head.

Figure 12b depicts the spatial distribution of sprinkler discharges. The maximum sprinkler discharge in the field is 0.1027L/s (1.628GPM) and it occurs at the inlet end of the sprinkler system. On the other hand, the minimum sprinkler discharge is 0.0996L/s (1.579GPM) and is located at the corner opposite to the inlet end of the field. The range of field-scale sprinkler discharge variation is 3.0% of the field-wide average discharge of 0.101L/s (1.6GPM). This

represents a highly uniform field-scale spatial distribution of sprinkler discharges. In addition, if the irrigation application rates can be shown to be less than the soil steady state intake rate, this results should also imply a highly uniform irrigation; provided the system is properly installed, well maintained, and is operated under conditions of low wind speed. Note that the observations made in relation to the pattern of the sprinkler pressure head contours (Figure 12a) apply to the sprinkler discharge contours as well (Figure 12b). The lateral inlet discharges vary between a minimum of 4.123L/s (65.4GPM) and a maximum of 4.158L/s (65.9GPM). The total system discharge is 57.9L/s (917.0GPM) with the corresponding total dynamic head (specified at the input) being 158.0m.

Double-line laterals

The irrigated field considered in this example as well is rectangular in shape with a width of 160.0m and a length of 749.6m (Table 5, Figures 12c and 12d). The field has zero-cross slope. The length of the main is 160.0m and it runs across the middle of the field dividing the field into two equal halves of each 160.0m wide and 374.8m long (Figures 12c and 12d). The mainline here is comprised of pipe sections with the same diameter and hydraulic roughness characteristics as that used for the single-line laterals example presented above. It is installed on a surface with a constant elevation of 100.0m from the reference datum and has 15 equally spaced off-take nodes each supplying a pair of 374.8m long laterals installed on either side, resulting in total of 30 laterals in the field (15 on each side). On both sides of the mainline the laterals are set on a uniform slope of -0.055%. Each lateral consists of three segments of different diameter aluminum pipes (Table 5): over the upper 128.0m reach of a lateral 76.2mm diameter pipe sections were used, followed by a middle segment (spanning the distance between 128.0m and 228.0m from inlet end of the lateral) with a diameter of 63.5mm, and a distal segment (between 228.0m and 374.8ft) with a diameter of 50.8mm. Note that boundaries of the field parcels with different lateral diameters are shown by dashed lines in Figures 12a and 12d. Each lateral has 41 sprinklers installed at a regular spacing of 9.14m. The local head loss coefficients and the parameters of the sprinkler pressure head–discharge function are also given in Table 5.

The simulated spatial distribution of sprinkler pressure heads and discharges are summarized in Figures 12c and 12d, respectively. Noting that the two halves of the sprinkler system considered here represent two hydraulically parallel networks with the same geometric, hydraulic, and topographic characteristics (Table 5), subsequent discussion will focus on describing the pressure head and discharge distribution patterns for one-half of the field. The implication being the same inferences can be made for the other half of the field.

Considering either half of the field, it can be noted that the maximum sprinkler pressure head (56.1m) occurs at the system inlet and the minimum pressure head (48.8m) occurs at the field corner opposite to the inlet. The range of the field-scale sprinkler pressure head variation is 14.5% of the average pressure head (51.2m). This represents a sprinkler system operating at a much lower level of irrigation uniformity than that envisaged for the single-line lateral example presented above. It, nonetheless, represents a system with a field-scale sprinkler pressure head variation that is well within the recommended range for acceptable level of uniformity. Referring to the direction normal to the laterals in Figure 12c, the sprinkler pressure head distribution over the upper half of the field (hydraulically speaking) shows appreciable levels of sensitivity to distance from the sprinkler system inlet along both coordinate axes: parallel and normal to the main. On the other hand, in the lower half of the field, pressure head exhibits significantly

reduced or little variability with distance measured from the system inlet in direction parallel to the mainline. However, sprinkler pressure heads shows appreciable levels of sensitivity to distance in a direction parallel to the laterals.

Considering either half of the irrigated field, the pressure had contours in each of the field parcels (field subdivisions with different lateral diameters) show discernibly different curvature pattern as influenced by the changes in lateral diameters (Figure 12c). Here as well, as in the single-line lateral example, the contours in the upper end of each field parcel tend to cluster more closely relative to the contours in the lower sections of, the same field parcel and, the parcel upstream. The implication being that within a parcel sprinkler pressure heads decrease with distance at a decreasing rate along the laterals, but then the rate of decrease in sprinkler pressure head increases as one crosses into the upper reach of the field parcel downstream (Figure 12c). Note that this is due to the interactive effects, of the lateral diameter configuration considered here and the decrease in discharge along a lateral, on the pressure head.

Figure 12d depicts the spatial distribution of sprinkler discharges with a maximum value of 0.1017L/s (1.612GPM) which occurs at the inlet end of the sprinkler system and a minimum value of 0.0945L/s (1.498GPM) at the corner opposite to the inlet. The range of field-scale sprinkler discharge variation is 7.5% of the field-wide average discharge of 0.0969L/s (1.536GPM). This represents a highly uniform spatial distribution of sprinkler discharges, which could lead to a highly uniform irrigation if the system is properly maintained and well managed. Note that the observations made in relation to the pattern of the sprinkler pressure head contours apply to the sprinkle discharge contours as well (Figure 12d). The lateral inlet discharges vary between 3.93L/s (62.3GPM) and 4.09L/s (64.8GPM). The system discharge is 119.2L/s (1889.1GPM) with a total dynamic head of 158.0m, which is specified at the input (Table 5). The system discharge is equally divided between the two halves of the irrigated field, this is due to the fact that the hydraulic, geometric, and topographic characteristics of the two subsystems are identical.

System hydraulic characteristics curves

Figure 12e depicts the functional relationship between total dynamic head and system discharge (system hydraulic characteristics) for both the single-line laterals and the double-line laterals layout configuration examples described above. While noting that the two sprinkler systems represent hydraulically different networks, some comparison of the system hydraulic characteristics can be made. Both curves show that the total dynamic head is a strictly increasing convex function of system discharge, which is in agreement with the general behavior of such a curve. The curve for the system with single-line laterals layout configuration has a steeper slope compared to that of the double-line laterals layout configuration. Considering the region of the system hydraulic characteristic curves where there is overlap, the preceding observation implies that for a given system discharge, the corresponding total dynamic head for the single-line laterals system would be much large than the total dynamic head for the double-line laterals system. In practical terms what this result suggests is that the pumps appropriate for operating these systems efficiently would have significantly different characteristics curves. In comparative terms it can be noted that high capacity, low head pumps would be more appropriate for the double-line laterals system and the opposite is true for the single-line laterals system.

Outreach

January 2012 to March 2012.

During this period we conducted in-field evaluations demonstrations in grower fields in the Yuma area. There were approximately five or seven producers present at each of seven on-farm evaluations.

This model was presented in a presentation at the SW Ag. Summit on March 8, 2012. About 20 producers and crop advisors were present at this meeting.

April 2012 to June 2012.

We demonstrated the utility of the model in a grower meeting at the Maricopa Agricultural Center. There were approximately 20 producers and crop advisors at this meeting.

Field evaluation-demonstration in central Arizona at the Maricopa Agricultural Center. No more than 3 growers and crop advisors attended this event.

July 2012 to September 2012

We provided demonstrations on the use of this model at workshop in Yuma. There were approximately 40 producers and crop advisors at this workshop in Yuma.
January 2013 to March 2013

We conducted four more demonstrations in grower fields. Three or four growers, farm workers, and crop advisors attended this event.

We wish to note that outreach programs continue beyond the life of the funded project as the data collected and knowledge gained becomes part of our expertise and technology that we are obliged to transfer to producers in on-going programs. For example we conducted four additional in field demonstrations during February 2014.

Beneficiaries

The beneficiaries are principally vegetable producers in the low desert. The information gained in this project allows growers to operate sprinkler systems for more uniform and efficient water application. Furthermore, we have this technology on the shelf to impact more producers as our outreach activities continue. However, water conservation benefits all residents relying in this precious resource in the arid southwestern United States.

Lessons Learned

Overall, the results of these field-scale hydraulic modeling studies suggest that typically the hydraulic design of sprinkler systems used in the Yuma area are robust. The practical effect of which is that if a typical field-scale sprinkler system in the Yuma area are properly set, well maintained, and operated under conducive ambient weather conditions, they can produce high levels of irrigation uniformity under widely varying field slopes and hydraulic roughness. The results of field irrigation uniformity studies also support the preceding observation: field-scale

sprinkler irrigation uniformities can be maintained at a high level (a UCC of about 0.8), provided the system is operated at relatively low average wind speed (about or less than 2.0m/s), irrigation does not take place under hot and dry weather conditions, attention is given to proper regular maintenance of the sprinkler system (frequent inspection and maintenance of system components especially sprinklers), and application rate is low enough to prevent runoff.

The following set of recommendations identifies the limitations of the current study and outlines possible challenges for further studies aimed at improving sprinkler irrigation system design and management in the Irrigation Districts of the Yuma area:

1. Field-scale sprinkler irrigation uniformity is a function of various factors (weather, system hydraulics, level of system maintenance, and irrigation management) that may possibly vary in time and space. Considering the limited nature of these studies, the results cannot be generalized with high degree of certainty for the entire Yuma area. Hence, additional field studies may need to be conducted, in order to establish typical irrigation uniformity levels, and the range of variation, across the irrigation district.

2. Irrigation uniformity defines one aspect of irrigation performance, the others being field application efficiency and irrigation adequacy. Irrigation uniformity is often used to characterize sprinkler system performance, because the factors used to compute uniformity are relatively easy and inexpensive to measure and that there are standardized field methods for collecting the requisite data. While high uniformity is a prerequisite for high application efficiency, high application efficiency does not automatically follow high uniformity. The duration of irrigation application must be set such that irrigation is adequate and efficient, considering irrigation interval, crop, soil, and atmospheric conditions.

3. Optimal design and management of field-scale sprinkler systems is key to the efficient irrigation of crops with such systems. Mathematical models are inexpensive and flexible tools for the design and management of sprinkler systems. A mathematical model capable of quantifying field-scale sprinkler irrigation performance (uniformity, efficiency, and adequacy) as a function of hydraulic, geometric, topographic, soil, atmospheric, and crop factors requires the coupling of a rigorous field-scale sprinkler hydraulic model with a droplet-dynamics submodule (for computing the pattern of precipitation around a sprinkler, e.g., Playan et al., 2009) and a soil water flow model (for simulating subsequent infiltration and soil water flow processes, e.g., Simunek et al., 2009). The development of a computationally efficient and robust coupled field-scale sprinkler model for system design and management applications remains a challenge.

4. A sprinkler system with high irrigation application uniformity may not necessarily be optimal from economic cost/benefit perspective. Hence, a more comprehensive field-scale sprinkler system evaluation may include economic evaluation of existing and alternative system layouts, pipe sizes, pipe appurtenances, and sprinkler combinations.

5. Field experience suggest that attention needs to be given to the proper setting and routine maintenance of the sprinkler system in order to realize potentially achievable field-scale sprinkler irrigation uniformities. Some of the issues that require

consideration in this regard are: proper setting of laterals such that sprinkler risers are vertical, routine maintenance of system components (particularly cleaning of sprinklers following or prior to an irrigation event), timely replacement of worn out sprinklers and damaged pipe sections, and need to guard against inadvertent mixing of sprinklers with different hydraulic characteristics.

6. Experience with field studies suggest that for field-scale sprinkler systems that are well maintained, a single test-plot placed somewhere in the middle of the field can provide precipitation data that can adequately characterize field-scale uniformity. However, if possible two or three test-plots distributed uniformly (preferably along the field diagonal from the sprinkler system inlet), unless other requirements dictate otherwise, can be used to obtain a more representative sample of the variations in field-scale irrigation uniformity.

7. Growers cognizant of the results of the studies have begun to implement our recommendations. At minimum, seven growers that we know of are operating sprinklers differently based on information gained in this project. These are large growers so we estimated we have impacted at least 10,000 acres. Outreach activities are on-going with other funding.

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Additional Information

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Soil Compaction Reduction of Date Yields

This project was completed on September 30, 2013

Project Summary

Production of high quality 'Medjool' dates is costly. Multiple orchard passes with heavy equipment are required for all but the smallest palms, including single passes for tillage, de-thorning, and bagging and multiple annual passes for pollination, fruit thinning and harvest. Ten annual passes through the field are common. For tall trees in particular, workers must be lifted to the crown, which necessitates large, heavy lifting machinery, weighing several tons. Current machinery management used in Medjool dates production relies of foam-filled tires to avoid tire blowouts and balance mechanical loads lifted to significant heights above the ground, but one undesirable consequence is the increase in tire stiffness which allow significant additional pressure and stresses to be transmitted to the soil.

Soil is a granular material composed of particles held together by internal forces, which give result to a mechanical property known as soil strength. Many soil properties affect the state of soil strength, but in addition to natural factors, external loading caused by mechanical means such as machinery traffic and tillage will have an effect of great magnitude in changing the void space where air and water are transported. If soil is not managed properly, soil strength can reach values so high that will negatively impact most physical, chemical and biological processes that take place in the soil with direct consequences in reducing the productivity potential of soil.

Defining the level of soil strength that can be classified as compaction is not a trivial question. The threshold value of soil strength at which the soil is no longer able to function at its full potential is a research question that must be answered in the context of the particular cropping system and the environmental conditions. Date palms have a shallow root system that differs from most tree crops, and the mechanical behavior of sandy or clay soils of the semi-desert is heavily influenced by textural characteristics. Therefore, if soil compaction is suspected to affect the productivity levels of palm dates, we must first characterize the dynamics of soil strength throughout the growing season, and establish the nature of the relationship between compaction levels and yield components, especially date quality.
Arizona date growers are concerned about compaction. In our informal discussions with growers, most thought that compaction could be a hindrance to improved fruit yields and quality. A small study, (Abdul-Baki, et al, 2002) comprising 14 'Deglet Noor' trees, in two locations in California suggested that there is some negative relationship between soil compaction and fruit yield and quality. This relationship was not measured, but presented as conjecture. Additionally, the small size of that study, the lack of statistical analysis and the level of grower concern suggests that further research is needed.

So, we proposed to characterize the dynamics of soil strength and root growth through the growing season, and establish the nature of the relationship between compaction levels, root growth and yield.

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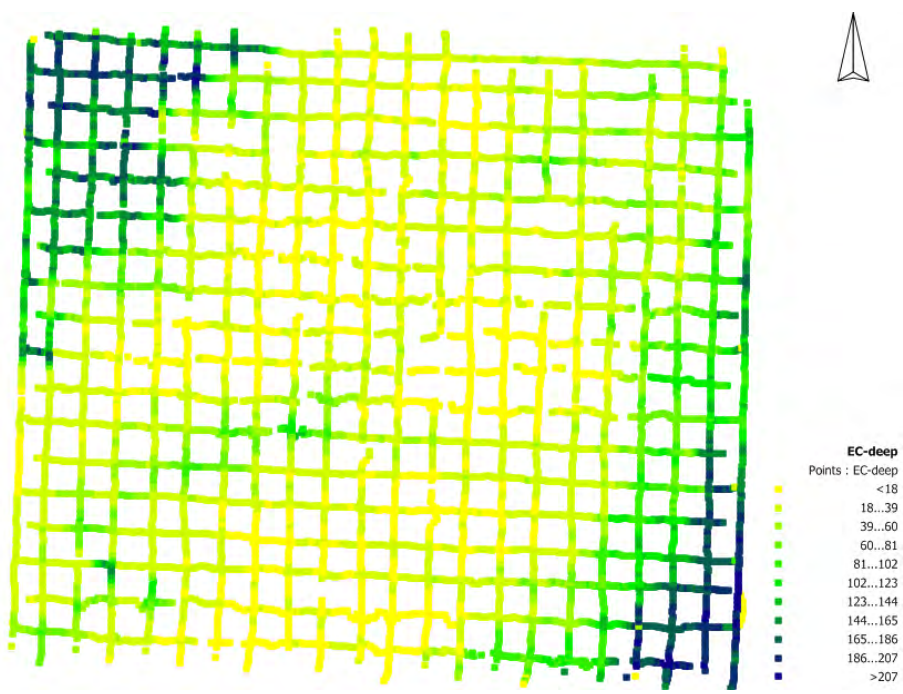
Project Approach

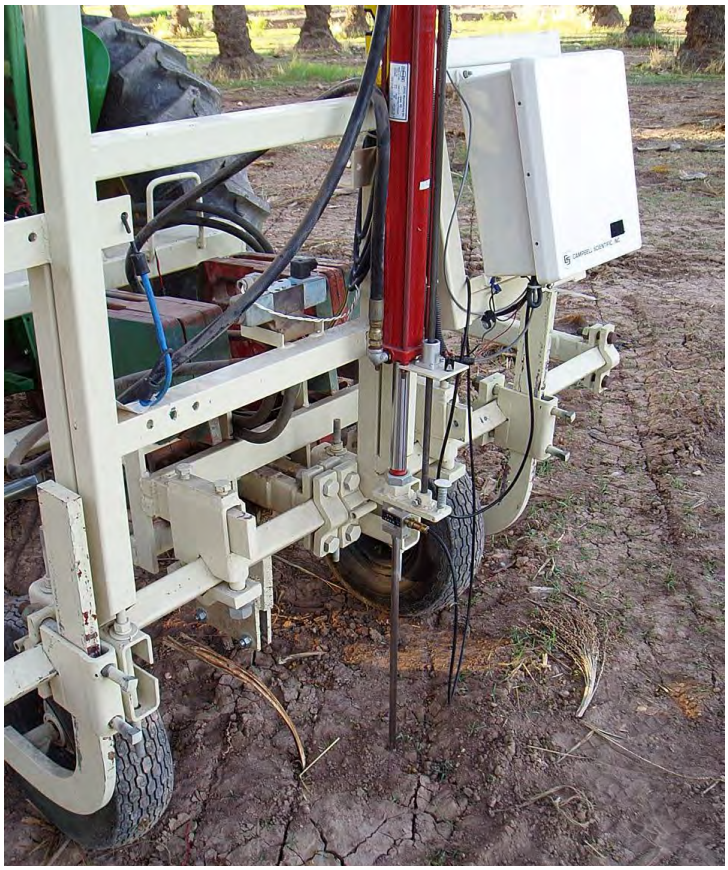
Soil compaction measurements and analysis. Summary/accomplishments:
Most of this work accomplished by Andrade-Sanchez, Huen, and with assistance from the field crews of the date growers. Occasional assistance from Moreno and Dr. Wright's field crew.

1. Successfully characterized in-field variability of soil in three flood irrigated orchards. Field characterization was achieved with the use of apparent electrical conductivity sensor (ECa), advanced global positioning system (GPS) receiver, and geospatial software for data analysis. The electrical conductivity or ECa of a soil or water sample is influenced by the concentration and composition of dissolved salts. Salts increase the ability of a solution to conduct an electrical current, so a high EC value indicates a high capacity of the soil to retain moisture which could be caused by a combination of salinity and heavy (fine) texture. Soil variability analyses defined field zones of high, medium, and low ECa for subsequent field research. The figure below provides a visual description of ECa field distribution in a flood-irrigated site:



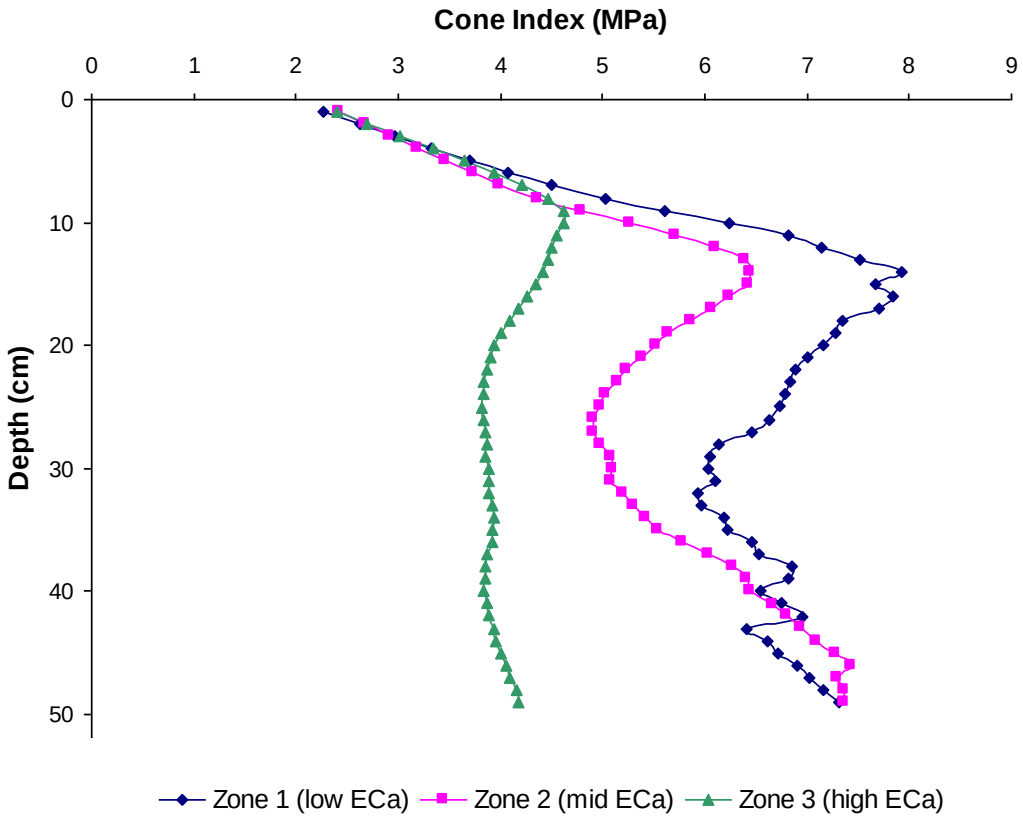
2. Soil electrical conductivity (ECa) survey was not an effective tool for soil variability assessment in Yuma Mesa study site due to extremely dry conditions of sand soil in the trafficked area.

3. Successfully adapted instrumentation to measure soil strength for compaction assessment in date orchards. The measuring system included a force sensor (load cell), GPS, Cone-Index probe, probe displacement sensor and ruggedized data logger. A farm tractor provided mobility as well as electric and hydraulic power requirements of this system. Details of the soil compaction system design and construction are seen in the picture below.

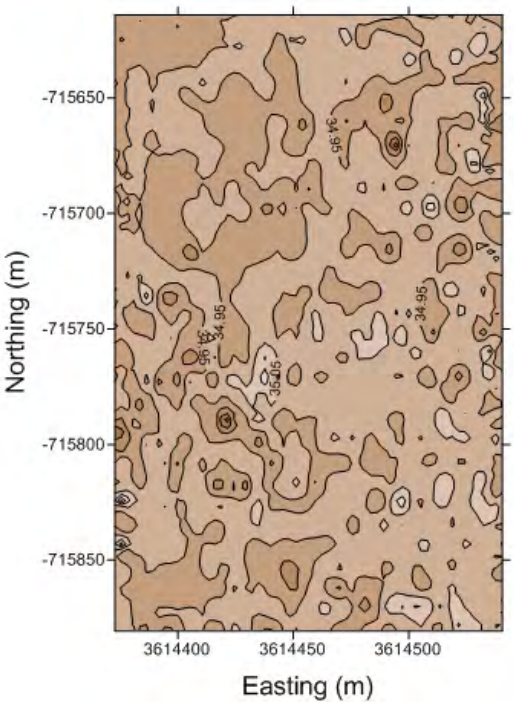


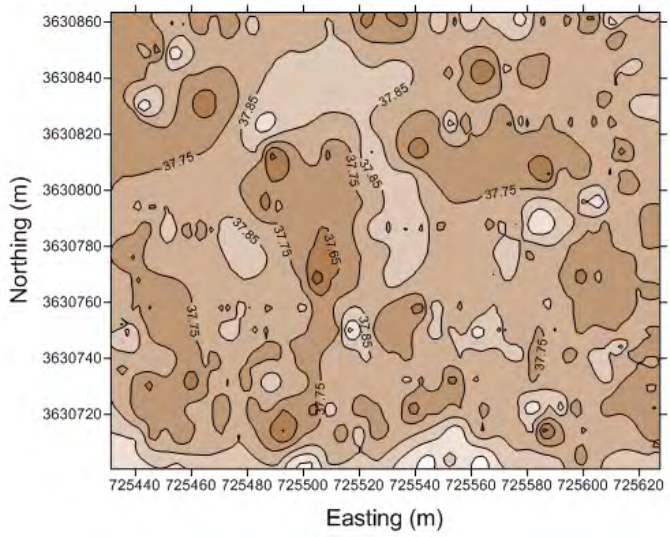
4. Implemented research design based on replicated soil compaction measurements in all four sites included in this study. The experimental factors included: ECa zone (high, medium, low); traffic pattern (high, low); distance away from tree trunk (5, 10, and 15ft); and soil profile depth (0-20 inches in 0.5 inch increments).

5. Field measurements of soil compaction were successfully carried out at two different stages in orchard management: first during the summer months at the time of maximum mechanical loading caused by lifting equipment; and later during the winter time after tillage operations. Typical values of subsoil compaction in a flood-irrigated site are seen in the graph below:



6. We successfully deployed a utility vehicle instrumented with ultra-precise GPS (RTK) to generate high precision field elevation data to study patterns of surface water distribution during irrigation events. Maps of elevation surveys in three orchards showed typical surface irregularities but no topographic trends to define low spots. Field distribution of soil ECa was not associated with fall or side slope values, confirming that soil variability in ECa was driven by soil physical/chemical properties.



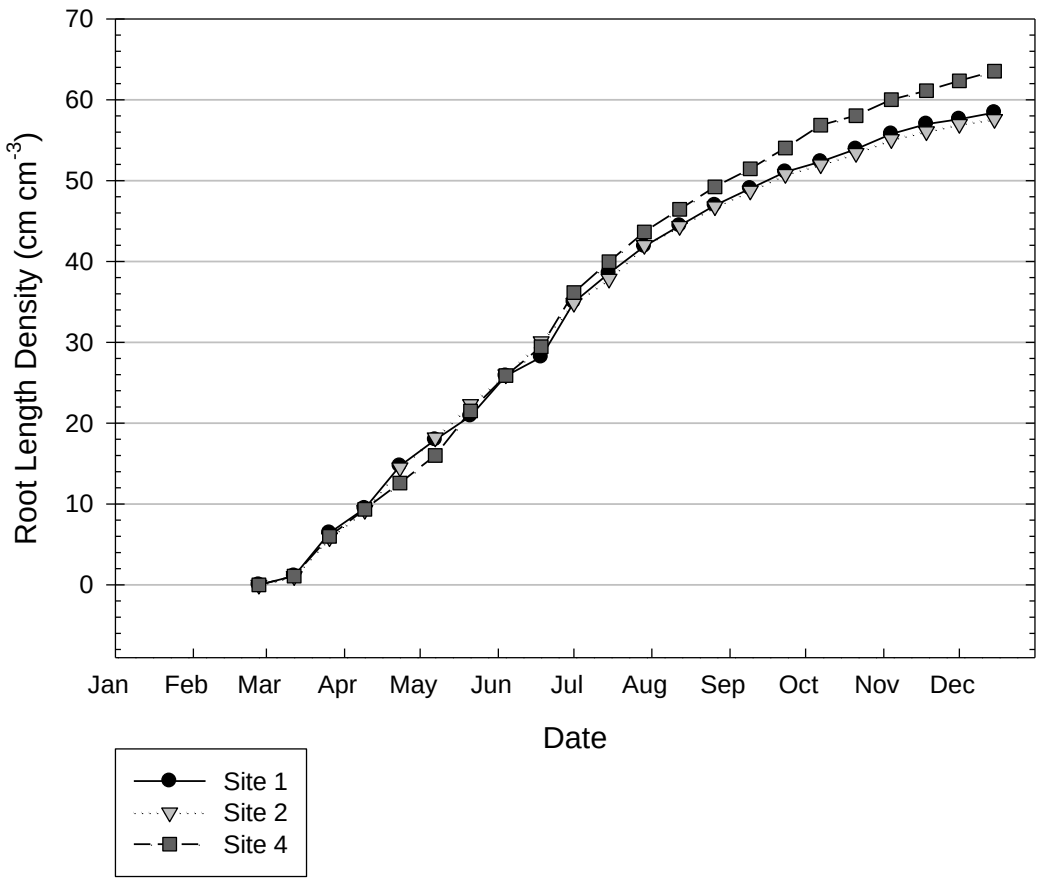


7. Soil sampling and subsequent physical/chemical analysis in two experimental sites confirmed that soil texture was the property with the strongest effect on ECa and therefore soil compaction. The results of this analysis and others also showed that ECa values increase with salinity and percent clay content. Top soil layer density is kept at reasonable-low levels via tillage and other floor management practices such as winter cover crops. Soil density is lowest where there is no machinery traffic (5 ft. away from trunk) but there is a slight increase in the middle of the panel (10 and 15 ft. away from trunk) as the expected effect of machinery traffic in these areas.

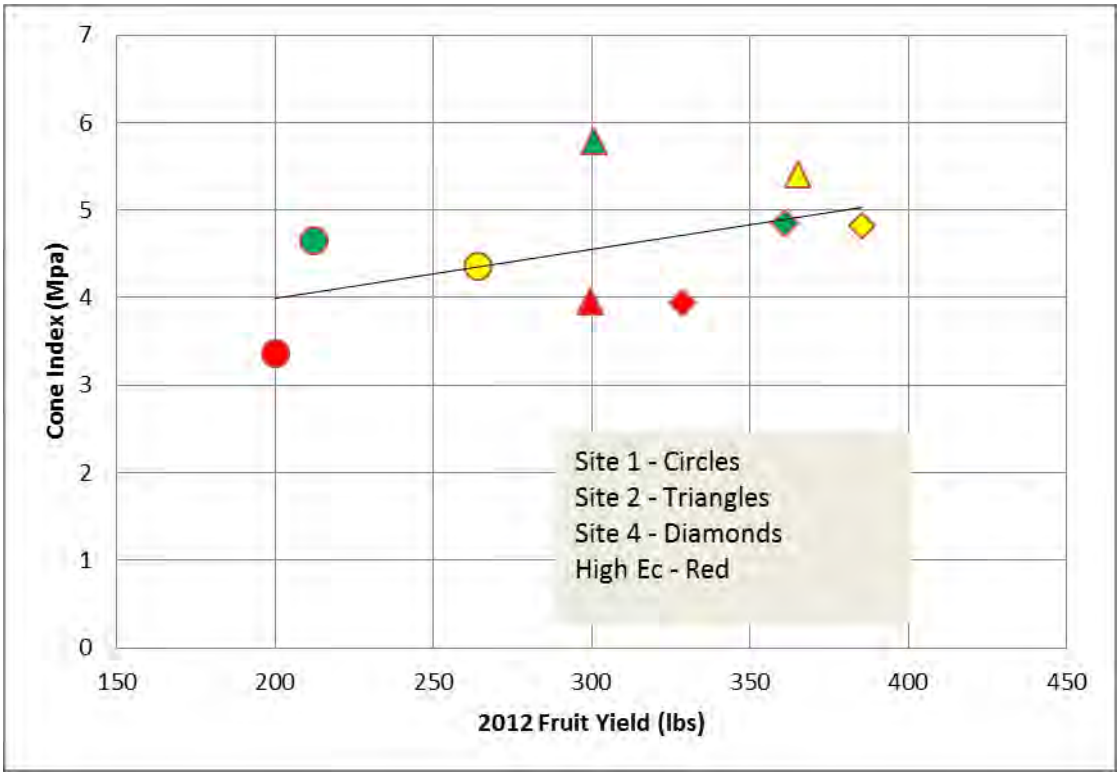
8. A pattern of soil profile stratification revealed that a layer of clayey soil sits on top of pure sand. The thickness of the clayey layer (or depth to the sand layer) determined the ability of the soil to hold moisture and thus determined the extent of soil compression as wet soil suffers more deformation to the same load than dry soil.

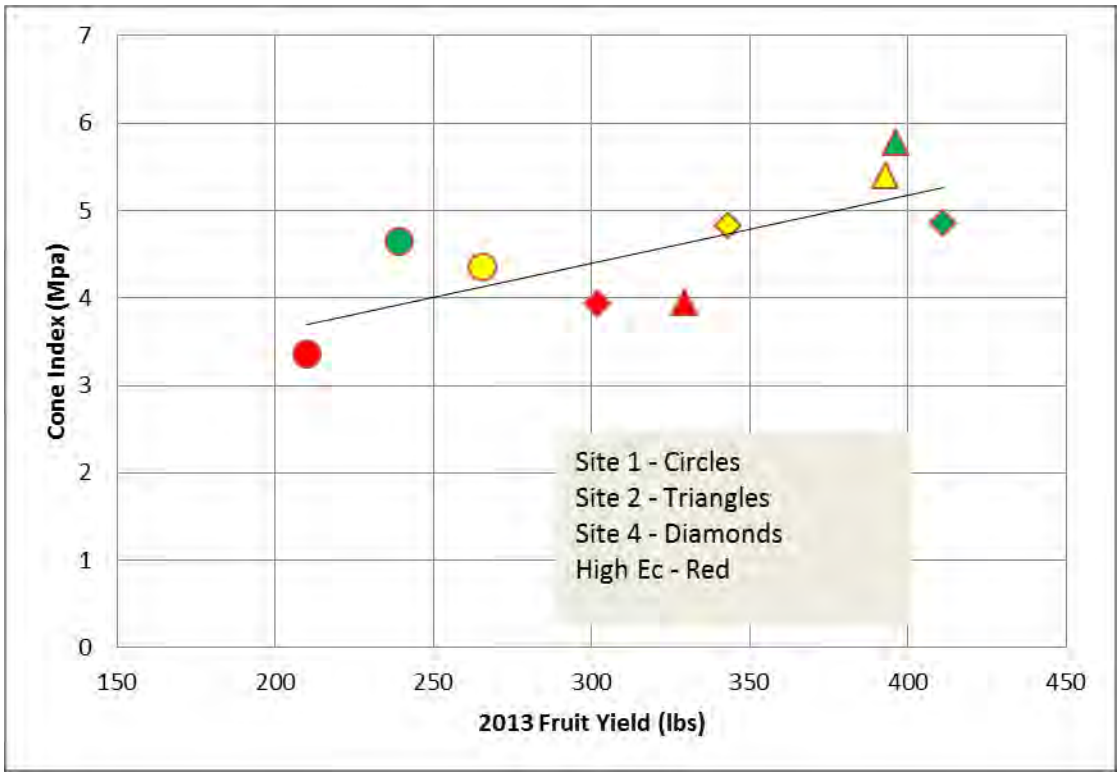
Root Density and Yield Summary/accomplishments:
This work accomplished by Wright, Moreno, Wright's field crew, with assistance from the field and packinghouse crews of the date growers.

1. Root length data was analyzed for the 2012 and 2013 calendar year for each of the three flood irrigated sites. Data is presented as average root length density (RLD) for the portion of the soil profile in which the root tubes are placed. We could not measure any effect of soil EC on root length density. As an example, the 2012 data is presented in the graph below (2013 data was similar):



2. We described the relationship between yield and ECa level and the Cone Index (a measure of soil strength) is as follows:





It is important to note that the trees at the Lost 20 site are smaller and would be expected to have lower yields, while the trees at the Sun Gardens site are the oldest and have the greatest yield.

Generally speaking, areas within sites with high ECa had lower yields and higher cone indices. This indicates that areas that are affected by higher soil salinity and greater compaction had lower yields. For 2012, yields of areas with high ECa and compaction were 13% less than the average yields of areas of low and medium ECa and compaction. For 2013, the loss was 17%. We did not see an effect of ECa or compaction on date fruit quality.

Goals and Outcomes Achieved

1. We characterized the-field variability of soil in three flood-irrigated date orchards. This has been completed. However, soil apparent electrical conductivity (ECa) survey was not an effective tool for soil variability assessment in Yuma Mesa study site due to extremely dry conditions of sand soil in the trafficked area.
2. We successfully adapted instrumentation to measure soil strength for compaction assessment in date orchards. The measuring system included a force sensor (load cell), GPS, Cone-Index probe, probe displacement sensor and ruggedized data logger. We were able to measure soil strength successfully, and implemented a research design based on replicated soil compaction measurements. The experimental factors included: ECa zone (high, medium, low); traffic pattern (high, low); distance away from tree trunk (5, 10, and 15ft); and soil profile depth (0-20 inches in 0.5 inch increments).
3. We showed that ECa zones were highly correlated to the degree of soil compaction. These patterns of higher compaction in zones of higher ECa (higher soil water retention) were consistent across sites under flood irrigation, and over time.
4. We found that the degree of soil compaction was extremely high, especially in the center of the trafficked areas where Cone-Index values exceeded 5 times the typical soil strength of agricultural soils with field crops under conventional tillage. Compaction levels in close proximity to the tree trunk were significantly lower due to the lack of machinery traffic.
5. We were able to successfully measure root length, but we were not able to find any correlation between root length density and soil compaction or ECa.
6. We found that there is an effect of ECa and soil compaction upon yield. For 2012, yields of areas with high ECa and compaction were 13% less than the average yields of areas of low and medium ECa and compaction. For 2013, the loss was 17%.

Beneficiaries

Beneficiaries of the project are the 12 owner-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. Wright shared these results with five of the growers via a PowerPoint presentation and on paper at a meeting, at the Yuma Agriculture Center, in February, 2014. The other members had the information e-mailed to them.

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), other locations in Imperial County California, and in northern Sonora. Of that quantity, about 4000 acres are mature trees (over 15 years old).

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 to 14,000,000 pounds in 2012. In 2013, it is expected that the date yield will surpass 16 million pounds. Typical net return to the grower is $1.50 per pound, and by this calculation, the value of the industry for 2012 (DatePac only) is $21,000,000 annually. There is likely another $7,000,000 in value for the portion of the industry that is not packing through DatePac.

Considering the entire 7000 acres, about 2500 acres are flood-irrigated. While only comprising 36% of the total acreage, those acres contribute about 60% of the yield. Just considering DatePac, about 8.4 million pounds of dates came from flood irrigated orchards in 2012. If 10% of the total yield came from areas of high ECa and soil compaction, then 840,000 lbs. of dates are affected by these two factors. Considering a 13% yield loss due to ECa and compaction, then the potential yield without these two factors would be 965,000 lbs., for a difference of 125,000 lbs. annually. The economic value of this lost yield could be as much as $187,500 annually. Reducing salinity and compaction could save the industry a significant amount of money.

As of March 2014, three of the 12 grower-members of the Bard Valley Medjool Date Grower's Association are purposefully reducing compaction by not driving on every other row in their date orchards. In some cases, this is as a result of the work, and in other cases, our work encouraged the growers to continue the efforts that they were already doing to reduce soil compaction. It is likely that more growers in the region will adapt the practice.

Lessons Learned

1. We learned that soil apparent electrical conductivity is an effective tool to assess soil variability in heavy, flood-irrigated soils. It was not effective in sandy soils, this was not expected. However, since soil compaction is not likely to be a problem in sandy soils, we are not as concerned with our inability to assess soil variability in this case.
2. We learned that we could measure soil strength effectively in date orchards.
3. We learned that ECa zones were highly correlated to the degree of soil compaction. These patterns of higher compaction in zones of higher ECa (higher soil water retention) were consistent across sites under flood irrigation, and over time.
4. We learned that soil compaction in date orchards was more than five times the typical soil strength of agricultural soils planted to field crops. This is likely due to the effect of the mechanization needed to farm date palms.
5. We learned that compaction levels increased as proximity to the tree trunk decreased.
6. We learned that it is not easy to correlate root length with soil compaction or ECa. This was not expected. Perhaps additional data collection or a repositioning of the root tubes to extend further into the compacted zone would have achieved different results.
7. We learned that there is an effect of soil apparent electrical conductivity and soil compaction upon yield.

The next step would be an investigation of ways to mitigate soil compaction. These would include establishing of no-drive zones, addition and incorporation of organic matter to improve the soil structure. Another initiative would be the establishment of cover crops (clover, vetch, cowpea, etc.) in alternating, no-drive rows of the orchard. Roots of these plants would loosen the soil, some would fix nitrogen to supplement the trees, and they could be incorporated annually to add organic matter to the soil.

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Additional Information

We presented portions of this data orally to the date growing community in March, 2013, and will present the completed project to the growers in spring, 2014.

White Fly Dispersal and CYSDV Epidemiology

This project was completed on September 30, 2013

Project Summary

Melon production in Arizona currently ranks 2rd nationally, and desert growers produce over 90% of all cantaloupes and honeydews consumed in the U.S. during the fall harvest season. However, the recent emergence of the cucurbit yellow stunting disorder virus (CYSDV) as a serious whitefly-transmitted virus of fall melons threatens to potentially eliminate fall melon production in Arizona. CYSDV first appeared in 2006 and has become progressively worse throughout Arizona, causing significant losses in melon yields (reduced fruit numbers and size) and quality (reduced sugar levels). The adult whitefly vectors CYSDV, and transmission of the virus requires only short feeding times on plants. Thus, preventing whiteflies from dispersing and feeding on newly emerging seedlings is critical for suppressing CYSDV in melons. CYSDV management through vector control with insecticides has been expensive and to date, only marginally effective. Experience has shown that cultural practices are an important factor in the area-wide management of whiteflies, and likely for CYSDV as well. Unfortunately, the wide host range of both the vector and virus make common cultural practices like sanitation and host – free periods impractical. However, our previous field research suggested that there is a strong association between the magnitude of whitefly dispersal onto fall melons and incidence of CYSDV infection. In essence, melon fields are more likely to be infected with yield-limiting levels of CYSDV in growing areas where whitefly populations are high. Furthermore, CYSDV incidence and high whitefly abundance appear to be consistently high near known sources of whiteflies (cotton, alfalfa, weedy areas, and suburban areas) and known virus reservoirs (spring melons, alfalfa, weeds). Anecdotally these observations make sense, however these epidemiological relationships had not been scientifically validated prior to this project.

The objective of this project was to test the hypothesis that the extent of CYSDV infection in a field is positively associated with whitefly/CYSDV movement and their reservoir crop sources. With this information, we developed useful guidelines for CYSDV and whitefly management in Arizona melons. The results of our research show that a landscape-based approach allowing simultaneous assessment of impacts of local (i.e., planting date) and regional (i.e., landscape composition) factors provides valuable insights on how to reduce crop disease risks. Specifically, we found that planting fall melon fields early in the growing season, eliminating volunteer melons during the summer (plants germinating from seeds produced by previous spring melon crops after harvest), and planting fall melon fields away from cotton and spring melon fields may significantly reduce incidence of CYSDV infection in fall melons. Because the largest scale of significance of the positive association between abundance of cotton and spring melon fields and CYSDV incidence was respectively 1750 m and 3000 m, reducing areas

of cotton and spring melon fields within these distances from fall melon fields may decrease CYSDV incidence.

Project Approach

In 2011 and 2012 we monitored incidence of CYSDV infection and whitefly abundance in fall melon fields in Yuma County, Arizona. Most fields were located in the Dome Valley, except for three fields sampled in the Yuma Valley in 2011. Different fields were sampled in each year (n = 24 in 2011 and n = 23 in 2012). Position of sampled fields was determined with a Global Positioning System (GPS). We considered effects of the following crops on CYSDV infection and whitefly abundance: alfalfa, broccoli, cabbage, cauliflower, cotton, and fall and spring melon. In both years, we recorded location of all spring melon fields in the vicinity of sampled fall melon fields with GPS. Spring melon fields were inspected regularly after harvest to determine whether they contained volunteer melon plants. Fields of cotton, alfalfa, broccoli, cabbage, and cauliflower were identified with remote sensing in 2011 and from the ground in 2012. To measure relative abundance of whitefly adults, a single yellow sticky trap was positioned approximately 20 cm above ground level along the edge of each melon field monitored. After each trapping period, traps were taken into the laboratory where the numbers of adults on the trap surface were counted under 20× magnification. Virus infection was determined by visually inspecting plants within quadrants in each field for the presence of leaves that expressed CYSDV symptoms. In each of the four quadrants, 2 melon beds, 30 m in length were arbitrarily chosen to evaluate CYSDV infection. At each sampling period, the number of plants with virus symptoms in each quadrant was averaged to determine percent CYSDV incidence. For landscape analysis, in each year, three separate GIS maps were produced for spring melon with or without volunteer melon plants, cotton and the other crops. We mapped all crops but cotton with ArcGIS version 10.0. We drew twelve concentric rings around the edge of each sampled melon field. The smallest ring had a width of 250 m and the distance of each subsequent ring increased by 250 m (i.e., the second ring had a width of 500 m, the third ring a width of 750 m, etc…). The area of each crop type located between the edge of a sampled melon field and the outside limit of a ring was measured in m^2 with ArcGIS. Separate ring analyses were performed for spring melon, cotton, and the remaining crops, because fields at a distance < 3 km from the edge of the sampled melon fields were sometimes planted in succession with more than one crop from spring to harvest of melon fields. Because particular melon development stages may be more vulnerable than others to virus infection, we used simple linear regression to evaluate the association between whitefly abundance during specific melon stages and percentage CYSDV infection at harvest. When appropriate, spring melon fields with or without volunteer melon plants were considered separately in analyses, as they may have different effects on local amplification of infectious *B. tabaci* vectors. We used stepwise regression to identify explanatory variables with significant effects ($P < 0.05$) at each of the 12 scales of analysis. To gain statistical power, we also used the regression approach described above and pooled data from each year to evaluate the association between areas of the surrounding crops, pre-bloom date, and percentage CYSDV infection at harvest. We used semivariograms to assess spatial patterns in the response and explanatory variables. In stepwise and multiple regression analyses of individual years and pooled data, we accounted for any spatial autocorrelation through tests of significance using effective sample sizes and effective degrees of freedom.

In general, our analyses of CYSDV infection show a consistent positive association between abundance of spring melons (a virus reservoir crop) and cotton (a non-virus reservoir crop) in

proximity of fall melon fields and CYSDV incidence at harvest. Analyses of whitefly abundance in melon fields indicate that these trends likely occurred because spring melon fields and cotton acted as sources of vectors for fall melon fields. Moreover, an increase in the abundance of spring melon fields with volunteers was associated with a greater rate of increase in CYSDV incidence than a similar increase in abundance of spring melon fields without volunteers. Fields of spring melons with volunteers likely produce whiteflies over a longer period than fields without volunteers, thereby representing a better source of infectious vectors for fall melon fields. Melon fields with earliest pre-bloom dates had the lowest incidence of CYSDV infection in both years. Thus, fall melon fields planted later in the growing season had a higher incidence of CYSDV infection than fields planted earlier.

These results indicate that management of spring melon fields after harvest (i.e., rapid destruction of harvested crops and prevention of volunteer melons), planting date of fall melons (i.e., avoidance of late-planting), and placement of fall melons relative to spring melons and cotton (i.e., crop isolation) could reduce extent of CYSDV infection in fall melons. From a practical perspective, the later melons are planted in the fall, and the closer fall melons are planted to cotton or spring melons, the higher the risk was from both high whitefly infestations and CYSDV infection. However, assessing how such programs reduce the incidence of plant diseases has been difficult because many tactics are involved and there is uncertainty about the spatial scale over which tactics need to be implemented. The spatially-explicit approach used here simultaneously identified and evaluated multiple factors linked to disease risk. We feel it will provide Arizona melon growers with a useful tool for the design of efficient control strategies of crop diseases in the near future.

Goals and Outcomes Achieved

The goals of this study were to evaluate how the agriculture landscape composition contributes in affecting incidence of CYSDV infection and population density of whitefly in fall melon fields. Because young plants may be most susceptible to damage by whitefly and plant viruses, we first evaluated the relationship between abundance of whitefly during various development stages of melon and extent of CYSDV infection at harvest. We then used geographic information system (GIS) and remote sensing technology combined with spatial statistics to assess: 1) the associations between abundance of various crops surrounding melon fields and extent of CYSDV infection and abundance of whitefly in melon fields, and 2) the spatial scale of the associations between regional abundance of the crops and incidence of CYSDV infection and abundance of whitefly. Although few studies so far have measured effects of landscape composition on plant disease epidemiology, our studies showed that landscape-based analyses can provide useful insights on effects of crop placement (fall melons relative to cotton/spring melons) and insect vector (whitefly) movement on disease (CYSDV) incidence.

We are planning to report the findings reported in this project to melon producers throughout the state. These results confirm a priori expectations about factors affecting CYSDV incidence in fall melons based on > 20 years of intensive study of this system. We believe that we will be able to convince producers to manage spring melon fields in accord with results presented in this study. We believe that this will significantly reduce problems from CYSDV in fall melon fields. Once we test the current statistical models, we will be able to present real disease strategies that will be applied in real time in real landscapes. This will hopefully be achieved within the next year or so using GIS generated maps where growers can indicate where they plan to plant fall

melons. Using information on the locations of cotton fields and previously grown spring melon fields, our model should be able to accurately predict their risk of CYSDV infection.

Beneficiaries

The stakeholders who directly benefitted from this project include Arizona melon growers, PCAs, and local Agro-chemical Industry representatives. The ultimate impact of this project on the beneficiaries will best be measured by changes in the incidence of virus in the future once growers have become aware of our final results (see above). We plan to make available to the growers/PCAs an on-line tool that will allow them to assess the risk of planting fall melons based on our models prediction for crop placement. We have provided the preliminary results of this research to the stakeholders in extension meetings over the past year and have made data available to them in on-line publications via our Vegetable IPM updates. Similarly both the whitefly abundance data and GIS maps of disease incidence have been available to growers upon request for the past two years; several growers have used this data in developing their fall melon planting schedules. For example, at the conclusion of this project, all major melon growers/shippers in Arizona (~15) and their PCAs (~25) have been made aware of the recommendations derived from our preliminary results. The impact of our recommendations was clearly evident in 2013 for many Yuma growers. For several years prior to 2013, melon production was severely affected by virus in the Yuma Valley. However, after attending our educational meetings and reading our extension updates over the past 2 years, 4 major melon growers (~2200 ac) shifted production of their melons out of the Yuma Valley and into the eastern part of Yuma county to isolate their fall plantings from the major sources of whiteflies and the CYSDV virus: cotton and spring melons. The result was a marked reduction in CYSDV at the harvest at the end of the fall 2013 growing season.

Lessons Learned

One of the largest constraints to the completion of this project was our poor planning in hiring a graduate student. We were unable to recruit a qualified candidate in the 1st year of this project and set back our modelling effort an entire year. This also placed a larger field workload on the PI. Fortunately we were able to hire a qualified technician to satisfy our needs. In hindsight, we should have had a qualified student already enrolled in the graduate program prior to proposing this project. Furthermore, we had to request a no-cost extension of the project because of this inability to hire qualified personnel. We learned from this that a project this ambitious require more time than the two years we proposed.

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Additional Information

We feel confident that once growers become aware of the results of this project they will begin to consider the practice of crop placement as a key management tactic for Whitefly and CYSDV suppression. We have already seen that growers who purposely plant their crops at large distances (> 5 miles) away from spring melons and cotton, have minimal problems with CYSDV; they also have the best quality and highest yielding melon crops in the region. Once

we integrate our model into a computer on-line app, they should be able to easily assess the risk of planting fall melons at any given region within Yuma County.

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

Publications

Carrière, Y, B. Degain, K. A. Hartfield, K. D. Nolte, S. E. Marsh, C. Ellers-Kirk, W. J. D. van Leeuwen, L. Liesner, P. Dutilleul, and J. C. Palumbo. 2014. Assessing transmission of crop diseases by insect vectors in a landscape context. J. Econ Entomol: Forum (In press; anticipated Feb 2014).

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Yuma Lettuce Ice Forecast System

This project was completed on January 15, 2013

Project Summary

The purpose of this project was to develop an improved means of forecasting minimum temperatures, frost and ice in produce fields in Yuma County, Arizona. Subfreezing temperatures force producers to alter their picking operations since contact (by humans or machines) causes cell damage that leads to ruined produce. Extended periods of low temperatures can also damage produce irrespective of contact damage and growers with advanced knowledge of serious frost event can irrigate or bring in portable wind machines to minimize crop losses.

Project Approach

For this project we chose to use the Weather Research and Forecast Model (WRF) to provide temperature forecasts for produce growers in the lower Gila and Yuma Valleys of Arizona. The WRF model, a state of the art, high-resolution mesoscale forecast model, is an open source model which allows users to adjust model configuration for specific locations and purposes.

This project used the University of Arizona WRF model (UA WRF) developed by the University of Arizona Department of Atmospheric Science. The UA WRF model includes adjustments to address both the aridity and the unique precipitation characteristics of the low deserts of Arizona. Model resolution was another important consideration in selecting the UA WRF model. The resolution of the UA WRF model is 1.8 km which approaches the scale of the irrigated fields in the area. Mr. Mike Leuthold, a project principal investigator, manages the operation of the UA WRF model.

For this project, the UA WRF model was configured to provide hourly forecasts of temperature, dew point and wind speed at shelter height (2.0 m above ground level) and temperature at produce height (0.3 m above ground level) for a total forecast period of 50 hours. The UA WRF model was evaluated during the first year of the project by comparing model forecasts to actual conditions as measured by a 6-station network of automated weather stations installed as part of the project. The weather stations were located adjacent to produce fields and measured temperature, humidity and wind speed at shelter height and temperature and leaf wetness at produce height. The weather data were summarized into relevant means, totals and extremes every 15 minutes and at the end of the 24-hour day. Cell phones were used to facilitate the transfer of weather station data to a data processing computer located in Tucson where the data were made available to growers in real time via an internet web page.

The accuracy of the UA WRF forecast model was evaluated during the winter of 2010/11. Model forecasts for temperatures at produce and shelter height were compared with data collected by the weather station network. These analyses revealed that forecasts were approximately 2°C too warm (warm bias). Both the model forecasts and the weather station data were made available to growers during this time and the growers were notified via websites, face-to-face meetings and project publications/handouts that the forecasts for 2010/11 were preliminary in nature and could be in error. Feedback from growers confirmed our analyses that the 2010/11 temperature forecasts were too warm.

Project personnel spent the spring and summer of 2011 investigating the cause of the warm bias in the forecast model. These investigations revealed that selected parameters used to initialize the land surface model (LSM) were the cause of the warm bias. Specifically, the LSM was being initialized using soil moisture and vegetation representative of desert areas as opposed to irrigated agricultural fields. In addition, the LSM was using incorrect soil types in many areas where produce was grown. When the LSM was adjusted to better reflect the underlying surface of produce fields (proper soil types, higher soil moisture and a higher vegetation fraction) the warm bias in the UA WRF was greatly reduced. This improved UA WRF model was designated the adjusted UA WRF model and was approved for use during the winter of 2011/12.

The Lettuce Ice Forecast Program became an operational forecast program during the winter of 2011/12 with forecasts generated by the adjusted UA WRF model. Adjustments included the aforementioned increases in soil moisture and vegetation cover, updated soil type information in produce production areas and upgraded land use classifications required to reflect urban expansion into selected production areas. Model forecasts were generated twice daily at 5 am and 11 pm with model outputs provided in three formats: 1) dynamic forecast movies that provide hourly maps of temperatures for the next 50 hours; 2) static forecast maps showing the expected minimum temperatures for the next two days; and 3) text forecasts that provided hourly

temperatures expected at shelter and produce heights for the next 50 hours. A revised website was developed that provided easy access to all forecast products and the real time weather data collected by the weather station network. The website was integrated into the Arizona Meteorological Network (managed by Dr. Brown), an agricultural weather information system operated by the University of Arizona and Arizona Cooperative Extension. All forecast products and weather data generated by the program were provided free of charge to growers, produce companies and other interested individuals/entities.

Mr. Nick Dawson (advised by Dr. Brown), the graduate student supported by this project, conducted a thorough evaluation of the adjusted UA WRF model during the winter of 2011/12. Specifically, he evaluated the accuracy of forecasts generated by the original UA WRF model (that generated the warm bias in 2010/11 and referred here as the control model) and the adjusted UA WRF model by comparing forecasted temperatures against actual temperatures measured by the automated weather stations. When examined across all nights during the winter period, control model forecasts continued to exhibit a warm bias which averaged 1.3°C and 1.4°C at produce and shelter height respectively. In contrast, forecast bias generated by the adjusted model averaged -1.2°C at produce height and -0.6°C at shelter height. This result suggested the adjustments to the UA WRF model were excessive and the resulting forecasts at produce level were now cold biased. However, when the two models were compared on nights with near or subfreezing temperatures, the adjusted model performed much better than the control model. When measured temperatures at produce height (at weather stations) were ≤2°C, forecast bias for the control and adjusted models averaged 3.2°C and 0.0°C, respectively. Root mean square error (RMSE) and mean absolute error (MAE) were also used to evaluate forecast accuracy on nights with minimum temperatures of ≤2°C. The RMSE and MAE of control model forecasts were 3.2°C and 1.6°C, respectively. In contrast, the RMSE and MAE of adjusted model forecasts were 1.6°C and 1.2°C, respectively. A similar error analysis was performed for nights with subfreezing produce level temperatures (≤0°C). Once again, the adjusted model produced more accurate forecasts. The resulting RMSE, MAE and bias values for control model forecasts were 3.3°C, 1.7°C and 3.2°C, respectively. In contrast, the RMSE, MAE and bias for forecasts generated by the adjusted model were decidedly better at 1.8°C, 0.8°C and 0.4°C, respectively.

A second analysis was performed during the winter of 2011/12 in an effort to provide growers with further details on forecast accuracy. This analysis evaluated the ability of the two forecast models to accurately predict frost events. The adjusted model performed much better than the control model using this assessment technique, accurately predicted subfreezing temperatures 85% of the time over the course of the winter. The control model proved to be significantly less accurate, predicting subfreezing temperatures just 11% of the time. This analysis was expanded to address how often the two models predicted a frost event that did not occur (false alarm). The adjusted model forecast subfreezing temperatures 12% of the time when temperatures remained above freezing. The control model performed better in this "false alarm" assessment owing to the warm bias in the model. The control model never generated a false frost forecast during the winter of 2011/12.

The Lettuce Ice Forecast Program website (http://ag.arizona.edu/azmet/LIF.htm) provided growers and other interested parties access to forecasts, real time data displays and text files used

to archive data collected by the real time weather network. The website was accessed 17293 times between 1 November 2011 and 31 March 2012.

A formal extension of the project from its original termination date of 30 September 2012 to 15 January 2013 allowed the program to remain functional through the winter of 2012/13. The primary reason for extending the project was to develop some form of local funding arrangement that would sustain the program in future years. The 2012/13 program operated in a similar manner. Only minor adjustments were made to the forecast model, website and real time weather network. The only significant change to the forecast model was the means with which adjustments were made to the vegetation fraction of the underlying surface. During the previous winter we had observed through satellite images that vegetation fraction changed rather quickly in many areas planted to produce due to double cropping, harvest and general crop development. During the winter of 2012/13 the vegetation fraction was updated every two weeks using vegetation indices derived from satellite data. We had investigated these utility of making these vegetation adjustments during the previous winter and found they improved forecast accuracy. Changes to the real time weather network were limited to station maintenance and replacement of selected sensors and data loggers. Two new data loggers were also installed to facilitate the use of infrared thermometers that were used to better assess the surface temperatures of produce at selected station sites.

The 2012/13 Lettuce Ice Program was announced at the annual Yuma Vegetable Workshop held in August of 2012. Dr. Brown presented a summary of the program and provided a handout on how to access program information from the website. He also prepared and set up a poster that summarized project activities and forecast model accuracy and performance. Approximately 50 growers attended the workshop. The fall of 2012 was very warm and the first cold weather did not arrive in Yuma County until mid-December. However, the remaining eight weeks of the winter (through late February) produced several very cold events that produced subfreezing temperatures that delayed harvest operations and damaged produced. On several occasions, Dr. Kurt Nolte, Yuma County Extension Director, extracted forecast information from the website and emailed it directly to growers as an alternative means of providing forecast information to growers. At the time of this report, website use statistics are available only for the first two months of the frost season (November and December of 2012). The website handled 5406 requests for project data and information during this period – a relatively high number given that temperatures were above normal during this period.

The 2012/13 forecast program concluded another successful run in early March. Several attempts were made to contact key growers in an effort to discuss the pros and cons of the current forecast program and to plan for program operations next winter. However, to date, project personnel have been unable to establish a meeting for such discussions. Individual growers and industry personnel have made a number of positive statements regarding the program, but to date, we have been unable to develop a consensus on whether there is interest and sufficient funding to continue the program next winter. We intend to continue these efforts at the conclusion of the produce season when growers and key industry personnel are not so busy.

Goals and Outcomes Achieved

The goal of this project was to provide high resolution temperature and frost forecasts for lettuce producers in Yuma County, Arizona. As no forecast model was in place at the start of this project, development of a functional model in year two of the project and validation of model accuracy were the target and performance measures of this goal, respectively. The project succeeded in meeting this goal. The UA WRF forecast model was used to provide weather forecasts during the winter produce season. Temperature forecasts were generated two times per day from mid-November through early March during the winters of 2010/11, 2011/12 and 2012/13. Data from the winter of 2010/11 were used to adjust the UA WRF forecast model for use in produce fields. Operational forecasts were generated during the winters of 2011/12 and 2012/13. The accuracy of model forecasts was evaluated during the winter of 2011/12 by comparing forecasted night temperatures with temperatures measured by the real time weather network. The RMSE, MAE and bias of operational temperature forecasts were 1.8^{o}C, 0.8^{o}C and 0.4^{o}C on subfreezing nights, respectively**.** A website was developed through which growers and other interested parties could access the forecasts as well as the real time weather data generated by a small network of automated weather stations located adjacent to produce fields. The website handled in excess of 17000 requests for forecasts, real time data and general project information during the winter of 2011/12.

The second goal of the project was to collect field data consisting of temperature, humidity and wind speed at shelter height and temperature and leaf wetness at produce height to both improve the forecast model and validate forecast accuracy. As no such data sets existed prior to this project, the successful collection of these data sets and providing this data set to growers via a website served as the target and performance measures for this goal. The project succeeded in meeting this goal as well. A network of six automated weather stations was established during the winter of 2010/11. Stations were located adjacent to produce fields in Yuma Valley (south, central and north) and the lower Gila Valley (south Gila, Dome Valley and Roll). Each station collected temperature, humidity and wind speed at shelter height and temperature and leaf wetness at produce height. Cell phones were installed at each station to facilitate collection and dissemination of data in real time. All data were made available to growers in real time (updated every 15 minutes) via the project website. The real time network proved to be a reliable system that remained operational throughout the period of the project.

Beneficiaries

The primary beneficiaries of this project are the lettuce growers and the companies that manage, harvest and ship produce. While the frost forecasts generated by this program are directed at those individuals and organizations that grow and/or harvest produce, the entire produce industry benefits from having improved forecasts and real time weather information for a key U.S. production area. Such information is useful when developing marketing and shipping plans for produce. Approximately 57,000 acres of produce is grown in Yuma County each year. The value of the 2010 crop was in excess of $750 million.

Growers that produce crops during the spring and summer growing season represent a second group that benefited from this project. The real time weather network remained functional throughout the spring and summer period. Website usage continued during the summer months indicating growers and PCAs were accessing data. For example, during the third quarter of 2012

(July-September), the website was accessed 2962 times (30+ times/day). Growers apparently found the data from the real time network useful for general crop and pest management.

The third beneficiary of the program is the scientific community. This project proved that modern weather forecast models, with proper adjustment, can provide accurate, high resolution weather forecasts in agricultural areas. Hopefully, as this project receives more notoriety through presentations at scientific meetings and publications, additional groups will use these weather models to improve agricultural weather forecasts in other regions and/or cropping systems.

Lessons Learned

Overall, this project achieved the goals set forth in the original project proposal. One important challenge remains to make the project a complete success – the development of a funding structure to sustain the operation of the program in the future. As indicated above, we have had some initial discussions, but we have been unable to get the growers and industry to meet with us regarding the program's future. We intend to initiate this meeting later this spring when the produce season is over. Project personnel believe part of the problem in getting feedback from the industry is that the project did not have personnel on the ground in Yuma during the winter months. Dr. Kurt Nolte, Yuma County Extension Director, provided considerable assistance that was very supportive and useful to the project. However, he has many other responsibilities and could direct only a limited amount of time to the project. The rest of the personnel affiliated with the project were located in Tucson, AZ, and only Dr. Brown was free to make regular trips to Yuma during the winter months. Dr. Brown found it difficult to locate or contact industry personnel on many trips. Our future plans, if supported by the industry, would be to have a local presence in Yuma County in future years. We believe this presence would involve hiring an agricultural student (part time) from Arizona Western College. The student's job responsibilities would be split between maintaining the real time weather network, interfacing with growers and industry personnel, and issuing advisories (via text or email) when significant weather events are expected.

Contact Person

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Additional Information

The following is a listing of publications, presentations, posters, and websites produced over the course of this project. Included at the end of this list are an example of a forecast map, a picture of a real time weather station and an example of a real time data display.

Publications/Document/Workshop Materials

Brown, P. 2010. Interim Access to Yuma Area Forecasts. Workshop & meeting handout; also available from website during winter of 2010/11.

Brown, P. and M. Leuthold. 2011. The 2011/12 Yuma Lettuce Ice Forecast Program: Internet Access of Program Forecasts & Weather Data. 2011 Workshop handout; also available from website during the winter of 2011/12.

Brown, P. 2011. Lettuce Data Formats. Described formatting of archived data from real time weather network (First published on 14 Nov 2011 and revised on 17 Nov 2011, 22 Nov 2011 and Jan 2012). Available from website.

Brown, P. and M. Leuthold. 2012. The 2011/12 Yuma Lettuce Ice Forecast Program: Internet Access of Program Forecasts & Weather Data (Revised: March 2012). Meeting handout; also available from website during the spring and summer of 2012.

Brown, P. N. Dawson and M. Leuthold. 2012. The 2012/13 Lettuce Ice Forecast Program for Yuma County. Workshop and meeting handout; also available from website during the winter of 2012/13.

Dawson, N., P. Brown and M. Leuthold. 2012. Utilizing the WRF Model for Frost Forecasting in Produce Fields Located in an Arid Environment. Submitted to Journal of Applied Meteorology and Climatology.

Public Presentations

Yuma Lettuce Ice Forecast System. Presented to Yuma Lettuce Producers, 16 November 2010 (Dr. Brown presented). Attendance: 5.

Development of a New Lettuce Ice Forecast System for Yuma County. Presented at the Southwest Agricultural Summit, 10 March 2011 (Dr. Brown presented). Attendance: 25.

An Overview of Lettuce Ice Forecasting. Presented at Lettuce Ice and Forecasting Workshop, 19 December 2011. (Dr. Brown presented). Attendance: 6.

Lettuce Ice Modeling and the Various Forecast Products. Presented at Lettuce Ice and Forecasting Workshop, 19 December 2011. (Mr. Dawson & Mr. Leuthold presented). Attendance: 6.

The Lettuce Ice Field Monitoring Program for Yuma Leafy Green Producers. Presented at Lettuce Ice and Forecasting Workshop, 19 December 2011. (Dr. Brown presented). Attendance: 6.

Yuma Lettuce Ice Forecast Program. SCBGP Grant Review Meeting, 30 January 2012. (Dr. Brown presented). Attendance: 15.

Lettuce Ice Forecast System for Yuma County. Presented at the Southwest Agricultural Summit, 8 March 2012 (Dr. Brown presented). Attendance: 12.

The Lettuce Ice Field Monitoring Program for Yuma Leafy Green Producers. Presented at the Yuma County Pre-season Vegetable Workshop, 30 August 2012. (Dr. Brown presented). Attendance: 40.

Weather Implications for Crop Management. Presented at Yuma Crop Production Meeting, 16 January 2013 (Dr. Brown presented). Attendance: 47.

Posters

Frost Forecasting for Lettuce Fields in Yuma, Arizona. (Authors: N. Dawson, M. Leuthold and P. Brown). Presented at 3rd Annual University of Arizona Earth Week Symposium, 29 March 2012.

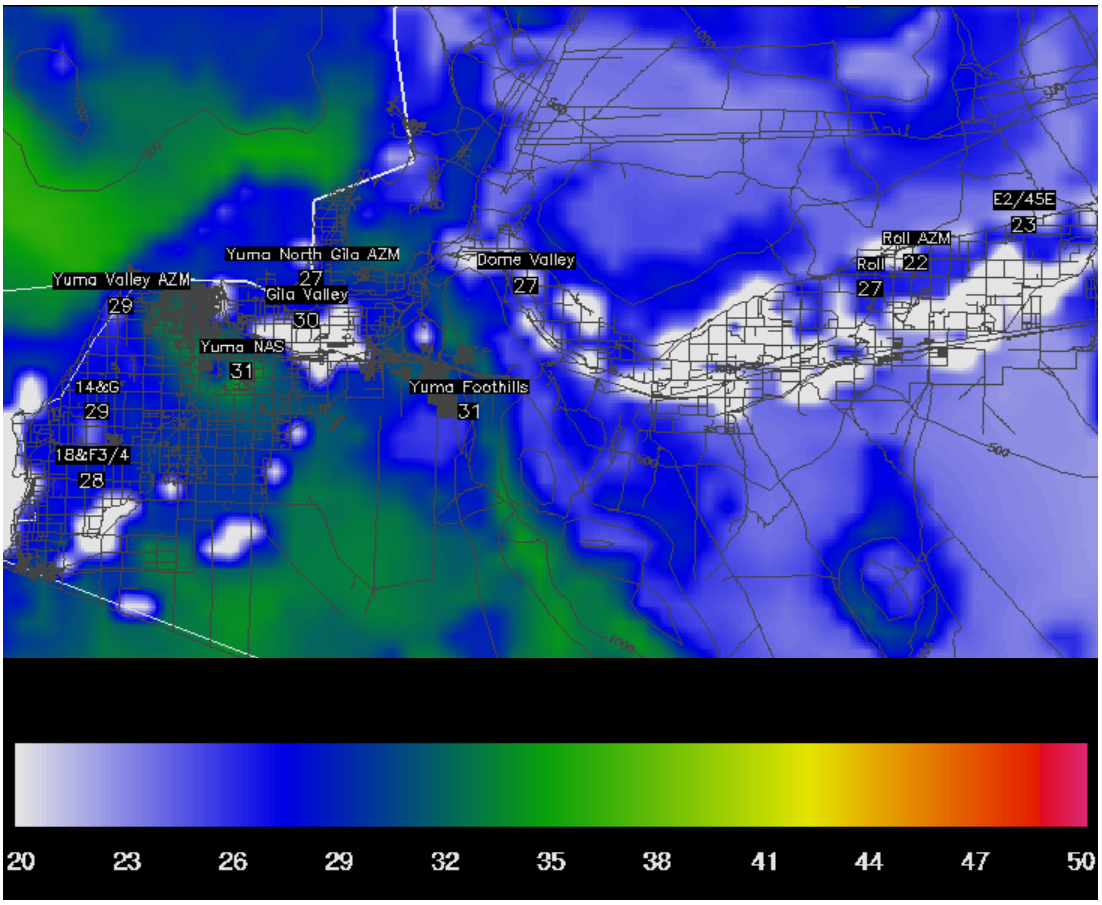
Yuma Lettuce Ice Forecast System. (Authors: N. Dawson, M. Leuthold, P. Brown and B. Russell). Presented at Yuma County Pre-season Vegetable Workshop, 30 August 2012.

Yuma Lettuce Ice Forecast System. (Authors: N. Dawson, M. Leuthold, P. Brown and B. Russell). Presented at Yuma Crop Production Meeting, 16 January 2013.

Websites

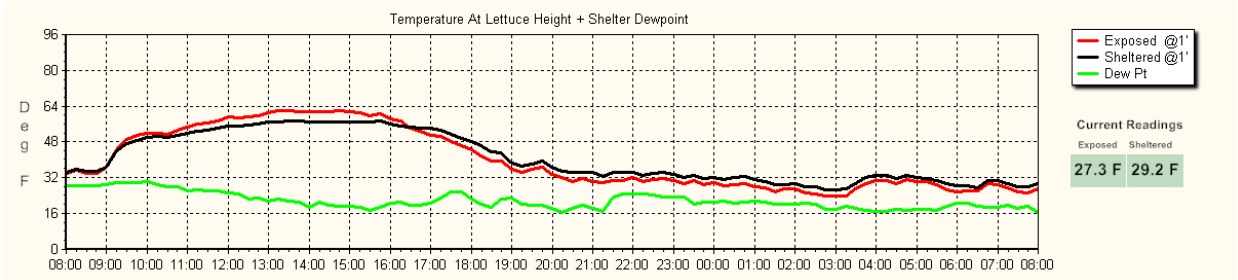
Lettuce Ice Forecast Program. URL: http://ag.arizona.edu/azmet/ls.htm. Project website from November 2011 through October 2012 (no longer active).

Lettuce Ice Forecast Program. URL: http://ag.arizona.edu/azmet/LIF.htm. Project website from November 2012 to present.



Example of a forecast map showing expected minimum temperatures at produce level. Forecast is for the morning of 13 January 2013.

Photograph of the Dome Valley automated weather station that provided data in real time for model validation and use by growers.



Example of a real time weather summary generated at 8 am on 13 January 2013. Summary shows the trends for sheltered and exposed temperatures and dew point at the South Gila Valley station site for the past 24 hours. The current values are provided to the right of the graph. Real time weather summaries were available via the project website.

Appendix A

referenced from page 3

2011 Southwest Ag Summit
Field Day & Breakout Session Speakers
March 9th and 10th, 2011

(Applications for 12 CA/AZ CEU's and 11.5 CA/AZ CCA's have been made)

1st DAY OF EVENT (March 9, 2011)

2011 Field Day for March 9th/Wednesday **(3 CA/AZ CEU's and CCA's)**

7:00 AM Registration/Yuma Ag Center

9:00 AM to Noon **Field Demonstration Day**
Mark Siemens, Ph.D., Yuma Agricultural Center, University of Arizona and
Kurt Nolte, Ph.D., Yuma County Cooperative Extension, University of Arizona

Field Demonstrations(not CEU or CCA eligible)

- Delta Plastics – Lay Flat Polytubing for Furrow/Flood Irrigation
- Keithly-Williams Seeds – Renaldo Semi-Automatic Transplanter
- Keithly-Williams Seeds – The RoboCrop Automated in-Row Weeder/Thinner
- Keithly-Williams Seeds – Williames Automated Transplanter
- Keithly-Williams Seeds – Kennco Mulch Retriever
- Empire Southwest LLC/Wilcox Ag Products – Conservation Tillage in Vegetable Production Using the Wilcox Eliminator
- Kurt Nolte, Yuma County Cooperative Extension – Field Trial of Quick Sol; a Soil and Plant Treatment
- Booth Machinery Inc. – Effects of Tillage on Soil Properties - Case IH Ecolo Tiger, 870 Disk Ripper, V-Ripper, 790 Disk, 165 Rollover Plow
- Dr. Mark Siemens, University of Arizona – New Technologies for Specialty Crop Production
- RDO Equipment Co. – John Deere 8360R Tier 4 Tractor with iGrade Leveling System
- SITECH Southwest – Trimble Autopilot with SVRS RTC Connection
- Bingham Equipment Co. – New Holland Ground Prep Tools
- Dr. David Still, Cal Poly Pomona – Lettuce Variety Trait Nursery
- Kurt Nolte, Yuma County Cooperative Extension – Point Injection Systems
- GreenVolts – Solar Solutions
- Bob Wolf, Kansas State University - Demonstration of Pesticide Drift Reduction with Advanced Nozzle Selection. (2 CEU's)2 CCA/PM
- Ryan Hayes, USDA-ARS - Lettuce Disease Assessment through Variety Selection. (1 CEU)1 CCA/CM

2nd DAY OF EVENT (March 10, 2011)

2011 Academic Speakers & Workshops for March 10th/Thursday **(7 AZ/CA CEU's and CCA's)**

7:00 AM Late Registration and Refreshments/Pivot Point, Old Town Yuma

7:45 AM Opening Remarks – Mark Ellsworth YFVA, CAPCA Award

Dean, Eugene G. Sander, College of Agriculture, University of Arizona

8:15 AM **Morning Keynote** – Jeanette Thurston, USDA
(1 CEU)PD

9:15 AM Networking Break, Tour of Vendor Exhibits

Morning Breakout Sessions / 9:30 AM – 12:00 PM

HILTON GARDEN INN – RIVERFRONT BALLROOM

Morning Session: Breakout #1, Desert Pest Management I (2 CEU's)1.5 CCA'S
Moderator: John Palumbo, Entomology Department, University of Arizona

9:30 – 10:10 AM *2011 Pesticide Legislative and Regulatory Forecast*
Renee Pinel, Western Plant Health Association (.70 CEU).50 CCA/PD

10:15 – 10:55 AM *Arizona Pesticide Regulatory Update*
Jack Peterson, AZ Dept of Agriculture (.70 CEU).50 CCA/PD

11:00 – 11:40 AM *Maneb To Mancozeb Label And Product Transition*
Jeff Boydston, United Phosphorus Inc. (.60 CEU).50 CCA/PM

HILTON GARDEN INN – LA JOLLA ROOM

Morning Workshop: Breakout #2, Minimizing Pesticide Spray Drift with Advanced Nozzle Selection (2 CEU's)CCA/PM

9:30 – 11:40 AM *Advanced Nozzle Selection for Minimizing Pesticide Spray Drift in Desert Grown Crops* (2 CEU's)CCA/PM
Bob Wolf, Kansas State University Emeritus

PIVOT POINT – REDONDO ROOM

Morning Session: Breakout #3, Desert Fertilizer Workshop 2 CCA'S
Moderator: Charles Sanchez, Soil, Water & Environmental Science, University of Arizona

9:30 – 10:00 AM *Ethics of a Certified Crop Advisor in Production Agriculture*
Terry Tindall, J.R. Simplot .50 CCA/NM

10:10 – 10:40 AM *Spatial Variability in Plant Available Phosphorus*
Charles Sanchez, Soil, Water & Environmental Science, University of Arizona .50 CCA/NM

10:50 – 11:20 AM *Late Season Fertilizer Recommendations for Arizona Wheat Producers*
Mike Ottman, University of Arizona, School of Plant Sciences **.**50 CCA/NM

11:30 – 12:00 PM *Managing Plant Nutrients & Soil Fertilizers for Cotton Production in Arizona*
Jeff Silvertooth, University of Arizona, Soil, Water & Environmental Science .50 CCA/NM

PIVOT POINT – ANZA ROOM

Morning Session: Breakout #4, Fresh Produce Safety: The Past, Present and Future

Moderator: Jorge Fonseca, School of Plant Sciences, University of Arizona

9:30 – 10:10 AM *10 Years of Fresh Produce Safety Research*
Jorge Fonseca, School of Plant Sciences, University of Arizona

10:50 – 11:20 AM *"Lab on a Chip" – Field Results in Minutes, Not Days*
Yeong-Jeol Yoon, Agricultural & Biosystems Engineering, University of Arizona

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Noon to 1:30pm **LUNCH**

Afternoon Breakout Sessions / 1:30 PM – 3:30 PM

HILTON GARDEN INN – RIVERFRONT BALLROOM

Afternoon Session: Breakout #5, Desert Pest Management II (2 AZ/CZ CEU's)

Moderator: John Palumbo, Entomology Department, University of Arizona

1:30 – 2:00 PM *Integrated Pest Management of Invasive Leafhoppers*
Vonny Barlow, UCCE, Riverside Co. (.50 CEU)CCA/PM

2:00 – 2:30 PM *1080-Pesticide Use Data: A Resource for the Vegetable Industry*
Al Fournier, UA-Maricopa Ag Center (.50 CEU)CCA/PD

2:30 – 3:00 PM *Regulatory Changes for Soil Fumigation Practices*
Randall Norton, UA-Safford Ag Center (.50 CEU)CCA/PM

3:00 – 3:30 PM *Bagrada Bug: What Do We Really Know About This New Pest?*
John Palumbo, Entomology Department, University of Arizona (.50 CEU)CCA/PM

HILTON GARDEN INN – LA JOLLA ROOM

Afternoon Workshop: Breakout #6, Organic Soil Amendments in Vegetable Production

1:30 – 3:30 PM *Developing an Organic Fertility Program for Leafy Greens and Cole Crops*
Monica Ozores-Hampton, Southwest Florida Research and Education Center, University of Florida

PIVOT POINT – REDONDO ROOM

Afternoon Session: Breakout #7, Advanced Ag Technologies

Moderator: Kurt Nolte, Yuma County Cooperative Extension, University of Arizona

1:30 – 2:00 PM *Lettuce Ice Forecasting for Yuma Leafy Green Producers*
Paul Brown, Soil Water & Environmental Science, University of Arizona

2:00 – 2:30 PM *The SpikeWheel Agrichemical Injector*
Mark Siemens, Agricultural & Biosystems Engineering, University of Arizona

2:30 – 3:00 PM *New Innovations in Mechanized Lettuce Thinning*
Ryan Herbon, Manufacturing Technology and Engineering Center, New Mexico State University

2011 Southwest Ag Summit Exit Survey

1. How would you describe your occupation? [Circle 1]
   a. Equipment Dealer
   b. Grower
   c. Marketing/ Sales
   d. Management
   e. PCA/Chemical Rep.
   f. Government worker
   g. Other

   _____

2. Does your occupation involve the melon or vegetable industry?

   a. Yes b. No

3. Did you attend the Field Demonstration at the Yuma Ag Center?

   a. Yes b. No

4. How has the SW Ag Summit affected your business? [Circle all that apply]

   a. Better informed about desert ag
   b. Enhanced marketing opportunities
   c. Gained information about food safety
   d. Developed networking opportunities
   e. Other _____

5. Will you share information you obtained from the SW Ag Summit with others?

   a. Yes b. No

6. If you share the information, with whom will you share it? [Circle all that apply]

   a. Staff
   b. Coworkers
   c. Media
   d. Friends/Family

7. Why did you attend the SW Ag Summit? [Circle all that apply]

   a. Academic breakout sessions
   b. Keynote address
   c. Booth displays
   d. Field Demonstration
   e. Marketing opportunities
   f. Continuing Education Credits
   g. Networking opportunities
   h. Other _____

8. What was the best part of the SW Ag Summit?

9. What part of the SW Ag Summit needs improvement?

10. What topics would you like to see at a future SW Ag Summit?

Appendix

The Good Ag Practices/Good Handling Practices Certification and Training Survey Instrument

In an effort to learn and improve our current GAP/GHP Certification Training program, we would appreciate if you could take a few moments of your time to give us some valuable feedback. We have included a stamped envelope for your convenience. The information you provide us will remain completely anonymous and NO results will be matched with individual names. This information will help us to improve our training program and to plan future training events. Thank you ahead of time for your input.

Approximate Date of Training:_____
Location:_____
Name of Your Operation:_____
Size of Your Operation:_____
Grow for: ____ personal use ____ Wholesale or Retail

1. How can GHP/GAP training be improved?
   _____
   _____.

2. What changes would you make in the presentation of GHP/GAP information?
   _____
   _____.

3. Did the notebooks contain all of the information that you expected to receive?
   _____
   _____.

4. Any suggestions that would make the training easier to follow?
   _____
   _____.

5. Do you feel that sufficient time was allocated to answering your questions?
   _____
   _____.

6. Do you like the idea of using a certified GHP/GAP label or logo for display once you have become certified?
   _____
   _____.

7. Do you like the idea that Stewart Jacobson, with the AZ Dept. of Agriculture, will follow up with a call and a visit, free of charge, if you should desire help developing your Food Safety Plan or preparing for an audit?
   _____
   _____.

8. After the training, did you follow through to become certified? _____ and why?
   _____
   _____.

9. If you did NOT, please explain why? (i.e. exemptions, too much paperwork, too costly, etc.)
_____
_____.

10. What changes would you like to see in the certification process? What would it take to encourage you to become certified? (i.e. More auditors, more cost effective, etc.)
_____
_____.

11. Are you aware of the Cost Sharing program from the AZ Department of Agriculture that will reimburse you for 75% of the cost of a successfully completed audit, up to $750? YES_____ NO_____

12. Will you take advantage of this program if funding remains available? YES_____ NO_____

13. Do you approach your growing operation and/or farm as a hobby or as a business? _____

14. Which of the following describes your operation? Check all that apply.
    - ☐ We pack harvested produce in the field for immediate delivery.
    - ☐ We send harvested produce to a buyer who packs it.
    - ☐ We send harvested produce to our own cooperative to pack.
    - ☐ We grade and pack in our own packing facility.
    - ☐ We harvest, pack, store and transport for a Farmer's Market, Roadside Stand or CSA.
    - ☐ Other _____

15. How do you sell your fruits and vegetables? Please check one answer for each type of sale.

Percentage of your fruit/vegetable sales comes from:	**0 %**	**1-24%**	**25 – 49%**	**50 – 74%**	**75 – 100%**
a. Wholesale to supermarkets, restaurants, or other institutions?	☐	☐	☐	☐	☐
b. Retail at farmer's markets, roadside stands or CSA's?	☐	☐	☐	☐	☐
c. Sales through cooperatives to which you belong?	☐	☐	☐	☐	☐
d. Sales to resellers (e.g., other farmers, packing houses, or distributors)?	☐	☐	☐	☐	☐
e. Other, please specify: _____	☐	☐	☐	☐	☐

16. Please check one answer for each activity.

For the 2013 growing season, you:	**Yes**	**No**	**Unsure**
a. Wrote or updated a food safety plan?	☐	☐	☐
b. Conducted your own food safety inspection?	☐	☐	☐
c. Had a third-party audit done on your farm?	☐	☐	☐

17. Listed below are statements about food safety. Circle how much you agree with these issues.

Use the scale 1 = Do Not Agree through 5 = Very Much Agree.

Do Not Agree				Very Much Agree	Food Safety Issue
1	2	3	4	5	Farmers have a responsibility for the safety of produce coming off their farms.
1	2	3	4	5	Preparing for a food safety audit will help my farm maintain produce sales.
1	2	3	4	5	How consumers feel about the safety of my farm's produce affects how much produce my farm sells.
1	2	3	4	5	I have adequate resources to write my own food safety plan.
1	2	3	4	5	I have adequate resources to prepare for and pass a GAP audit.

18. Any Additional Comments:

_____

_____

_____.

Please return in the enclosed envelope to: Karen Edwards, U of A, Cooperative Extension, 2200 W. 28th Street, Suite 102, Yuma, AZ 85364. Thank you for your input....we value your opinions and together we can grow safer!

Your GHP/GAP Training Team,

Kurt Nolte
Stewart Jacobson
Karen Edwards

Appendix D
referenced from page 15

Agricultural Consultation and Training
Arizona GHP/GAP Certification Cost Share Application

To be eligible for reimbursement the operation must have received Good Handling Practices (GHP) and Good Agricultural Practices (GAP) audit certification on or between ***October 1, 2010 and September 30, 2013***. The amount of reimbursement is 75% of certification costs (maximum of $750).

PRODUCER/HANDLER IDENTIFICATION			
First Name and/or Company Name	M.I.	Last Name	
Address			
City	County	State	Zip Code
Social Security Number or Employer Identification Number (EIN)		Did the Applicant participate in GHP/GAP training? YES NO	
Phone Number	Contact Name	Email Address	

GHP/GAP AUDIT INFORMATION		
Name of Auditor	Auditor Duty Station	
Date Audit Completed	Total Amount of Fees Paid for Certification $	Date Fees Paid

<u>NOTE</u>: You must attach a copy of your certification, billing, and proof of payment (in the form of a cancelled check) to your application.

SIGNATURE

Certification by Producer:

I certify that the above information is true and correct, and the operation stated above received GHP/GAP certification on or between **October 1, 2010 and September 30, 2013**.

Notice of Penalties: Penalty for knowingly making false statements or false entries, or attempts to secure money through fraudulent means, may include fines and/or incarceration and/or forfeiture of agriculture assistance funds under applicable federal and state law.

Certified Operations Signature _____ Date ____ / ____ / ____
Month Day Year

Mail Application and Supporting Documents To:	**For Official Use Only**		
Arizona Department of Agriculture SCBGP - GHP/GAP Cost Share Reimbursement 1688 West Adams Street Phoenix, Arizona 85007	Application Number		Reimbursable Costs From Invoice
	☐ 75% =	$	☐ $750
	Approved By		Date

Appendix E

referenced from page 23

School Garden Food Safety

Trainings for

- implementing safe growing and handling practices
- standards-based lessons that bring the garden into your classroom curriculum
- intro to gardening taught by local experts

THE UNIVERSITY OF ARIZONA

COLLEGE OF AGRICULTURE AND LIFE SCIENCES

COOPERATIVE EXTENSION

Garden to Cafeteria

Receive free training on the safe handling of foods grown in school gardens for use in school cafeterias.

Contact Monica Pastor for more details
MPastor@cals.arizona.edu
602-827-8217
http://cals.arizona.edu/agliteracy

The Arizona Department of Agriculture, Agricultural Consultation and Training has funded all or a portion of this Project, using Specialty Crop Block Grant funds provided by the USDA, Agricultural Marketing Service.

Appendix F
referenced from page 23

School Garden Food Safety Training

July 31, 2013

8:30 am Registration and "Bell Work"

9:00 Welcome and Introductions – Monica Pastor, *Area Associate Agent*
University of Arizona Cooperative Extension
MPastor@cals.arizona.edu

School Garden Food Safety – Dr. Kurt Nolte, *Area Agent and Director*
Yuma County Extension & Experiment Station
KNolte@cals.arizona.edu
And
– Stewart Jacobson, *Food Safety Projects Coordinator*
Arizona Department of Agriculture
SJacobson@azda.gov
And
– Kathryn Mathewson,
School Garden Sanitarian/Health Educator
Arizona Department of Health Services
Kathryn.Mathewson@azdhs.gov

Pages 1 - 27

Pages 29 - 43

11:45 Garden Layout Discussion

Noon *Lunch on your Own*

1:00 pm Agriculture in your Classroom – Monica Pastor
Overview
Fruits and Veggies Mathematics
Plant Seedling
Locally Grown
Group Work in Grade level/subject matter/school Teams
Group Reports
A Thin Slice of Soil

Pages 45 - 57

3:00 pm *Break*

3:30 Gardening 101 – Kelly Young, *Horticulture Agent*
University of Arizona Cooperative Extension, Maricopa County
kyoung@cals.arizona.edu

Folder

4:30 Evaluation and Adjourn

In some way, agriculture has touched your life today!

The Arizona Department of Agriculture, Agricultural Consultation and Training has funded all or a portion of this Project, using Specialty Crop Block Grant funds provided by the USDA, Agricultural Marketing Service.

Appendix G
referenced from page 23

School Garden Food Safety

Training Manual

brought to you by

THE UNIVERSITY OF ARIZONA | COLLEGE OF AGRICULTURE AND LIFE SCIENCES COOPERATIVE EXTENSION

and

Arizona Department of Health Services

a Garden to Cafeteria program

The Arizona Department of Agriculture, Agricultural Consultation and Training has funded all or a portion of the Project, using Specialty Crop Block Grant funds provided by the USDA, Agricultural Marketing Service.

Agriculture Literacy Program

Monica Pastor, *Associate Area Agent*
MPastor@cals.arizona.edu
602-827-8217

Brandon Moak, *Program Coordinator, Sr*
BMoak@cals.arizona.edu
602-827-8218

http://cals.arizona.edu/agliteracy

In some way, agriculture has touched your life today!

School Garden Food Safety

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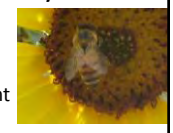
The Arizona School Garden Food Safety Program

Kurt Nolte and Stewart Jacobson
University of Arizona
Arizona Department of Agriculture

School Garden Food Safety Training Team



- Monica Pastor, Area Programmatic Agent
  UA College of Ag and Life Sciences Cooperative Extension
- Kurt Nolte, Area Agent and Director
  UA College of Ag and Life Sciences Cooperative Extension, Yuma County
- Kathryn Mathewson, School Garden Sanitarian/Health Educator
  Office of Environmental Health, Arizona Department of Health Services
- Brandon Moak, Program Coordinator, Sr.
  UA College of Ag and Life Sciences Cooperative Extension
- Stewart Jacobsen, Food Safety Projects Coordinator
  Agricultural Consultation and Training, Arizona Department of Agriculture

The Arizona Department of Agriculture, Agricultural Consultation and Training has funded all or a portion of this project using Specialty Crop Block Grant funds provided by the USDA, Agricultural Marketing Service.

The views or findings presented are the Grantee's and do not necessarily represent those of the State or the Arizona Department of Agriculture.

Arizona Department of Agriculture

What We'll Cover This Morning

- **Field level food safety and the AZ School Garden Guidelines**
- **Policies, SOPs and Records**
- **Writing a school garden food safety plan**
  - **General information**
  - **Growing and field maintenance**
  - **Harvesting**

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Lettuce linked to E. coli outbreak 'possibly' grown in Yuma area

May 07, 2010 4:54 PM

There's a "possibility" that romaine lettuce linked to a widespread E. coli outbreak could have come from the Yuma area, acknowledged a local agriculture agent.

"A potential location has been identified in Yuma," Kurt Nolte, Yuma County Cooperative Extension director and agriculture agent, said Friday.

However, as of late Friday afternoon, the Food and Drug and Administration had not confirmed that the lettuce was grown here, he said. "The investigation is ongoing."

enlarge

YUMA SUN FILE PHOTO

Romaine lettuce linked to a widespread E. coli outbreak could have come from the Yuma area, according to Kurt Nolte, Yuma County Cooperative Extension director and agriculture agent. However, the Food and Drug Administration as of Friday afternoon had not confirmed that it was grown here.

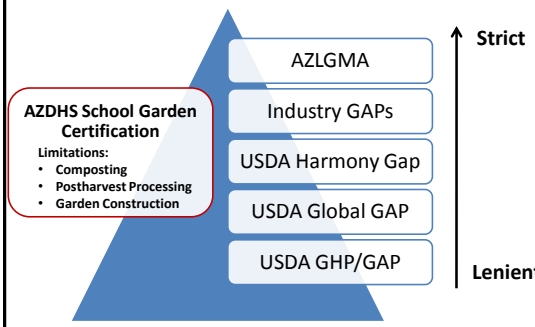
Why Certification?

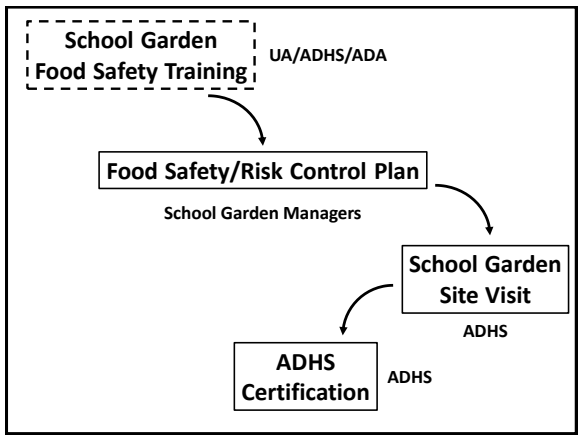
- Arizona school gardening does not require certification
- However, produce grown in a garden on school grounds to be served in the cafeteria to students, teachers, parents, or visitors s needs to be from an AZDHS certified garden to comply with suggested standard food safety protocols
- Minimize the Risk of Food Borne Pathogens within Specialty Crops. Public Safety
- Your Protection, Limits Liability (School, School District, Cafeteria, Teachers, Students, Volunteers, Visitors)

Developing a Risk Control or Food Safety Plan

- What are areas that are high risk, how can you monitor risk?
  - Regular testing?
  - Regular self-inspections?
  - Site inspections?
  - Change the way something is done?
- Consider changes in terms of time and money that reduce risk
- Document changes and continue to measure or monitor the risk

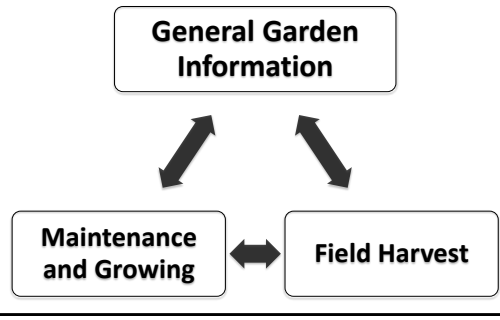
US Produce Safety Programs





AZ Garden Safety/Risk Control Plan

(More Later)



PREVENTION is the Key to Reducing Microbial Contamination of Fresh Fruits and Vegetables

If you did not RECORD IT, you did not do it

- Record keeping allows you to keep track of garden operations and worker training
- Document activities should this information ever be required
- Use record sheets for activities that require compliance

Automatic Failure

- Immediate food safety risk
- Presence of rodents, pets, etc.
- Practices that might jeopardize the safety of produce
- Falsification of records
- No Garden Safety Manual
- No one designated to oversee an established food safety program

Audit Components

P = Policy

SOP = Standard Operating Procedure

R = Records

Policies, SOPs & Records

- We will be assembling a collection of:
  - Policies (P)
  - Standard Operating Procedures (SOP)
  - Records (R)
- What's the Difference?

Policy

Policy = Consists of Simple Facts or Statements that may be verified through record keeping

Policy Examples:

- Students that are ill are not allowed in the garden…
- Eating is confined to designated areas…
- Gloves will not be taken to the restroom…
- Product containers are not intended for personal use…

Policy

- **Policy = Consists of Simple Facts or Statements**

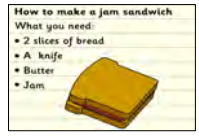
"Everyday In April, I'll serve Peanut Butter and Jelly Sandwiches for Lunch in the Cafeteria"

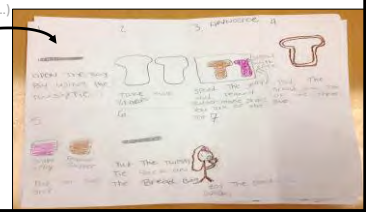
Noteworthy Items in Statement:
When: **Today (4/18/2013), Lunch**
What: **Sandwich, Peanut Butter & Jelly**
Who: **I, You, Students, Volunteers…**
Where: **Cafeteria**
How: **???**

Standard Operating Procedures (SOPs)

Standard Operating Procedures =
Set of prescribed methods to be routinely followed

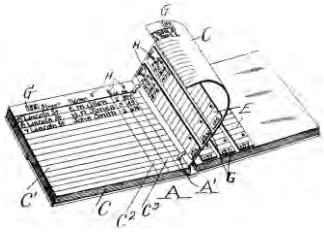
Noteworthy Items in Statement:
When: Today (4/18/2013), Lunch
What: Sandwich, Peanut Butter & Jelly
Who: I, You, Students, Volunteers…)
Where: Cafeteria
How: **Follow SOPs**





Records

Records = Collection of Logs that Shows Compliance



Records

Records = Collection of Logs that Show Compliance

Compliant Example
Cafeteria Lunch Menu Record Log Sheet

Date	Meal	Item Served	Bread	Peanut Butter	Jelly	Ham	Lettuce	Tomato	Initials
4/12/13	Lunch	PBJ	Yes	Yes	Yes	No	No	No	KN
4/15/13	Lunch	PBJ	Yes	Yes	Yes	No	No	No	KN
4/16/13	Lunch	PBJ	Yes	Yes	Yes	No	No	No	KN
4/17/13	Lunch	PBJ	Yes	Yes	Yes	No	No	No	KN
4/18/13	Lunch	PBJ	Yes	Yes	Yes	No	No	No	KN

Records

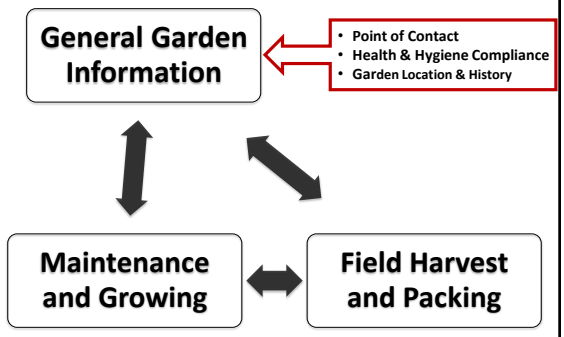
Records = Collection of Logs that Show Compliance

Noncompliant Example
Cafeteria Lunch Menu Record Log Sheet

Date	Meal	Item Served	Bread	Peanut Butter	Jelly	Ham	Lettuce	Tomato	Initials
4/12/13	Lunch	PBJ	Yes	Yes	Yes	No	No	No	KN
4/15/13	Lunch	PBJ	Yes	Yes	Yes	No	No	No	KN
4/16/13*	Lunch	Ham	Yes	No	No	Yes	Yes	Yes	KN
4/17/13	Lunch	PBJ	Yes	Yes	Yes	No	No	No	KN
4/18/13	Lunch	PBJ	Yes	Yes	Yes	No	No	No	KN

***4/16/13: Ran out of jelly, served ham sandwich**
***Corrective Action: Replenished jelly supplies**

Garden Safety/Risk Control Plan



1. General Garden Information

Point of Contact

- Garden Manager
- Responsible of ALL Activities
- Develops Risk Control Plan (P, SOP & R)

- The Person in Charge (PIC) who is knowledgeable about or trained in the School Garden Guidelines and Food Safety.
- Individual responsible for implementing the Food Safety Plan
- PIC maintains written documentation demonstrating that the Food Safety Plan is being adhered to by students, volunteers, visitors, teacher etc.
- PIC has determined that school districts liability insurance covers school garden produce and has received approval from administration and/or others

Training Log

School Garden Food Safety

Date: _____ Trainer: _____ Location: _____

Name	Adults supervise youth	Illness procedure	Sun protection	Hydration	Hand washing & hygiene	Bandaging wounds	Proper use of machinery	Proper use of equipment	Closed-toed shoes	Sanitization of equipment	Harvesting procedures	Eating & smoking areas	Harvesting gloves	Emergency contamination procedures	Preparation & transportation of produce

The Arizona Department of Agriculture, Agricultural Consultation and Training has funded all or a portion of this Project, using Specialty Crop Block Grant funds provided by the USDA, Agricultural Marketing Service.

1. General Garden Information

Point of Contact

- Garden Manager
- Responsible of ALL Activities
- Develops Food Safety Plan (P, SOP & R)

Health & Hygiene Compliance and Training Program

- Hand Washing (P, SOP, R)
- Restrooms (R)
- Illness, Injury & Body Fluids (P, SOP, R)
- Eating (P)
- Gloves (P)

1. General Garden Information

Point of Contact

- Garden Manager
- Responsible of ALL Activities
- Develops Risk Control Plan (P, SOP & R)

Health & Hygiene Compliance and Training Program

- *Hand Washing (P, SOP, R)*
- Restrooms (R)
- Illness, Injury & Body Fluids (P, SOP, R)
- Eating (P)
- Gloves & Hairnets, Optional (P)

- Toilet facilities and hand washing stations, including soap, dispensed hand towels, and drainage collection are provided at, and in close proximity to, all garden areas
- Water used for hand washing is from a municipal source or meets the minimum drinking water quality standards
- Signs should be posted in garden area to wash hands or use the bathroom
- Drainage collection, if not plumbed to a sanitary sewer, should include a holding tank that is larger than the water supply holding tank

Restroom & Hand Washing Facilities Maintenance Log

School Garden Food Safety

Date	Restroom & Hand Washing Facilities		Soap		Toilet Paper		Trash Can		Potable Water		Initials
	Checked	Cleaned	Checked	Filled	Checked	Filled	Checked	Emptied	Checked	Filled	

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1. General Garden Information

Point of Contact

- Garden Manager
- Responsible of ALL Activities
- Develops Risk Control Plan (P, SOP & R)

Health & Hygiene Compliance and Training Program

- *Hand Washing (P, SOP, R)*
- Restrooms (R)
- Illness, Injury & Body Fluids (P, SOP, R)
- Eating (P)
- Gloves & Hairnets, Optional (P)

- An adequately stocked first aid kit must be provided
- Gardeners with intestinal illness (diarrheal symptoms) or infectious disease will not be allowed to work in contact with fresh produce
- PIC should promptly report any illness, cuts, abrasions, lesions, boils, soars, infected wounds or other injury or illness to the PIC and seek prompt attention and logged
- Produce that has come into contact with feces, blood, saliva or other body fluids will be immediately removed from the field

Injury and Illness Reporting Log

School Garden Food Safety

Date	Name	Injury/Illness Reported	Action Taken*	Did student return?	Garden Manager's Initials

* Ex: ice applied, bandaged, sent to nurse

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1. General Garden Information

Point of Contact

- Garden Manager
- Responsible of ALL Activities
- Develops Risk Control Plan (P, SOP & R)

Health & Hygiene Compliance and Training Program

- *Hand Washing (P, SOP, R)*
- Restrooms (R)
- Illness, Injury & Body Fluids (P, SOP, R)
- Eating and Garden Conduct (P)
- Gloves & Optional Hairnets (P)

- Food and drink are only allowed in designated areas
- Pets or other domestic animals are not allowed in the garden area
- Smoking, chewing gum or tobacco, eating and drinking are prohibited in the garden
- Urinating, defecating, spitting and nose-blowing onto the ground is never allowed in or around the work area
- Single-use, food grade non-latex gloves are worn when handling produce, particularly during harvest.

1. General Garden Information

Point of Contact
- Garden Manager
- Responsible of ALL Activities
- Develops Risk Control Plan (P, SOP & R)

Health & Hygiene Compliance and Training Program
- Hand Washing (SOP, R)
- Illness, Injury & Body Fluids (SOP, R)
- Restrooms (R)
- Eating (P)
- Gloves & Optional Hairnets (P)

Garden Location & History
- Soil Lead Assessment (P, R)
- Proximity to Utilities (P)
- Slope (P)
- Construction Materials (P)

1. General Garden Information

Garden Location & History
- Soil Lead Assessment (P, R)
- Proximity to Utilities (P)
- Slope (P)
- Construction Materials (P)

1. General Garden Information

Location & History
- Soil Lead Assessment (P, R)
- Proximity to Utilities (P)
- Slope (P)
- Construction Materials (P)

•Unless using commercially produced soil in a container garden, the soil in the garden is tested for lead, and that the level of lead in the soil is less than 300 ppm

Arizona Department of Health Services

Division of Public Health Services
Public Health Preparedness Services

150 N. 18th Avenue, Suite 130
Phoenix, Arizona 85007
(602) 364-3122
(602) 364-3146 FAX
Internet: www.azdhs.gov

School Gardens Program — Date: _____

Name: _____

School: _____

Mailing Address: _____

Phone: _____

Soil sampling protocol for lead testing:

Do:

1. Take samples only in the garden area,
2. Illustrate on the garden map where samples were taken,
3. Use clean sampling tools to avoid contaminating the sample (like a metal trowel or spade),
4. Take 5 to 10 subsamples in the garden area. Take thin, vertical slices of soil making sure to include the surface soil to about 4 inches deep in each subsample,
5. Mix the subsamples in a clean, plastic container or bag with a clean, plastic utensil,
6. Place less than 1 cup of mixed soil in a clean container (like a sandwich size zip-type plastic bag) and label,
7. Label your shipping box with "Soil Sample" on the top and sides,
8. Include your shipping label,
9. Include this form in the shipping box,
10. Include the garden map in the shipping box,
11. Email, call or fax when shipping your soil sample.

Don'ts:

1. Use paper bags, as they can't be sealed against the elements,
2. Use bronze instruments, can cause contamination,
3. Allow sample to sit out uncovered, to prevent contamination,
4. Include in the sample mulch, such as bark and wood,
5. Use contaminated sampling tools or container.

Submit soil sample along with this form and garden map to:

Kathryn Mathewson
150 N 18th Avenue, Suite 140
Phoenix, AZ 85007
(602) 364-3952
Fax. (602) 364-3146
Kathryn.Mathewson@azdhs.gov
Allow 4 to 8 weeks for processing.

Soil Sampling SOP
AZ Lead Testing Labs

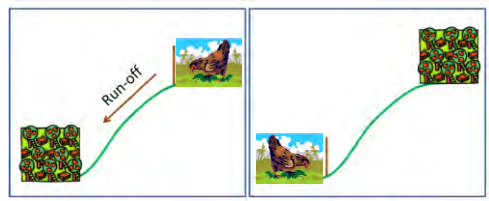
1. General Garden Information

Garden Location & History
- Soil Lead Assessment (P, R)
- Proximity to Utilities (P)
- Slope (P)
- Construction Materials (P)
- Document Land Use History (R)

•The garden will not conflict with underground utilities, call 811 before digging

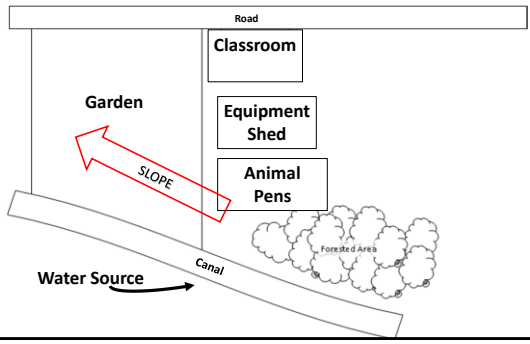
•Locate garden(s) in areas that are away from potential contamination sources. Locations not recommended: close proximity to wells, septic systems, garbage dumpsters, in ground storage tanks, compost areas, school animals (rabbits, tortoises, birds, etc.), animal enclosures or in low-lying, poorly drained areas

Contamination source is located downhill and away from garden to assure that rain does not lead to run-off contamination of garden



Higher risk — Lower risk

Mapping Your Garden: Include Slope and Water Source



1. General Garden Information

Garden Location & History

- Soil Lead Assessment (P, R)
- Proximity to Utilities (P)
- Slope (P)
- Construction Materials (P)
- Document Land Use History (R)

- The garden will not conflict with underground utilities, call 811 before digging
- Locate garden in areas that are away from potential contamination sources

It is imperative to have sewage treatment systems that function properly where there is no evidence of leaking or runoff.

1. General Garden Information

Garden Location & History

- Soil Lead Assessment (P, R)
- Proximity to Utilities (P)
- Slope (P)
- Construction Materials (P)
- Document Land Use History (R)

- The garden will not conflict with underground utilities, call 811 before digging
- Locate garden in areas that are away from potential contamination sources
- Raised beds shall use only non-toxic, non-leaching materials for the frame. Materials such as untreated lumber, bricks, cement blocks and straw bales are recommended, railroad ties and pressure treated lumber is not

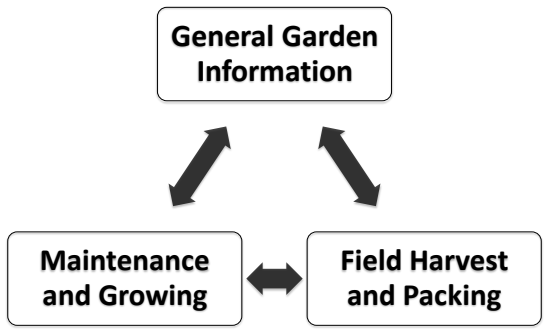
1. General Garden Information

Garden Location & History

- Soil Lead Assessment (P, R)
- Proximity to Utilities (P)
- Slope (P)
- Construction Materials (P)
- Document Land Use History (R)

- It is recommended that you document the land use history.

Garden Safety/Risk Control Plan



2. Garden Maintenance and Growing Practices

Irrigation Water Source & Quality

- Municipal, Open, or Well (R)
- All water sources must meet minimum EPA Recreational Water Standard (R)
- It is highly recommended that collected rain water is not used on edible plants (SOP)

2. Garden Maintenance and Growing Practices

Irrigation Water Source & Quality

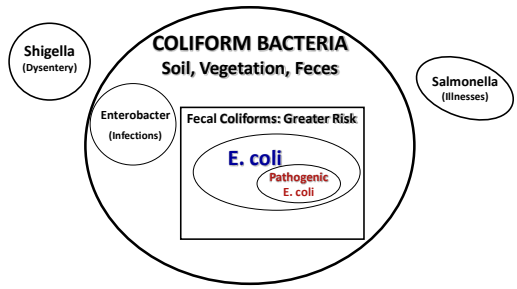
- Municipal, Open, or Well (R)
- All water sources must meet minimum EPA Recreational Water Standard (R)
- It is highly recommended that collected rain water is not used on edible plants (SOP)

Water Quality Risks

- A water quality assessment must be performed to determine the quality of water used for irrigation purposes
- E. coli 0157:H7, Salmonella, Lysteria, Giardia, and Cyclospora outbreaks have been caused by contaminated water
- However, for School Garden Safety, generic E. coli is used as an overall indicator of water quality

Enteric Bacteria

Bacteria of the Intestines



2. Garden Maintenance and Growing Practices

Irrigation Water Source & Quality

- Municipal, Open, or Well (R)
- All water sources must meet minimum EPA Recreational Water Standard (R)
- It is highly recommended that collected rain water is not used on edible plants (SOP)

- If well water is used for growing the produce, the well water is tested once during the growing season
- If surface water (lake, stream, canal, ditch etc.) is used, the irrigation water is tested three times during the growing season and meets the microbial requirements of the EPA Recreational Water Standard
- Water quality tests for municipal water sources are also required, at anytime during the year, and are available at little or no cost

Water Quality and Testing

- Test for generic *E. coli* and request that the results be quantified.
- Do NOT request an absence-or-presence test.
- If only one sample is taken, it must be below 126 CFU/100 mL.

Water source	Testing frequency
Municipal water in US	At least 1x/year
Well water	At least 1x/year during production
Surface water	At least 3x/year * Before use * At peak use * Close to harvest

Water Testing Log

School Garden Food Safety

Water Source*	Garden Location	Date Sampled	Testing Lab	Results

* Municipal water tests must be acquired on a yearly basis. Well water must be tested at least once during the growing season. Surface water must be tested three times during the growing season (first at planting, second at peak use, and third at or near harvest).

The Arizona Department of Agriculture, Agricultural Consultation and Training has funded all or a portion of this Project, using Specialty Crop Block Grant funds provided by the USDA, Agricultural Marketing Service.

Valley Pioneers Water Company 2009 Detected Contaminants Report

Contaminant	Unit	MCL	MCLG	Average	High	Range	Major Sources	Violation
Regulated by testing monthly in the Distribution System								
Total Coliform	Sample	0	0	0	0	0	Naturally present in the environment.	No
Fecal Coliform	Sample	0	0	0	0	0	Sewage treatment plants, septic systems, agricultural livestock operations and wildlife	No
Disinfection Byproducts taken annually at the end of the Distribution System								
Haloacetic Acid (HAA5)	mg/L	.060	0	.0016	.002	.001-.002	Some people who drink water containing haloacetic acids in excess of the MCL over many years may have an increased risk of getting cancer	No
Total Trihalomethanes (TTHMs)	mg/L	.080	0	.0057	.0098	.0025-.0098	Some people who drink water containing trihalomethanes in excess of the MCL over many years may experience problems with their liver, kidneys, or central nervous systems, and may have an increased risk of getting cancer.	No
Regulated by testing every three years at Point of Entry last sample year 2007 - (Nitrates are sampled annually)								
Arsenic	mg/L	.010	0	.0076	.0094	.0058-.0094	Erosion of natural deposits; Runoff from orchards; Runoff from glass and electronics production wastes	No
Barium	mg/L	2	2	.0079	.0114	.0043-.0114	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits.	No
Chromium	mg/L	0.1	0.1	.0077	.008	.007-.008	Discharge from steel and pulp mills; Erosion of natural deposits	No
Fluoride	mg/L	4	4	.81	.88	.74-.88	Erosion of natural deposits; Water additive which promotes strong teeth; Discharge from fertilizer and aluminum factories	No
Nitrate	mg/L	10	10	2.9	2.9	2.9	Runoff from fertilizer use; Leaching from septic tanks, sewage; Erosion of natural deposits	No
Radioactive Contaminants								
Beta/photon emitters	Mrem/yr	4	0	0	0	0	Decay of natural and man-made deposits	No
Alpha emitters	pCi/l	15	0	0	0	0	Erosion of natural deposits	No
Combined radium	pCi/l	5	0	0	0	0	Erosion of natural deposits	No

Regulated by testing every three years at customer's tap

Contaminant	AL	ALG	Units	90th Percentile	Number of sites over AL	Violation	Sample Date/Year	Likely source of contamination
Copper	1.3	1.3	mg/L	.057	20	No	8/28/08	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Lead	.015	0	mg/L	.001	20	No	8/28/08	Corrosion of household plumbing systems, erosion of natural deposits

(MCL) Maximum Contaminant Level – The "Maximum Allowed" is the highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology.
(MCLG) Maximum Contaminant Level Goal – The "Goal" is the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety.
(mg/L) Miligrams per liter – means the same as parts per million (ppm)
(ppm) Parts per million – one part per million corresponds to one minute in two years, or a single penny in $10,000.
(ppb) Parts per billion – one part per billion corresponds to one minute in 2,000 years, or a single penny in $10,000,000.
(pCi/l) Picocuries per liter – picocuries per liter is a measure of the radioactivity in water.
(mrem/yr) Millirems per year – measure of radiation absorbed by the body.

2. Garden Maintenance and Growing Practices

Irrigation Water Source & Quality

- Municipal, Open, or Well (R)
- All water sources must meet minimum EPA Recreational Water Standard (R)
- It is highly recommended that collected rain water is not used on edible plants (P)

- Rainwater harvesting is not recommended

2. Garden Maintenance and Growing Practices

Irrigation Water Source & Quality

- Municipal, Open, or Well (R)
- All water sources must meet minimum EPA Recreational Water Standard (R)
- It is highly recommended that collected rain water is not used on edible plants (P)

Plant Fertilizers & Soil Amendments

- Commercially available synthetic fertilizers (P)
- Composted animal waste is not recommended, this includes worm castings and compost teas
- Fertilizers containing animal, fish byproducts or seaweed based amendments must be from widely familiar, brand-name sources

- Any synthetic granular or liquid fertilizer must be from a commercially produced source, applied to garden according to the manufacturers recommendations
- Records from the supplier kept on the premise at all times

Soil Amendments Log

School Garden Food Safety

Date	Location Applied	Rate/Ratio	Incorporated (Y/N)	Product	Supplier

The Arizona Department of Agriculture, Agricultural Consultation and Training has funded all or a portion of this Project, using Specialty Crop Block Grant funds provided by the USDA, Agricultural Marketing Service.

2. Garden Maintenance and Growing Practices

Irrigation Water Source & Quality

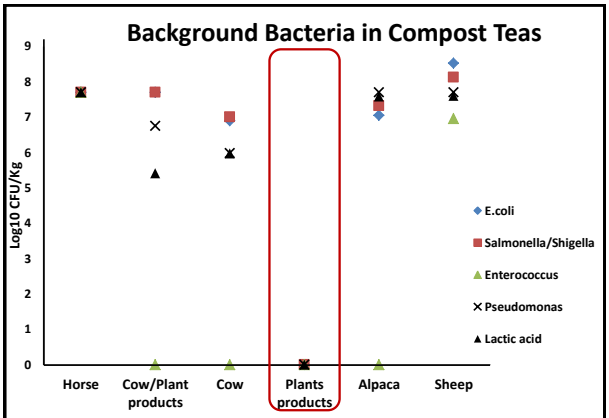
- Municipal, Open, or Well (R)
- All water sources must meet minimum EPA Recreational Water Standard (R)
- It is highly recommended that collected rain water is not used on edible plants (P)

Plant Fertilizers & Soil Amendments

- Commercially available synthetic fertilizers (P)
- Composted animal waste is not recommended, this includes worm castings and compost teas (P)
- Fertilizers containing animal, fish byproducts or seaweed based amendments must be from widely familiar, brand-name sources (P)

- Composted animal waste is not recommended
- This includes compost teas

Compost Teas



2. Garden Maintenance and Growing Practices

Irrigation Water Source & Quality

- Municipal, Open, or Well (R)
- All water sources must meet minimum EPA Recreational Water Standard (R)
- It is highly recommended that collected rain water is not used on edible plants (P)

Plant Fertilizers & Soil Amendments

- Commercially available synthetic fertilizers (P)
- Composted animal waste is not recommended, this includes worm castings and compost teas (P)
- School prepared compost must be of plant origin and according to Certified Organic Protocols (P, SOP, R)
- Fertilizers containing animal, fish byproducts or seaweed based amendments must be from widely familiar, brand-name sources (P)

- Composted animal waste is not recommended, including compost teas
- However, only plant derived composted products are acceptable if composted within the parameters of the USDA Certified Organic Program

Composted Plant Materials

If plant derived compost will be made at the school:

Be certain to follow Certified Organic composting protocols.

- Manage piles to have active, uniform composting
- High temperatures, good moisture, proper aeration, and repeated mixing or turning
- RECORD COMPOSTING CONDITIONS AND TURNINGS
- Obtain composting records if purchasing certified compost

USDA Organic Certified Compost Program:

Compost Piles: 130 F – 170 F for minimum of 3 days

Windrow Systems: 130 F – 170 F for 15 days minimum.

School Compost Log

School Garden Food Safety

Date	Location	Source of Compost*	Recorded Temperature

* i.e.: company's name if compost was purchased or what was used to create compost if made at the school (temperature records are essential if creating own compost)

At this time, school prepared compost can only be used on non-edible plants and must only contain plant products.

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2. Garden Maintenance and Growing Practices

Irrigation Water Source & Quality

- Municipal, Open, or Well (R)
- All water sources must meet minimum EPA Recreational Water Standard (R)
- It is highly recommended that collected rain water is not used on edible plants (P)

Plant Fertilizers & Soil Amendments

- Commercially available synthetic fertilizers (P)
- Composted animal waste is not recommended, this includes worm castings and compost teas (P)
- School prepared compost must be of plant origin and according to Certified Organic Protocols (P, SOP, R)
- Fertilizers containing animal, fish byproducts or seaweed based amendments must be from widely familiar, brand-name sources (P, R)

Any fertilizer containing animal products such as manure, blood meal or dried blood must be from a commercially produced source and records from the supplier kept on the premise at all times

Soil Amendments Log

School Garden Food Safety

Date	Location Applied	Rate/Ratio	Incorporated (Y/N)	Product	Supplier

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Irrigation Water Source & Quality

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- All water sources must meet minimum EPA Recreational Water Standard (R)
- It is highly recommended that collected rain water is not used on edible plants (SOP)

Plant Fertilizers & Soil Amendments

- Commercially available synthetic fertilizers (SOP)
- Composted animal waste is not recommended, this includes worm castings and compost teas (P)
- Fertilizers containing animal, fish byproducts or seaweed based amendments must be from widely familiar, brand-name sources (P, R)

Pest Control, Animal Intrusion and Garden Security

2. Garden Maintenance and Growing Practices

Pest Control, Animal Intrusion and Garden Security

- Weeds are controlled with mulches, hand-pulling, or weeding implements, not with herbicides (P)
- Garden is protected from animal intrusion by fencing or other means (P)
- Monitor for and document the presence of animals, and properly remove contaminates.

2. Garden Maintenance and Growing Practices

Pest Control, Animal Intrusion and Garden Security

- Weeds are controlled with mulches, hand-pulling, or weeding implements, not with herbicides (P)
- Garden is protected from animal intrusion by fencing or other means (P)
- Monitor for and document the presence of animals, and properly remove contaminates.

Measures are taken to reduce the opportunity for wild and/or domestic animals from entering the school garden

Animal/Pest Deterrent Log

School Garden Food Safety

Date	Product	Location Applied	Supplier

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2. Garden Maintenance and Growing Practices

Pest Control, Animal Intrusion and Garden Security

- Weeds are controlled with mulches, hand-pulling, or weeding implements, not with herbicides (P)
- Garden is protected from animal intrusion by fencing or other means (P)
- Monitor for and document the presence of animals, and properly remove contaminates and extend school's normal security measures (R)

Animal Presence Log

School Garden Food Safety

Date	Location	Description of Sighting	Contaminates Removed	Determent Introduced

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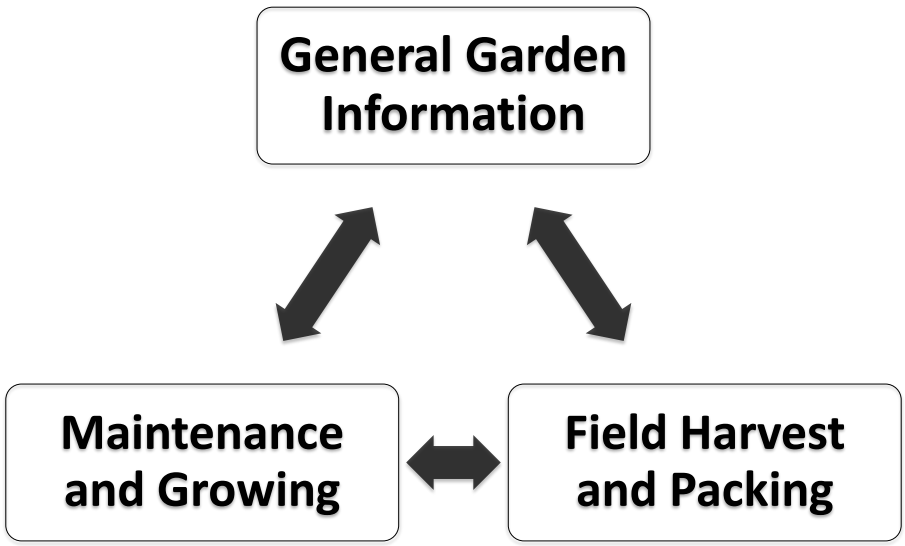
Garden Safety/Risk Control Plan



3. Field Harvest and Packing

Field Harvest

- Individuals harvesting the produce shall follow proper harvesting etiquette and assessments (P, SOP, R)
- All soil and particulate matter is manually cleaned from the produce before placing in the harvest container (P)

Some Recommended Harvesting Etiquette and Assessments:

- Complete the pre-harvest assessment
- Wash hands before beginning to work or returning to the garden
- Wear closed-toed shoes
- Avoid contact with animals
- Eat and drink in designated areas away from the garden
- Stay out of garden if ill
- Wear single-use, food grade non-latex gloves for harvesting

3. Field Harvest and Packing

Field Harvest

- Individuals harvesting the produce shall follow proper harvesting etiquette and assessments (P, SOP, R)
- Coordinate harvesting with adult supervision (P)

- Review with workers the hygiene requirements and sun protection techniques
- All soil and particulate matter is manually cleaned from the produce before placing in the harvest container
- Produce with bird droppings on it is not harvested unless the produce item will be washed and cooked prior to consumption

Pre-Harvest Assessment

School Garden Food Safety

Field or Production Area: _____ Date: _____ Harvest Date: _____

Questions	Yes	No	Action Taken	Initials
Has the garden been certified by the ADHS Sanitarian?				
Does the school district's liability insurance cover school garden produce?				
Is the equipment in safe working condition and free from defect?				
Have all knives, scissors, harvesting containers, and other harvesting equipment been cleaned and sanitized?				
Are there enough of the required harvesting gloves (single-use, non-latex, plastic gloves)?				
Is there enough potable water available?				
Are there enough new and clean, one-time use paper or plastic bags if not using reusable harvest containers?				
Are the restroom facilities accessible, well-stocked, and clean?				
Has the garden been inspected for evidence of contamination, including human and animal contaminates?				
Have contaminates plus affected plants and soil been removed and disposed of in a trash container?				

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School Garden Harvesting: Field Packing

Field Harvesting

A reasonable effort should be made to <u>remove excessive dirt and mud</u> from the product itself and/or any containers that are used during harvest.

Field Harvesting

<u>Only</u> use water that is the microbial equivalent of drinking water (potable) to harvested product

Water Testing Log

School Garden Food Safety

Water Source*	Garden Location	Date Sampled	Testing Lab	Results

* Municipal water tests must be acquired on a yearly basis. Well water must be tested at least once during the growing season. Surface water must be tested three times during the growing season (first at planting, second at peak use, and third at or near harvest).

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3. Field Harvest and Packing

Field Harvest

- Individuals harvesting the produce shall follow proper harvesting etiquette and assessments (P, SOP, R)
- Coordinate harvesting with adult supervision (P)

Harvest Aides, Tools and Equipment

- Maintaining and tote hygiene (P, SOP, R)
- Store produce in food-grade quality, reusable containers that has been washed, rinsed, and sanitized with Cl or quaternary ammonia containing products
- Use single service containers such as paper bags, during harvesting and post harvest

Field Harvesting

- **Clean and sanitize harvest containers**
- **Damaged containers need to be properly repaired or disposed of**

Equipment Sanitization Log

School Garden Food Safety

Equipment*	Date	Cleaned By	Cleansing Agents

* i.e.: specific gardening tools, storages containers, etc.

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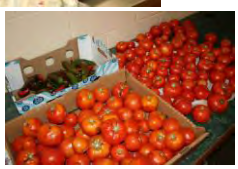
Field Harvesting

Harvesting containers, totes, etc. are not used for carrying or storing non-produce items during the harvest season

Cafeteria Receiving

- **In a garden pack operation, ONLY new or sanitized containers are used**
- **Reject any produce if there are odors or evidence of contamination**
- **Store produce from school garden separately from commercial produce**
- **Record who, how, and where the school garden produce was harvested and cleaned**



Last Minute Questions?

Kurt Nolte, UA, 928-503-4956
Stewart Jacobson, ADA, 602-542-0950

ADHS School Garden Program

Mission:

To enable fresh produce from an on-site garden to be served safely in school cafeterias.

Vision:

To bring safe, fresh produce grown by students into their school cafeteria.

ADHS School Garden Program

Overview

- Arizona Food Code Requirements
- Farm vs. School Garden
- Classroom vs. Cafeteria
- Food Safety
- Approval Process & Risk Factors Covered by Program
- Risk Control Plan
- Site Visit
- Advice for Cafeteria Management

Arizona Food Code Requirements

- School Cafeterias are licensed Food Establishments
- All Food Establishments must serve food from an Approved Source
- The Food regulatory agency must approve all sources of food in its licensed establishments
- Approved means "acceptable" and "conforms with principles, practices and generally recognized standards that protect public health"

Farm vs. School Garden

Farm	School Garden
Large population served	Smaller population served
Acreage is vast	Smaller/limited plots
Paid Employees	Students/Volunteers
For Profit	Non-profit
GHP/GAP Certification (Fee applied)	ADHS Certification (No charge)

Classroom Vs. Cafeteria

Classroom Setting

- Population served
  - 15~40 students
- Parents
  - Might sign permission slips
  - Aware their student is in the garden
- Food safety
  - Small setting where vegetables are being sampled
  - Not being processed or cooked, eaten immediately

Cafeteria Setting

- Population served
  - ~50~5,000 students
- Parents
  - Assume food is safe
  - Might be unaware the school has a garden and using in cafeteria
- Food safety
  - Food is processed and/or cooked
  - Food is held longer in storage and not eaten immediately

Food Safety

CDC Surveillance Report 1988-1992

Identified 5 risk factors contributing to foodborne illnesses

- Inadequate Cooking
  - Salmonella, app, Escherichia coli (E-coli), Campylobacter, Vibrio cholera
- Improper Holding Temperatures
  - Listeria monocytogenes, Clostridium perfingens, Salmonella, E-coli, Bacillus Cereus, Staphylococcus
- Contaminated Equipment
  - Salmonella, E-coli, Hepatitis A, Norovirus, Staphylococci Enterotoxins,
- Poor Personal Hygiene
  - Salmonella, E-coli, Shigella, Norovirus, Hepatitis A
- Food from Unsafe Sources/Untreated Water
  - Clostridium botulinum, Giardia lamblia, Cryptosporidium parvum, Vibrio cholera, Hepatitis A, Norovirus

http://www.fda.gov/Food/FoodSafety/RetailFoodProtection/FoodCode/FoodCode2001/ucm123544.htm

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Bacteria, Viruses, and Protozoa

- Can't see, taste or smell
- Only a few cells may cause illness
- Bacteria grow quickly in these conditions
  - Food
  - Non-acidic conditions
  - Time
  - Temperature
  - Oxygen
  - Moisture

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Tip of the Iceberg

- Foodborne illness is a significant burden
  - About 48 million (1 in 6 Americans) get sick each year
  - Between 1990-2007, 12.3% of outbreaks were associated with produce
  - 128,000 are hospitalized
  - 3,000 die
- Immune-compromised individuals more susceptible
  - Infants and children, pregnant women, older individuals, those on chemotherapy
- Foodborne illness is not just a stomach ache—it can cause life-long chronic disease
  - Arthritis, kidney failure

http://www.foodandfarming.info/docs/386Produce_Analysis_2010_Final.pdf

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School Garden Food Safety

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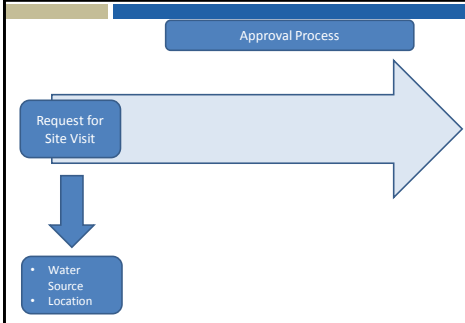

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Request for Site Visit

ARIZONA DEPARTMENT OF HEALTH SERVICES
OFFICE OF ENVIRONMENTAL HEALTH
150 N. 18th Avenue, Suite 140, Phoenix, Arizona 85007
REQUEST FOR SITE VISIT FOR SCHOOL GARDENS

Name of School Garden:		
Street address:		
City:	Zip code:	School phone:
Person In Charge (PIC):		
Email:	PIC phone:	Fax number:
Mailing address:		
City:	State:	Zip code:

Water source: Municipal ____ Well* ____ Irrigation* ____ Other*___
If other, please describe: _____
*Provide a copy of the most recent bacterial analysis

What produce will you be growing: _____
What is your growing season: _____

Type of produce beds: Flat ____ Sunken ___ Raised ___
If raised, what type of material will be used for the frame, describe: _____

Soil tested for lead: Yes____ No____ If yes, date tested: _____ and the amount of lead: _____
What type of fertilizer will be used, describe: _____

What is the distance, measured in feet, from the garden to the following areas:
Water source ____ Septic system ____ Garbage dumpster ____ Storage tanks ____ Feed lot ____
Parking lot ____ Bathroom ____ Hand wash sinks ____ Pest control applications ____
Composting area and method _____

Describe the desired location for the garden, include size, number of plots, fencing, harvesting equipment, pest control methods, does the area properly drain during and after rain, etc.
Please provide a map with the location of the beds, walkways, water source, fencing, and hand wash sinks.
_____
_____
_____
_____
_____
_____
_____

Include a copy of your Food Safety Plan and garden map.
Print Name: _____ Signature: _____ Date: _____

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Name of School Garden:		
Street address:		
City:	Zip code:	School phone:
Person In Charge (PIC):		
Email:	PIC phone:	Fax number:
Mailing address:		
City:	State:	Zip code:

Water source: Municipal ____ Well* ____ Irrigation* ____ Other*___
If other, please describe: _____
*Provide a copy of the most recent bacterial analysis
What produce will you be growing: _____
What is your growing season: _____

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Water Source

- Municipal, tested by water company
- Well water, sampled once
- Irrigation, sampled three times
- Harvested rainwater only on non-edible plants

Rain Water Harvesting Water Quality Issues

- Microbial Contamination
  - Influenced by the weather, air pollution, and type of storage tanks
  - Bacteria, protozoa, Viruses,
    - Legionella, Salmonella, and Shigella, Campylobacter, Giardia, Vibrio, Norovirus
- Chemical Contamination
  - Particulates from auto emission, corrosion of roof paints and materials
    - Asbestos fibers, cadmium, copper, and lead

http://vwrrc.vt.edu/pdfs/specialreports/sr382008.pdf

Roof Water Disease Outbreaks				
Year	Location	Cases	Organism	Association
1978	Trinidad	63	Salmonella	Strong
1981	Caribbean	13	Legionella	Probable
1983	England	257	Campylobacter	Possible
1992	Australia	89	Giardia & Cryptosporidium	Possible
1997	New Zealand	4	Salmonella	Strong
1999	Australia	23	Campylobacter	Probable
2000	Australia	28	Salmonella	Strong
2003	New Zealand	5	Salmonella	Strong
2006	New Zealand	4	Legionella	Strong
2009	Australia	27	Salmonella	Strong
2010	New Zealand	93	Norovirus	Probable

http://www.pwwa.ws/pdfs/Stan_Abbott_RWH_Consumption_Health_Handout.pdf

Potential Survival of Fecal Pathogens in the Environment

Material	Duration of Survival			
	Cryptosporidium	Salmonella	Campylobacter	E. coli 0157:H7
Water - Frozen	>1 year	>6 months	2-8 weeks	>300 days
Water - Cold (5ºC)	>1 year	>6 months	12 days	>300 days
Water - Warm (30ºC)	10 weeks	>6 months	4 days	84 days
Soil - Frozen	>1 year	>12 weeks	2-8 weeks	>300 days
Soil - Cold (5ºC)	8 weeks	12-28 wks	2 weeks	100 days
Soil - Warm (30ºC)	4 weeks	4 wks	1 week	2 days

Source: Human and Animal Pathogens in Manure, Olsen, M. E.

Type of produce beds: Flat ____ Sunken ___ Raised ___

If raised, what type of material will be used for the frame, describe: _____

Soil tested for lead: Yes____ No____ If yes, date tested: _____ and the amount of lead: _____

What type of fertilizer will be used, describe: _____

What is the distance, measured in feet, from the garden to the following areas:

Water source ____ Septic system ____ Garbage dumpster ____ Storage tanks ____ Feed lot ____

Parking lot ____ Bathroom ____ Hand wash sinks ____ Pest control applications ____

Composting area and method _____

Describe the desired location for the garden, include size, number of plots, fencing, harvesting equipment, pest control methods, does the area properly drain during and after rain, etc.
Please provide a map with the location of the beds, walkways, water source, fencing, and hand wash sinks.

_____

_____

_____

_____

_____

_____

Include a copy of your Food Safety Plan and garden map.

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Location

Is key to preventing contamination, the garden should be up hill from the following:

- Septic system
- Dumpsters
- Storage tanks
- Animal enclosure
- Compost pile
- Parking lots
- School animals
- Bird habitats
- Chemical application
- Low lying, poorly drained area
- History of land use
- Next to a wall
- Rail road ties

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Raised Beds

Made of non-toxic, non-leaching material

- Cedar
- Cypress
- Pine
- Oak
- Composite material
- Masonry materials

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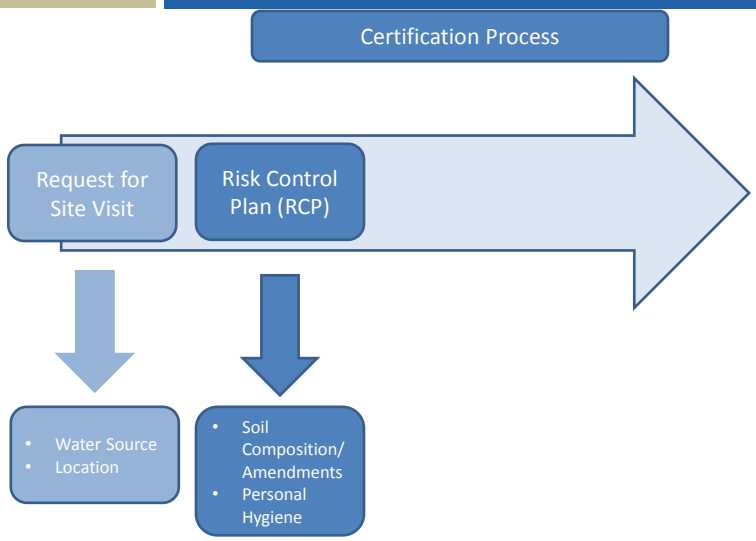

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Risk Control Plan

Did you attend the University of Arizona College of Agriculture and Life Sciences Cooperative Extension Course? Yes____ No____

1. What company will you use to test the soil? What will you do if the soil tests over 300 ppm for lead?_____

2. What is the source of your water? What company will you use to test the water, if necessary?

3. What type of construction material are you using for your raised gardens, if applicable?

4. What source are you going to use to obtain your commercial fertilizer and/or compost?

5. Where will gardeners wash their hands? How will you train gardeners in proper hand washing techniques? Will you have a log on-site to document hand wash training?

6. How will you keep sick gardeners out of the garden? Will you have a log of sick gardeners?

7. How will produce be transported to the cafeteria and what type of containers will you be using?

8. What cleaning and sanitizing process will be used for the harvest containers prior to use? Where will the cleaning process take place?

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Did you attend the University of Arizona College of Agriculture and Life Sciences Cooperative Extension Course? Yes____ No____

1. What company will you use to test the soil? What will you do if the soil tests over 300 ppm for lead?_____

2. What is the source of your water? What company will you use to test the water, if necessary?

3. What type of construction material are you using for your raised gardens, if applicable?

4. What source are you going to use to obtain your commercial fertilizer and/or compost?

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Soil Composition

- Soil is tested for lead (free at ADHS lab)
  - Must contain less than 300 ppm

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Soil Testing Protocol

Do:

- Take samples only in the garden area,
- Illustrate on the garden map where samples were taken,
- Use clean sampling tools to avoid contaminating the sample (like a metal trowel or spade),
- Take 5 to 10 subsamples in the garden area. Take thin, vertical slices of soil making sure to include the surface soil to about 4 inches deep in each subsample.,
- Mix the subsamples in a clean, plastic container or bag with a clean, plastic utensil,
- Place less than 1 cup of mixed soil in a clean container (like a sandwich size zip type plastic bag) and label,
- Label your shipping box with “Soil Sample” on the top and sides,
- Include your shipping label,
- Include this form in the shipping box,
- Include the garden map in the shipping box,
- Email, call or fax when shipping your soil sample.

Don’t:

- Use paper bags, as they can’t be sealed against the elements,
- Use bronze instruments, can cause contamination,
- Allow sample to sit out uncovered, to prevent contamination,
- Include in the sample mulch, such as bark and wood,
- Use contaminated sampling tools or container.

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Soil Amendments

- Commercial fertilizer and commercial compost
- School made, plant derived compost only on non-edible plants based on USDA recommendations

http://nfsmi.org/documentlibraryfiles/PDF/20110822025700.pdf

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School Made Compost

- Compost is beneficial to plants and reduces waste in landfills
- Compost can contain dangerous pathogens
  - Aspergillosis, Farmer's Lung, Histoplasmosis, Legionnaire's Disease, Paronychia, Tetanus
- Compost can pose a safety hazard: Fire

http://www.nachi.org/compost-pile-hazards.htm

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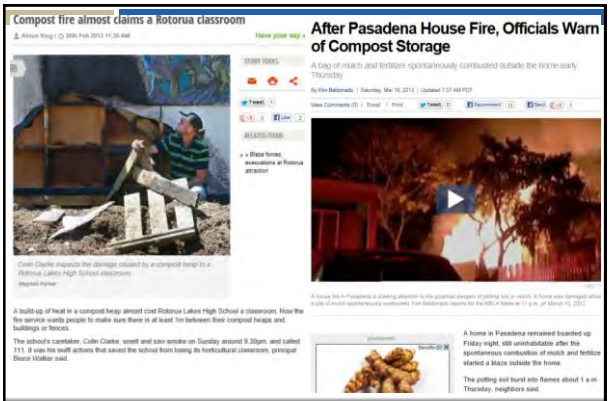

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Potential Survival of Fecal Pathogens in the Environment

Material	Duration of Survival			
	Cryptosporidium	Salmonella	Campylobacter	E. coli 0157:H7
Soil - Frozen	>1 year	>12 weeks	2-8 weeks	>300 days
Soil - Cold (5ºC)	8 weeks	12-28 wks	2 weeks	100 days
Soil - Warm (30ºC)	4 weeks	4 wks	1 week	2 days
Cattle manure - Frozen	> 1 year	>6 months	2-8 weeks	>100 days
Cattle manure - Cold (5ºC)	8 weeks	12-28 weeks	1-3 weeks	>100 days
Cattle manure - Warm (30ºC)	4 weeks	4 weeks	1 week	10 days
Liquid manure	>1 year	13-75 days	>112 days	10-100 days
Composted manure	4 weeks	7-14 days	7 days	7 days
Dry surfaces	1 day	1-7 days	1 day	1 day

Source: Human and Animal Pathogens in Manure, Olsen, M. E.

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5. Where will gardeners wash their hands? How will you train gardeners in proper hand washing techniques? Will you have a log on-site to document hand wash training?

6. How will you keep sick gardeners out of the garden? Will you have a log of sick gardeners?

7. How will produce be transported to the cafeteria and what type of containers will you be using?

8. What cleaning and sanitizing process will be used for the harvest containers prior to use? Where will the cleaning process take place?

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Produce Contact Surfaces

- Harvesting equipment
- Harvesting storage containers
  - Food grade quality
  - Cleaned and sanitized

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Gardener Personal Hygiene

- Sick gardeners
- Hand wash sink available
- Contaminated hands
  - Bacteria and viruses
    - Handling animals
    - Touch face or mouth
  - Wash hands and use single-use food grade non-latex gloves when harvesting

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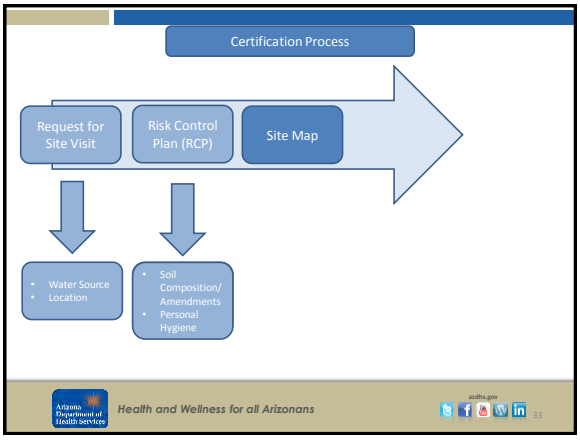

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School Garden Site Map

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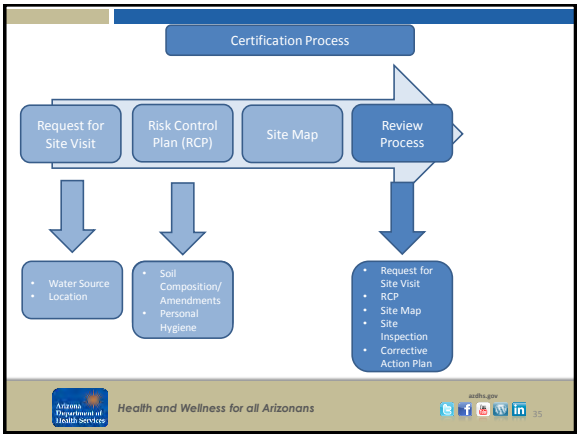

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Approval Process

- ADHS reviews documents
  - Site Visit Request Form
  - Risk Control Plan
  - Garden Map
  - Soil test results for lead
- Schedule a Site Visit
  - Verify above documents
  - Notify school of any corrective actions needed
    - Create a Corrective Action Plan with school
  - Issue a Certificate of Approval

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Corrective Action Plan

School Garden Corrective Action Plan

School Garden Name: _____ Garden Number: _____

Specific observation and risk noted during site visit:

_____

_____

_____

Preventive Goal to be achieved:

- **Location**
- **Water Quality**
- **Soil Composition and Amendments**
- **Gardener Health and Hygiene**
- **Facilities, Equipment, Tools and Sanitation**

Risk to be controlled:

_____

_____

What must be achieved to gain compliance in the future;

_____

_____

How will active managerial control be achieved:(Who is responsible for the control, what monitoring and record keeping is required, who is responsible for monitoring and completing records, what corrective actions should be taken when deviations are noted, how long is the plan to continue)

_____

_____

_____

_____

_____

How will the results of implementing the Corrective Action Plan be communicated back to the School Garden Sanitarian:

_____

_____

As the person in charge of the _____ located at _____, I have voluntarily developed this corrective action plan, in consultation with _____ and understand the provisions of this plan.

_____ _____ _____

(Person in Charge) (School Garden Sanitarian) (Date)

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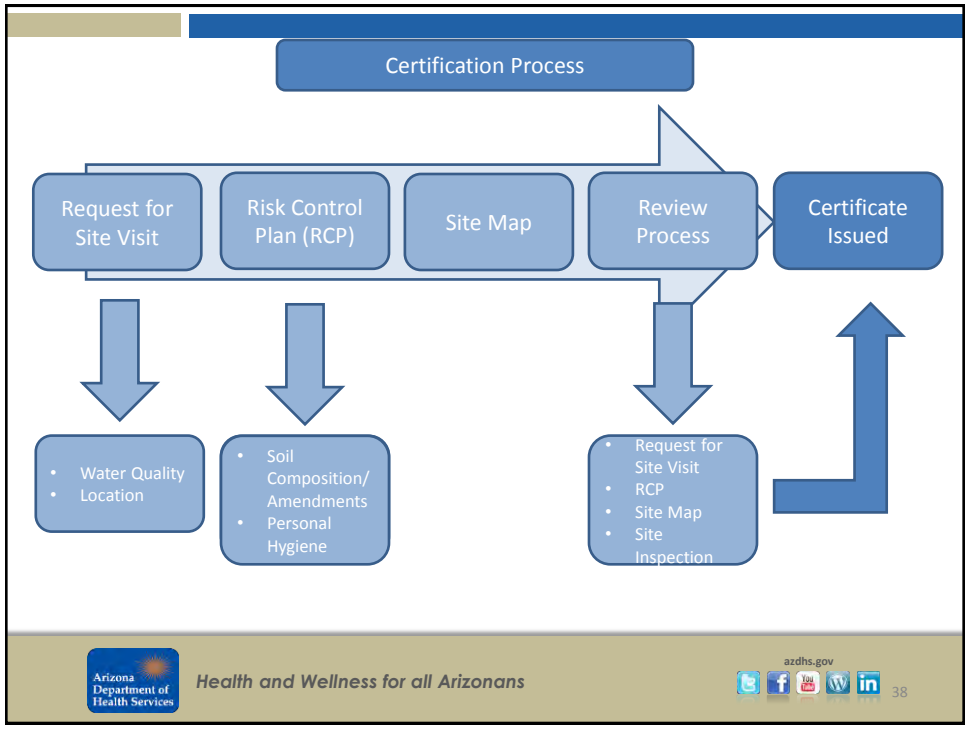

Certificate of Approval

- Good for one year
  - Includes one unannounced Site Visit
- County will be notified of approval
- Renewal letter
  - Set up a Site Visit with School
  - Unannounced Site Visit

School Garden Certificate of Approval
Wilson test

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Advice for the Cafeteria Manager

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Advice for the Cafeteria Manager

- Inspect produce
  - Spoilage, broken skin, odor, wet produce, wilted, brown, or animal feces on it
  - Broken plant cells allow bacteria to enter
- Containers are clean and sanitized
- Keep the produce separate from commercial
  - Label, weigh, and keep a chart

Resources: http://www.fns.usda.gov/fns/safety/produce-safety.htm

School Garden Harvest Log

School Name:

	Item Harvested	Date Harvested	Date Used	ID/Field/Row	Quantity	Measur	Use in school
	EXAMPLE: Lettuce	1/1/2013	1/5/2013	8th grade	5	lbs	salad bar
	EXAMPLE: tomatoes	1/1/2013	1/6/2013	7th grade	10	pints	salad bar
1							
2							
3							
4							

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For a Centralized Kitchen

- Track the produce
  - Identifying number or location
  - Harvest date
  - Date received
- Give produce back to the school of origin

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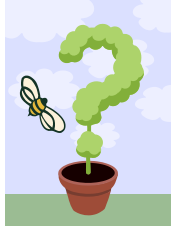
School Gardens

- Beneficial
  - Encourage healthy eating
  - Give students' life skills
  - Build students' self-esteem
- Educational
  - Teach students' the fruits and vegetables that can be grown in their area
  - Teach students' how to plant, care and harvest crops

Making Safe Choices

Thank you for bringing gardens to Arizona's students!



Kathryn Mathewson, MAdmin, RS
School Garden Sanitarian/Health Educator
602-364-3952
kathryn.mathewson@azdhs.gov

Locally Grown

LEVEL: Grades 4 -12

SUBJECTS: Language Arts, Science, Social Studies, Health and Math

AZ ACADEMIC STANDARDS: Measurement & Data, Expressions & Equations, Ratios & Proportional Relationships, Quantities, Mathematical Practices, Listening/Speaking, Reading Process, Comprehending Informational Text, Inquiry Process, Life Science, Geography, Economics and Health.

MATERIALS

Map of Arizona with counties outlined and major cities indicated, **"Arizona Food Produced Instate More Common"** article from Nov. 28, 2010 article in *The Arizona Republic* newspaper, **Crops by County in Arizona** table from USDA 2007 Census of Agriculture, **"The Rise of the Locavore"** article in the May 20, 2008 *Bloomberg Businessweek* magazine, **MyPlate** template, and lined writing paper.

VOCABULARY

Commodities, Locavore, Arizona Grown, Agriculture

RELATED LESSONS

http://cals.arizona.edu/agliteracy/lessons.htm

- A is for Apple
- Arizona! How the Heck Did I End Up Here?
- Can You Walk On Eggs?
- Pecan Power
- To Bee Or Not To Bee
- Let's Make Stew
- Let Us Learn About Lettuce

SUPPORTING INFORMATION

Agriculture provides for our basic needs of food, clothing and shelter. Nature provides the other basic need of water. Many people have made the decision to find out where and how the food they eat is grown.

Arizona's geography and climate make it an ideal state to grow a variety of fruits, vegetables, nuts, beans, and grains, as well as raise meat animals, dairy and eggs for our consumption.

Arizona has 15,637 farms and ranches and 99.3% are family owned. A majority, 84.3%, are 99 acres or less. Seventy-seven of the farms/ranches are certified organic.

The local food movement, locavore, is on a steady upward trajectory. Consumers want to meet the person who grew their food. The USDA farm bill has provided $2.3 billion for research to help small growers, and improve their access to farmer's markets.

Students can look at careers in agriculture while they learn about the industry. Many people view agriculture as the farmer or rancher growing a crop or raising livestock. There are many more jobs in the food industry including scientists, veterinarians, marketing, managers, nutritionists, range management, lawyers, health inspector, researcher, packer, and statistician to name a few.

GETTING STARTED

Make copies of the Arizona map and the Crops by County in Arizona" census data. For older students provide the newspaper articles for discussion.
Provide computer access to www.myfoodapedia.gov for students to use after they create their meal.

BRIEF DESCRIPTION

Students will plan a nutritious, low calorie meal and learn which foods in that meal are grown in Arizona.

OBJECTIVES

Students will:
-Plan a meal.
-Investigate if any of the items are grown in Arizona
-Explore the geography of the state to learn why agriculture products grow at a particular climate and elevation.
-Evaluate if the meal is nutritionally healthy.
-Discuss careers needed to develop, grow, harvest and provide those food items for their use.

ESTIMATED TEACHING TIME

30 - 45 minutes per session

GETTING STARTED(cont'd)
Make copies of the MyPlate template and the food groups explanation, http://www.choosemyplate.gov/foodgroups/index.html.

PROCEDURES
Session One
1. Have students work in teams of four to plan a healthy favorite meal.
2. Do not limit the items they can have in their meal.
3. The meal needs an appetizer, main course, beverage and dessert. Discuss with younger students what is meant by an appetizer.
4. The main course should include a protein plus fruits and/or vegetables. It can also include grains and dairy.
5. Ask students to write down every food item needed to prepare their meal. For example, if they want pizza for their main course they need all necessary ingredients for the dough, sauce, and toppings including seasoning.
6. Homework for younger students is to ask them to share the written meal plan with their parents/guardians to make sure they have included all necessary ingredients.

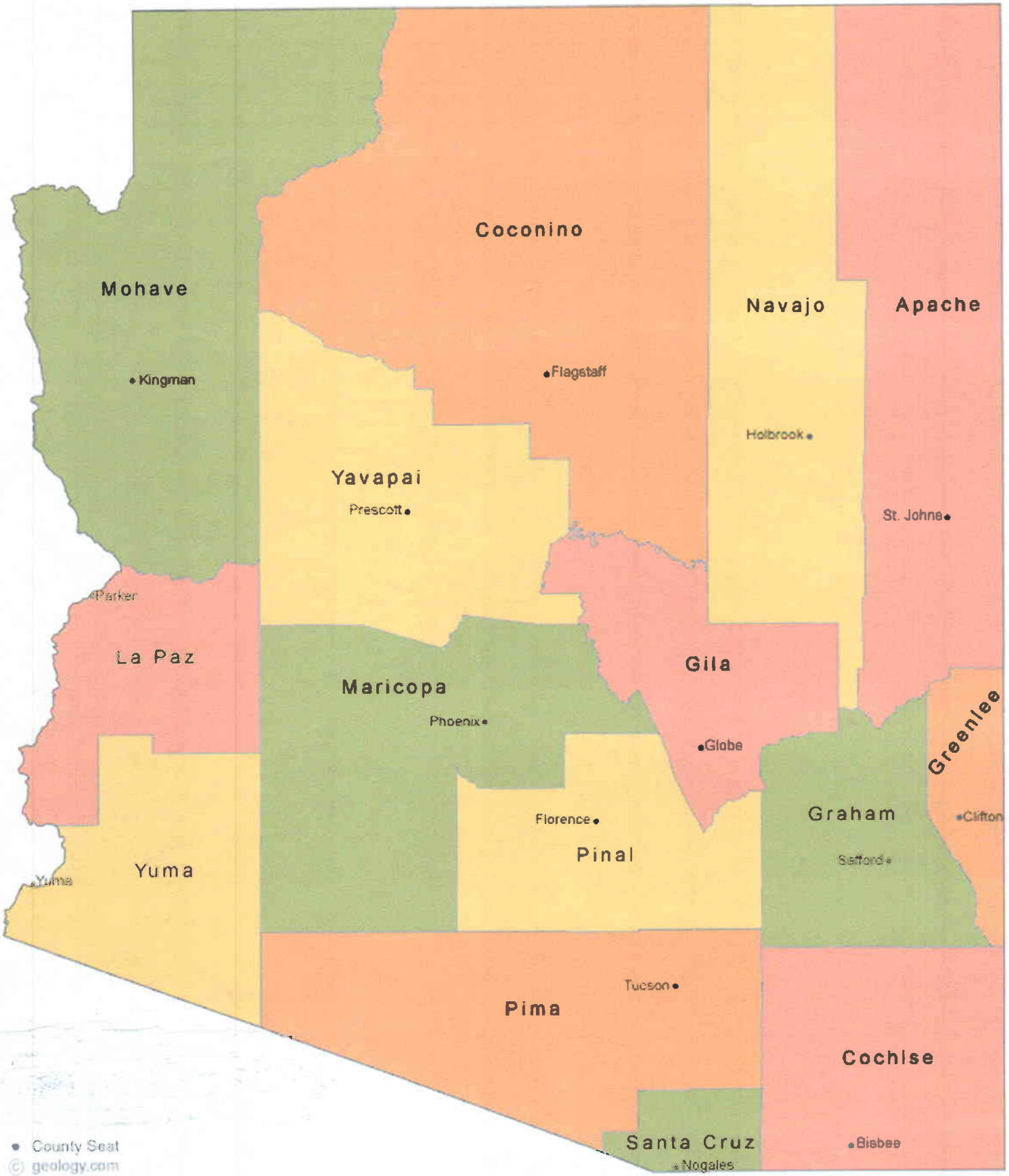
Session Two
1. Students will stay in the same team and use "Crops by County in Arizona" census data to determine which ingredients needed to prepare their meal are produced in Arizona.
2. They need to write down the county(ies) in which the item is produced.
3. Ask students to find those counties on their Arizona map. Many items are produced in multiple counties.
4. Ask older students to look at where items are produced in Arizona and then discuss why one item may be grown in a certain area. Answers may range from soil, elevation, water availability and/or climate as examples.
5 - Use the term Locavore and ask them what they think it means. (*A Locavore is a person who wants to purchase items that are grown or produced locally.*)
6 - Ask if their meal can be considered a Locavore meal? Ask them to explain why they think it is locally grown. Ask them what they consider locally grown. (Some define local as within 50 miles radius of the home and others define it as within state boundaries.)
7 - Ask them if they can make changes to their meal to have it be predominantly made from food items grown locally.
8 - Ask if they realized how many different food items were grown in Arizona?

Session Three
1- Re-assign the teams so only one person from any team that participated in Session 1 is in a new five member team.
2 - Members will share the main course their team in Session 1 planned.
3 - Teams should choose one main course from those five options and research the nutritional aspects of the main course.
4 - Ask them to look at the MyPlate template to choose a main course that uses the majority of the required items of fruit, vegetables, grains, protein and dairy.
5 - Ask them to choose a main course that they think would have the least amount of calories.
6 - Have them write down what they guess the total calories would be for the main course.
7 - Provide computer internet access to the teams.
8 - Using the website www.myfoodapedia.gov have the teams determine the total calories for their main course. How close was their calorie guess?
9 - Ask teams to report the total calories for the meal along with the food groups included in the main course.
10 - The team with the lowest calories and most balanced meal should share the main course description with the class.

EVALUATION OPTIONS
1 - Ask students to name ten food items grown in Arizona.
2 - Ask students to research one AZ grown food item and determine the scientific reason(s) it can be grown in Arizona.
3 - Ask students to plan a menu that is nutritionally balanced and low in calories.
4 - Have students list 10 food items grown in their county that they have never eaten.

EXTENSIONS AND VARIATIONS
- Have students go to the grocery store and determine if they can find Arizona Grown items.
- Have students attend a farmer's market and ask if they would want to purchase food items there. Ask them to have a conversation with the person selling the food item to find out how it is grown.
- Have students look at a processed item such as a jar of salsa and determine the number of jobs needed to produce the salsa. Make sure they include farmer, farm employee, nutritionist, trucker, marketing, grocery store employee, as well as label designer and jar manufacturing.

CURRICULUM DESIGN
Monica Kilcullen Pastor
University of Arizona
Cooperative Extension,
Maricopa County


Coconino
Mohave
Navajo
Apache
Kingman
Flagstaff
Holbrook
Yavapai
Prescott
St. Johns
Parker
La Paz
Gila
Maricopa
Phoenix
Globe
Greenlee
Graham
Clifton
Florence
Pinal
Safford
Yuma
Yuma
Pima
Tucson
Cochise
Santa Cruz
Nogales
Bisbee
County Seat
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Arizona Food Produced In-state More Common

by Megan Finnerty and Richard Ruelas - Nov. 28, 2010, 12:00 AM, *The Arizona Republic*

It's easier than you may think to eat locally produced food in Arizona, particularly at this time of year.

The "eat local" idea has long been associated with Saturday morning markets, specialty grocers and concept restaurants. But harvest season – that's now, in our desert climate – means produce aisles in nearly any grocery are stocked with locally grown food.

Shoppers can leaf through greens at Bashas', pick through the pomegranates at Whole Foods Market and browse the cabbage at Safeway. They can be confident that though the food isn't always marked or marketed as local, much of it comes from farms in the state.

Grocery stores aren't the only ones with local food. Order a foot-long at Subway or a salad at Chili's and you're almost certainly getting local lettuce this time of year.

Most of the milk and eggs we consume year-round also come from local suppliers.

Eating local food is an idea pushed by advocates for small farms and environmentalists who want to reduce the pollution associated with shipping food. The movement spawned the term "locavore."

True locavores generally pledge to eat only foods produced within 100 miles. More broadly, the government allows labeling agriculture local if it is produced within the state.

"People are consuming more local products than they think they are," said Sandy Kelley of Shamrock Farms, the Phoenix-based dairy that supplies much of the Valley's milk.

This time of year, Safeway stocks about 27 Arizona-grown items in the produce section. Bashas' supermarkets, including AJ's Fine Foods and Food City, offer a comparable number. Whole Foods Market offers slightly less in the produce section.

Not all are labeled as such because stores can't guarantee items are from Arizona, although for most leafy greens, according to the Arizona Farm Bureau, the chances of it being from the state are about 85 percent.

And consumers put off by higher prices for boutique items from local farms should know that "local" doesn't mean "luxury." At grocery stores, in-season produce is typically priced to move.

Restaurant suppliers including U.S. Foodservice, Shamrock Farms and Sysco aren't stocking local ingredients because it is trendy but because it reduces shipping cost.

At the grocery store

It's rarely obvious that grocery-aisle produce is local.

Only Bashas' and Whole Foods Markets reliably label Arizona-grown items. But Safeway spokeswoman Cathy Kloos said the chain has plans to start.

Bashas' started posting grown-in-Arizona signage about three years ago and saw an immediate bump in sales.

Jack Armstrong, Bashas' senior produce buyer, said customers "seem to be happier when they see it's from their own backyard." And it's more efficient.

"It can be in my warehouse in less than a day, sometimes a few hours," he said.

Armstrong adds two or three new growers to his stores each year, although few farmers and food makers in the state have a large enough production capacity to serve the chain.

The meat aisle is more complicated. A great portion comes from major producers in the Midwest, according to Shamrock Foods, the largest distributor in the state.

But the Arizona Beef Council says state ranches produce enough beef to supply 5.6 million residents. It is not clear where all of that beef goes, though. Basilio Aja, executive director of the council, said about 50 percent of beef consumed in the state is from Arizona.

Bashas' partnered with Local First Arizona, an organization that promotes Arizona-based businesses, to develop labels for items ranging from tomatoes from Sunizona Family Farms in Willcox to My Nana's Tortilla Chips from Phoenix.

The move appeals to Jennifer McHenry, 36, of Mesa. She shops for locally grown produce at Whole Foods and Sprouts Farmers Markets.

A mother of two, she tried shopping at farmers markets near her home, but ran out of time for those special trips.

"If more places used local labels, it would be an incentive to shop in mainstream markets," she said.

Darcy Landis works with about 200 local vendors to stock five Whole Foods stores with a range of products including chocolate, skin cream, produce and salsa.

Landis, Whole Foods' "metro forager" for Arizona and southern Nevada, is most proud to offer shoppers Black Sphinx dates, grown only in Phoenix's Arcadia neighborhood, harvested from privately owned trees. The thin-skinned, sweet dates have a cult following.

"They are, in my opinion, the best dates you can get," Landis said. "And through November and December, they're really fresh."

When shopping for staples, nearly every Arizonan buys local eggs and milk.

Hickman's Egg Ranch and the Shamrock Farms dairy supply a large portion of grocery stores' egg and milk supply, whether branded as such or not.

Cartons may not be labeled as local to allow both companies the flexibility to add in non-Arizona milk or eggs if needed.

But both companies say that is not common.

Eating out

Restaurant suppliers including U.S. Foodservice and Shamrock Foods also stock Arizona ingredients to keep costs down.

"It just makes good sense from a business standpoint," said Rob Ahrensdorf of Shamrock Foods, the largest restaurant supplier in the Valley. Shamrock Farms is an affiliate of Shamrock Foods.

Shamrock's customers include Subway, Applebee's and Chili's.

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"There are times you're going to be buying local because that's when it's on the trees, that's when it's coming from the ground," Ahrensdorf said. "It's less expensive because they're not trucking it from Chile."

The egg market, over the past decade, has been increasingly dominated by Hickman's, located in Buckeye and Maricopa. Nearly every restaurant or institutional kitchen gets eggs from Hickman's, said Clint Hickman, the family-owned company's vice president of sales and marketing.

"You have to go to great extremes to not eat a Hickman's egg," he said.

In mid-November, lettuce pickers dismantle their operations in central and northern California and move them to Yuma. From that time until the growing season ends in April, it's almost certain that all lettuce served in restaurants is from Arizona.

Still, true locavores will take the extra effort to find leafy greens grown as close to home as possible.

"People are always so surprised that we have so many farms in the Valley," said Pamela Hamilton, publisher of the quarterly locavore guide *Edible Phoenix*.

"This time of year, all the greens we have growing, spinach, kale, mustard greens, they're really lovely. And they're the vegetables that lose the most nutrients when they're shipped from far away."

Whether a restaurant chooses to trumpet local ties, though, is up to each owner.

Foodie places like FnB in Scottsdale and Quiessence in Phoenix reprint menus often to highlight in-season produce.

Others push value. The fact that they serve local greens for a few months is merely circumstantial.

Hamilton welcomes the extra seasonal members into the local food movement, even if most are unknowingly joining.

"People shop local for a bunch of different reasons," Hamilton said. "If you're doing it for economic reasons, Yuma lettuce or Hickman's Eggs are great . . . If you're doing it because you're supporting small farmers or want to eat organically, you might make other choices.

Crops by County in Arizona (2007 Census of Agriculture)

	Apache	Cochise	Coconino	Gila	Graham	Greenlee	La Paz	Maricopa	Mohave	Navajo	Pima	Pinal	SantaCruz	Yavapai	Yuma
almonds				X				X	X	X			X	X	
apples	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
apricots	X	X	X					X	X	X			X	X	
artichokes										X	X				X
asparagus										X	X			X	
avocados									X						
barley	X	X			X		X	X		X	X	X		X	X
beans	X	X	X		X			X		X	X	X	X		
beef	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
beets	X	X	X	X				X		X	X	X		X	
bell peppers	X	X	X	X					X	X	X	X		X	
bison								X	X						
blackberries		X		X				X		X	X			X	X
blackeyed peas		X													
blueberries		X													
boysenberries		X													
broccoli	X	X		X			X	X		X	X	X			X
brussels sprouts		X													X
cabbage	X			X				X		X	X	X			X
cantaloupes	X	X	X	X	X		X	X	X	X	X	X	X	X	X
carrots	X	X	X	X				X	X	X	X	X	X	X	
catfish								X							
cauliflower	X			X				X		X	X	X			X
celery													X		X
cherries(sweet)	X	X	X	X	X				X	X	X				
cherries(tart)	X	X	X		X					X			X	X	
chicken	X	X			X			X		X	X		X		
collard greens		X						X							
corn grain		X	X		X	X		X		X	X	X	X	X	X
cotton seed products															
cucumbers	X	X	X	X	X			X	X	X	X	X	X	X	
dairy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
dairy goats		X	X		X			X	X	X	X	X	X	X	X
dates								X							X
deer				X											
ducks	X	X	X	X				X		X	X	X		X	
eggplant		X	X	X							X	X		X	
eggs	X	X	X	X	X			X	X	X	X	X	X	X	X
emus		X			X			X				X		X	
escarole & endive															X
figs								X	X					X	
fruits(greenhouse)												X			
garlic		X		X	X		X			X	X	X		X	

	Apache	Cochise	Coconino	Gila	Graham	Greenlee	La Paz	Maricopa	Mohave	Navajo	Pima	Pinal	SantaCruz	Yavapai	Yuma
geese		X						X	X			X		X	
grapefruit								X	X		X	X			X
grapes	X	X	X	X	X	X		X	X	X	X		X	X	
green peas	X	X								X	X	X			
herbs	X		X	X				X		X	X	X		X	X
hogs and Pigs	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
honey		X	X		X		X	X	X	X	X	X		X	X
honeydew melons	X	X	X	X			X	X		X	X	X			X
kale															
lemons					X			X		X	X	X			X
lettuce	X	X	X	X			X	X		X	X	X		X	X
lima beans	X									X					
limes								X							X
meat goats	X	X	X	X	X	X	X	X	X	X	X	X		X	X
mustard greens				X				X			X	X			X
nectarines	X		X					X		X			X	X	
oats	X	X			X			X				X			
okra		X		X	X			X		X	X	X	X		
olives								X				X			
onions, dry	X	X	X		X		X	X		X			X	X	
onions, green	X	X	X	X	X			X		X	X	X	X	X	X
oranges					X			X		X	X	X		X	X
ostriches			X					X				X			
parsley				X				X			X	X			X
peaches	X	X			X	X		X	X	X	X	X	X	X	X
peanuts										X					
pears	X	X	X		X	X			X	X		X	X	X	
peas, dry southern															X
peas, sugar/snow		X			X										
pecans	X	X	X	X	X	X		X	X	X	X	X		X	X
peppers, chili	X	X	X	X	X			X		X	X	X	X	X	X
persimmons												X			
pheasants	X									X					
pigeon/squab								X	X	X	X			X	
pistachios		X			X	X	X	X	X		X	X	X		
plums & prunes	X	X	X		X					X		X		X	
pomegranates		X					X		X	X				X	X
potatoes	X	X	X	X				X	X	X		X			
pumpkins	X	X	X		X	X				X	X	X		X	
quail		X								X					
rabbit	X	X	X	X				X	X	X	X	X		X	
radishes	X	X	X	X				X		X	X	X			
raspberries		X						X							
rhubarb		X													
safflower															X
sheep & lambs	X	X	X	X	X	X		X	X	X	X	X	X	X	X

	Apache	Cochise	Coconino	Gila	Graham	Greenlee	La Paz	Maricopa	Mohave	Navajo	Pima	Pinal	SantaCruz	Yavapai	Yuma
shrimp								X				X			
snap beans	X	X	X	X				X		X	X	X		X	
sorghum		X					X	X			X	X			X
spinach		X						X		X	X	X			X
squash	X	X	X	X	X			X	X	X	X	X	X	X	
strawberries		X						X		X				X	
sweet corn	X	X	X	X	X			X		X	X	X		X	X
sweet potatoes											X				
tangelos								X	X	X		X			X
tangerines								X		X	X	X			X
tomatoes(field)	X	X	X	X	X			X	X	X	X	X	X	X	X
tomatoes(greenhouse)		X			X						X	X		X	X
trout			X			X			X	X				X	
turkeys	X	X	X	X				X	X	X	X	X	X	X	X
turnip greens				X				X			X	X			X
turnips		X		X				X		X	X	X	X		
vegetables(greenhouse)		X			X			X		X	X	X		X	X
walnuts		X				X								X	
watercress	X									X					
watermelons	X	X	X	X	X		X	X		X	X	X	X	X	X
wheat grain		X			X		X	X	X		X	X			X

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The Rise of the 'Locavore'

How the strengthening local food movement in towns across the U.S. is reshaping farms and food retailing

by Pallavi Gogoi

Drive through the rolling foothills of the Appalachian range in southwestern Virginia and you'll come across Abingdon, one of the oldest towns west of the Blue Ridge Mountains. If it happens to be a Saturday morning, you might think there's a party going on—every week between 7 a.m. and noon, more than 1,000 people gather in the parking lot on Main Street, next to the police station. This is Abingdon's farmers' market. "For folks here, this is part of the Saturday morning ritual," says Anthony Flaccavento, a farmer who is also executive director of Appalachian Sustainable Development, a nonprofit organization working in the Appalachian region of Virginia and Tennessee.

It's a relatively recent ritual. Five years ago, the farmers' market wasn't as vibrant and it attracted just nine local farmers who sold a few different kinds of veggies. Today, there's a fourfold jump, with 36 farmers who regularly show up with a dizzying array of eggplants, blueberries, pecans, home-churned butter, and meat from animals raised on the farms encircling the town. It's a sign of the times: Hundreds of farmers' markets are springing up all around the country. The U.S. Agriculture Dept. says the number of such markets reached 4,692 in 2006, its most recent year of data, up 50% from five years earlier. Sales from those markets reached $1 billion.

NEW NICHES

The rise of farmers' markets—in city centers, college towns, and rural squares—is testament to a dramatic shift in American tastes. Consumers increasingly are seeking out the flavors of fresh, vine-ripened foods grown on local farms rather than those trucked to supermarkets from faraway lands. "This is not a fringe foodie culture," says Flaccavento. "These are ordinary, middle-income folks who have become really engaged in food and really care about where their food comes from."

It's a movement that is gradually reshaping the business of growing and supplying food to Americans. The local food movement has already accomplished something that almost no one would have thought possible a few years back: a revival of small farms. After declining for more than a century, the number of small farms has increased 20% in the past six years, to 1.2 million, according to the Agriculture Dept.

Some are thriving. Michael Paine, 34, who started farming in 2005 on just one acre in Yamhill, Ore., today has six acres of land and 110 families who buy his lettuce, cabbage, peppers, and eggplants. "I like to surprise my families with odd varieties of tomato or an odd eggplant variety, and they love it," says Paine.

Patrick Robinette saw a growing interest among Americans in specialty beef, and in 2001 started raising 10 cows at Harris Acres farm in Pinetops, N.C. Soon his grass-fed beef was in high demand. He now raises 600 head of cattle and delivers beef to the North Carolina governor's mansion. He has standing orders from 37 restaurants, three specialty stores, and six cafeterias.

LARGE RETAILERS ACT

The impact of "locavores" (as local-food proponents are known) even shows up in that Washington salute every five years to factory farming, the Farm Bill. The latest version passed both houses in Congress in early May and was sent on May 20 to President George W. Bush's desk for signing. Bush has threatened to veto the bill, but it passed with enough votes to sustain an override. Predictably, the overwhelming bulk of its $290 billion would still go to powerful agribusiness interests in the form of subsidies for growing corn, soybeans, and cotton. But $2.3 billion was set aside this year for specialty crops, such as the eggplants, strawberries, or salad greens that are grown by exactly these small, mostly organic farmers. That's a big bump-up from the $100 million that was earmarked for such things in the previous legislation.

Small farmers will be able to get up to 75% of their organic certification costs reimbursed, and some of them can obtain crop insurance. There's money for research into organic foods, and to promote farmers' markets. Senator Tom Harkin (D-Iowa) said the bill "invests in the health and nutrition of American children...by expanding their access to farmer's markets and organic produce."

The local food movement has not been lost on the giants of food retailing. Large supermarket chains like Wal-Mart (WMT), Kroger (KR), and even Whole Foods (WFMI) depend on their scale to compete. Their systems of buying, delivering, and stocking are not easily adapted to the challenges of providing local food, which by its nature involves many diverse groups of farmers. People have gotten used to eating tomatoes and strawberries at all times of the year, and many parts of the country are too cold to produce them in the winter. Thus, even Whole Foods, which bills itself as the world's leading retailer of natural and organic foods, has committed to buying from barely four local farmers at each of its stores.

Wal-Mart, which in the last couple of years ran a "Salute to America's Farmers" program, says that buying from local farmers not only satisfies customers' desires, but also fits the company's commitment to sustainability and cutting down on food transportation. However, the company admits that local farms can never take over the produce aisle completely. "It gets complicated since not every state grows apples and lettuce, and even when they do, it doesn't grow at all times of the year," said Bruce Peterson, formerly Wal-Mart's senior vice-president of perishables, in an interview 17 months ago. He has since left the company.

BROAD AGENDA

Nonetheless, all the giants are devoting a small but growing share of shelf space to locally bought produce. Some are even inviting the farmers into the store to promote their goods. "Obviously supermarkets don't want to lose that business," says Michael Pollan, author of the best seller *The Omnivore's Dilemma*. Neither Wal-Mart nor Whole Foods will quantify how much business they get from locally grown food.

The very definition of "local" food presents a ceiling of sorts for successful small farmers. If they start shipping more than 250 miles or so, they cease to be local and their appeal vanishes. The optimal solution is to locate near densely populated areas, but that's where acreage is scarce. "Land prices are very expensive around metro and urban areas, which is a barrier to entry," says Pollan. He thinks the solution will be for farmers to look for ways to farm more varieties of food (BusinessWeek.com, 5/21/08).

The local food movement has many of the same hallmarks of the organic foods movement, which sprang up in the 1970s to place a premium on foods grown without pesticides and synthetic fertilizers. Indeed, almost all of today's small farmers use organic techniques. But many consumers believe that organic foods, though

seemingly healthy, may still damage the environment. For instance, organic fruits that are grown in Chile and Argentina and then shipped halfway around the world require fossil fuels and carbon emissions to power tankers and trucks thousands of miles. Instead of just focusing on pesticides and chemicals, consumers who have been educated by movies like *An Inconvenient Truth* now pore over "food miles" and "carbon footprints." The message seems to be: If you buy organic, you care about your own body; if you buy local, you care about your body and the environment.

As more and more consumers take those values to the store with them, the impact is being felt far from the predictable centers of "green" consciousness. In Bloomington, Ind., supermarket chains such as Kroger still dominate, but an upstart called Bloomingfoods Market that specializes in local fare lately has been stealing market share. Today the cooperative has 7,000 shopping members, up from 2,000 five years ago. It works with 180 farmers to offer everything from strawberries and persimmons to squash and shiitake mushrooms. "We're seeing a real renaissance," says Ellen Michel, marketing manager for Bloomingfoods.

As the local food movement grows more mainstream, it's showing up in unexpected places. Corporations such as Best Buy (BB) in Minneapolis, DreamWorks (DWA) in Los Angeles, and Nordstrom (JWN) in Seattle are providing local options in their cafeterias. "We try to purchase as much as we can from farmers in a 150-mile radius," says Fedele Bauccio, CEO of Bon Appetit Management, which runs more than 400 cafeterias for companies like Oracle (ORCL) and Target (TGT).

BLOSSOMING INTEREST

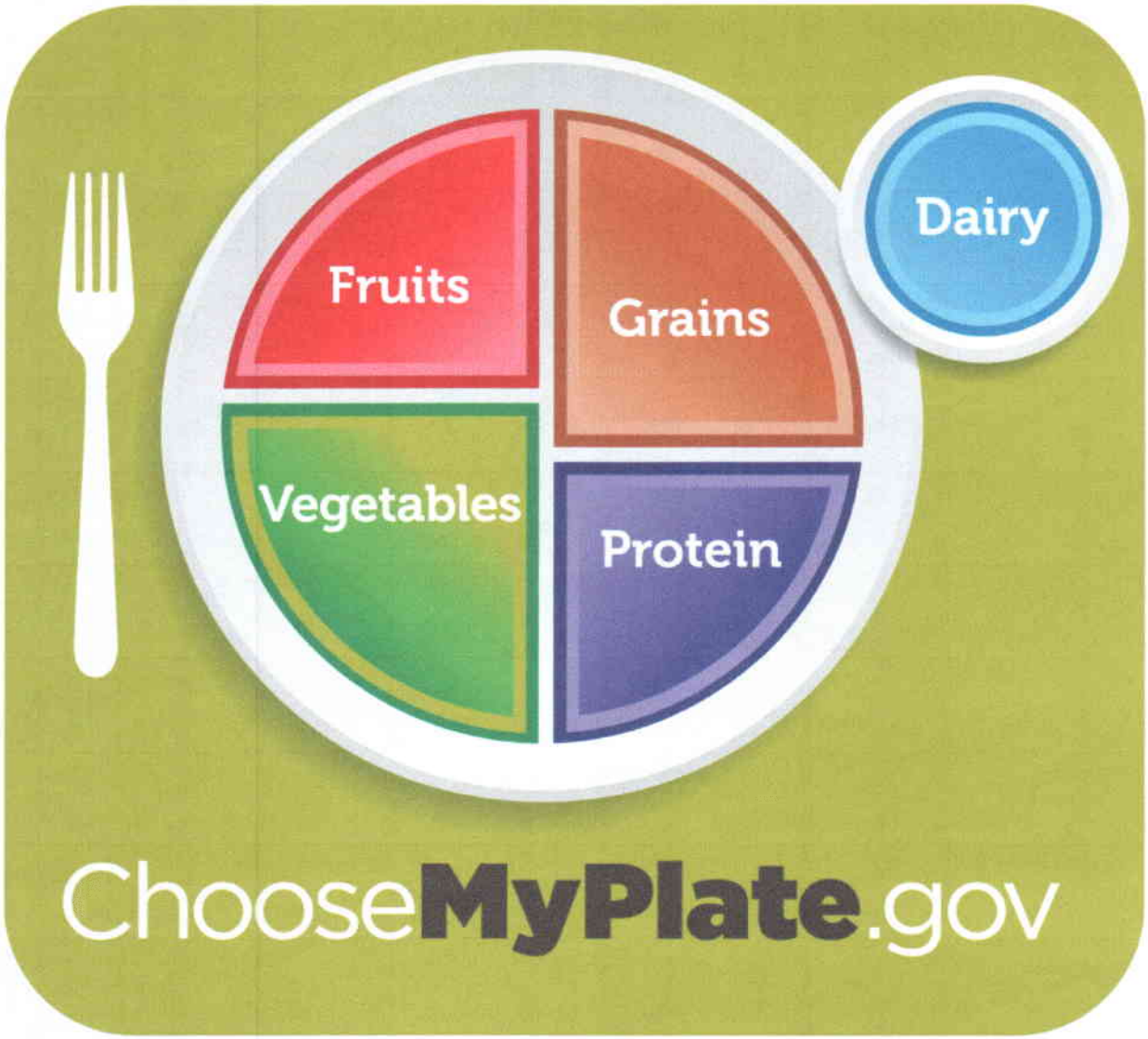
As many as 1,200 school districts around the country, from Alabama to Iowa, have linked up with local farms to serve fresh vegetables and fruit to children. Colleges such as Brown, Cornell, the University of Montana, and the University of California at Berkeley are buying from their state's own producers. Last year, Iowa's Woodbury County mandated that its food-service supplier buy from local farmers for places where it serves food, such as its prison and detention center.

And in hundreds of towns, people are signing up for CSAs, or community-supported agriculture organizations, where they pay a local farmer for a weekly supply of produce during the harvest season. In 2000, there were around 400 farms that had CSA programs; today there are more than 1,800 nationwide. Families typically pay a farm $150 to $650 each year in return for a weekly basket of vegetables, fruit, eggs, meat, or baked goods. In New York City, where 11,000 residents participate with 50 farms, the demand is so high that there's a wait list. And in some inner cities, like the Bronx, a borough of New York City, organizations are training community gardeners to grow vegetables like collard greens, herbs, and beets for their community, changing food habits in the process.

"We are even teaching people how to prepare seasonal produce," says Jacquie Berger, executive director of Just Food, a nonprofit that helps fresh-food growers sell to residents in the Bronx.

That may be less of an issue in more pastoral settings such as Abingdon. But residents of the Virginia town look forward to Saturday at the farmers' market, mingling, passing out petitions, and letting the kids snack on berries while their parents shop for the week's groceries in a fresh setting. "There's a groundswell of interest not just for vegetables and fruits, but also eggs, poultry, and meat—people want it close to home, as fresh as possible, and produced sustainably," says farmer Flaccavento.

Gogoi is a contributing writer for BusinessWeek.com.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A Thin Slice of Soil

Everything Depends on the Soil

One of our most important natural resources is soil. All living things depend on it as a source of food, either directly or indirectly. Plants depend on the soil to anchor them in place. Soil stores water and nutrients which it then makes available for plant growth. Some animals eat only plants for food. These are called herbivores. Humans eat plants, but we also use animals for food. We are called omnivores. Some animals eat only other animals. These are called carnivores. But we all have something in common. All of our food can be traced back to plants growing in the soil.

Our food producing land is a limited resource. Farmers and ranchers in the United States work hard to produce enough food to feed everyone in this country, plus a large number of people in other countries. A farmer in the United States, on average, produces enough food to feed 144 people. They realize they must get maximum production out of their soil, while at the same time protecting it for future generations.

As world population continues to increase, each person's food producing portion of land is becoming smaller and smaller. This means farmers must work harder to grow more food on the land they are using. It is the responsibility of all of us to use the soil wisely, to insure a bright future.

Materials Needed for Lesson
Large Apple
Paring Knife

Procedure

1. Cut the apple into four equal parts. Three parts represent the oceans of the world. The fourth part represents the land area.
2. Cut the land section in half lengthwise. Now you have two one-eighth pieces. One section represents land such as deserts, swamps, Antarctic, arctic, and mountain regions. These regions are not suitable for man to live.
3. Slice the remaining one-eighth section into four equal parts. Three of these one-thirty second sections represent the areas of the world which are too rocky, too wet, too hot, or where soils are too poor for production, as well as areas developed by man.
4. Carefully peel the last one-thirty second section. This small bit of peeling represents the soil of our earth on which mankind depends for food production!
5. Discuss what this soil is used for. Possible questions:
   - What if this valuable top soil upon which man depends should suddenly disappear?
   - What must happen to the amount of food farmers grow if the world's population continues to increase while our earth's top soil remains the same?
   - Have the students make a pie chart depicting the percentages of land used to grow our food versus all the other areas of the world such as water or land regions.

Adapted from Project Food, Land & People Resources for Learning Facilitator Training.

School Garden Food Safety

Guidelines

The following are guidelines for the safe handling of foods grown in school gardens for use in the school cafeteria. Following these guidelines will help reduce contamination from pathogens and maintain a safe environment for children, volunteers, and teachers who work in the garden. Prior to using the food items in the school cafeteria, school gardens will need to implement these guidelines and have the garden certified by the Arizona Department of Health Services (ADHS).

> "*School kitchens fall under the jurisdiction of the Arizona Food Code, which states that kitchen facilities may only use foods considered an "approved source." The Arizona Food Code leaves this definition up to the local health authority. The local health authority is considered the county health department in this instance. In the past, county health departments considered school garden produce to be an unapproved source for use in kitchen facilities.*" http://www.azed.gov/health-nutrition/school-gardens

These general guidelines are designed to reduce the risk of microorganisms contaminating fresh produce grown in school gardens. They also provide information about high risk areas for contamination and how to avoid or minimize such contamination. It is important to recognize that these guidelines do not guarantee the product is free from microbial contamination but verify that the school has taken proactive measures to reduce the risk of contamination by adhering to generally recognized best practices for safe food production and harvest.

Microorganisms and pathogens are a natural part of the environment and can be a problem whether you choose to use organic or conventional gardening methods. It is essential to understand how these microorganisms are typically introduced into the gardening environment and the potential means by which they can contaminate fresh produce in order for school gardens to safely provide healthy foods grown by, and for, students.

In order to implement a successful school gardening program, it is critical to involve students, teachers, school administrators, facilities staff, food service staff, and the community throughout the planning process. The school district and the ADHS will need to approve the implementation of these guidelines as an acceptable safety measure.

The Arizona Department of Agriculture, Agricultural Consultation and Training has funded all or a portion of this Project, using Specialty Crop Block Grant funds provided by the USDA, Agricultural Marketing Service.

General Guidance

Every school garden must implement a Risk Control Plan and have it approved by the Registered Sanitarian with ADHS prior to utilizing garden-grown food items in the school cafeteria. The Plan should document appropriate training of student and volunteer workers in proper hygiene and harvesting as outlined below. A designated Garden Manager (Person in Charge) must document and maintain all necessary records as well as document any corrective actions.

Worker Health and Hygiene

All workers (students, staff and volunteers) must be trained in proper hand washing techniques and hygiene procedures. The Centers for Disease Control and Prevention recommended procedure can be seen in Figure 1. Any wounds should be properly bandaged before working in the garden.

Figure 1 Proper Hand Washing
What is the right way to wash your hands?

- Wet your hands with clean running water (warm or cold) and apply soap.
- Rub your hands together to make a lather and scrub them well; be sure to scrub the backs of your hands, between your fingers, and under your nails.
- Continue rubbing your hands for at least 20 seconds. Need a timer? Hum the "Happy Birthday" song from beginning to end twice.
- Rinse your hands well under running water.
- Dry your hands using a clean towel or air dry.

Washing hands with soap and water is the best way to reduce the number of germs on them. If soap and water are not available, use an alcohol-based hand sanitizer that contains at least 60% alcohol. Alcohol-based hand sanitizers can quickly reduce the number of germs on hands in some situations, but sanitizers do **not** eliminate all types of germs.

Centers for Disease Control and Prevention
http://www.cdc.gov/features/handwashing

The Garden Manager needs to tell a worker that if s/he is sick, they must not work in the garden. Anyone who is ill should not handle food within 24 hours of vomiting or diarrhea, or before being cleared by a medical professional (e.g., the school nurse) after experiencing a combination of fever and sore throat.

It is recommended that all workers should be trained on the use of machinery including the location of controls to safely start and stop the equipment. Equipment that requires an on/off switch should only be handled by an adult but in case of emergency the students should know how to stop the equipment.

Since workers will be out in the sun they should be encouraged to wear hats and apply sunscreen while gardening. The garden is an ideal way to utilize the SunWise Skin Cancer Prevention School Program, located at http://www.azdhs.gov/phs/sunwise.

Garden Review

Prior to implementing the garden it is important to consider previous land use and determine if the soil contains lead or other contaminants. The ADHS lab will conduct free lead tests in samples submitted by a school. The Garden Manager needs to document the quality of the water source for the garden, any soil amendments that will be utilized, methods implemented for pest control and procedures to deter animals from entering the garden. Shovels, rakes, and other field equipment must be cleaned on a regular basis. If there are students with allergies at the school, keep allergenic types of foods (wheat,

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strawberries, melons, tree nuts and peanuts are the most common) separate from other areas of the garden.

Land Use and Land Use History

- Document the history of the land use prior to installing the garden. The school district should have record of the prior use of the land before the school was built. It is also important to note how the land was used after the installation of the school. If the garden is placed in an area that was previously used for parking or an area where chemicals may have been applied for weed and pest control, then it is important to have the soil tested by a lab.
- Avoid damaging underground utilities by calling 811 (AZ Blue Stake) before you dig.
- Position the garden away from potential contamination sources such as garbage containers, school animals (rabbits, tortoises, birds, etc.), septic systems, in-ground storage tanks, and water runoff from playgrounds, roofs, walkways, and/or parking areas. Do not place the garden in a low lying, poorly drained area or an area subject to any kind of chemical application. Manage the planting area to avoid standing water and excess debris.
- Use non-toxic, non-leaching materials for raised bed gardens.
- It is important to work with the maintenance staff to ensure they use safe practices on the school grounds near the garden. These safe practices would ensure chemicals for weeds or pests would not be used in the vicinity of the garden. Also, equipment such as lawn mowers, weed whips, or blowers may kick up rocks and could harm workers and should only be used when no workers are present in the garden.

Water Source

- Only use potable water for the portion of the garden in which food is grown. Municipal water tests must be acquired from the local water provider on a yearly basis. Well water must be tested at least once during the growing season. Surface water must be tested three times during the growing season (first at planting, second at peak use, and third at or near harvest). The Garden Manager needs to keep documentation of the water test results.

  - If using containers to transport water, they need to be sanitized on a regular basis and only used for water.
  - At this time, we recommend that water from rainwater harvesting can only be used on non-edible plants. It is extremely difficult to keep up-to-date, accurate records of the quality of the water harvested through rainwater harvesting techniques. We recommend that this water can still be captured but used on plants not grown for food, such as: flowers, trees, shrubs, and grass.

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- Do not use gray water on edible plants. "Gray water has a high probability of containing pathogenic microorganisms" (http://www.nwri-usa.org/pdfs/CrookTechnicalMemorandumonGraywater.pdf page 2).

Soil Amendments

- Unless using commercially produced soil in a container garden, the soil in the garden must be tested for lead; lead levels should be less than 300ppm. The lead test is required since many gardens could be near older buildings that might have lead based paint. Areas that have been flooded in the past may have increased risk of lead contamination. You may also want to test the soil to document nutrient levels, such as available calcium, magnesium, sodium, potassium, nitrate, phosphate, salinity, and pH.
- Mulch made from wood chips is an excellent method to preserve soil moisture or fertilizers.
- It is recommended that the garden only use commercially available compost. Request a copy of records from the commercial source to ensure that safety standards were met.
- Hands should be washed thoroughly after handling soil or compost.
- School prepared compost must contain only plant products and can only be used on non-edible plants. The compost must maintain a temperature of 130^0 – 150^0 for three days during the decomposition process. Fully composting the plant products, which involves periodically turning the pile with a shovel, normally takes a minimum of 1-2 months under optimal temperature and moisture conditions. The compost pile should be kept in an area separate and down slope from the garden. Do not use manure in the compost. Manure that has not been composted completely is a safety hazard.
- The Garden Manager must document the source of compost as well as record temperature levels of school prepared compost.
- Composting nuisances and risks such as the presence of pathogens, odor, vectors (small animals or insects that carry disease), fires, and litter can be prevented or minimized through proper design and operation.

Pest Control

Use organic methods to minimize or alleviate pests such as insects, weeds, animals, and fungi. These methods include traps, mechanical controls, crop selection, and non-synthetic chemicals and biological controls.

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Animal Intrusion: Wild and Domestic

Animals need to be excluded from the garden area. The Garden Manager should monitor for presence of animals by looking for animal prints or waste in the garden. Ideas to limit animal access to the garden include utilizing scare balloons, fencing, metallic tape, CDs, tassels, or other barriers or deterrents. These methods provide movement and flashes from sunlight that are disturbing to vectors.

Security

To the extent that is practical, secure the perimeter of the garden with fencing. Extend the school's normal security measures in the garden, such as a sign-in sheet.

Field Harvest and Field Packing

The Garden Manager should conduct a pre-harvest assessment that includes a review of hygiene requirements with the workers prior to harvest as well as making sure potable water is available to the workers. Workers should wear closed toe shoes and should check shoes prior to harvest to avoid bringing contaminants into the garden. These contaminants may include animal feces, food, gum, or phlegm. The Garden Manager needs to ensure toilets and wash facilities are clean. Adults should supervise when harvest begins. Avoid injuring the produce during harvest and handling.

Field Sanitation

It is recommended that the Garden Manager develop a clean-up procedure in case contamination occurs. During the pre-harvest assessment the Garden Manager should determine if there is evidence of contamination (human or animal) in the garden. The contaminated area should be isolated and labeled as "no harvest" or pull the contaminated plants immediately. Discard all plants that are contaminated. It is important to periodically remove rotten produce.

Emergency Clean-Up Procedures

A clean-up procedure in the event an accidental contamination occurs needs to be developed. Accidental contamination could include a worker getting sick or cutting themselves on a tool and having blood on the ground, a plant or on a harvest tool. Discard all plants and soil that are contaminated. If you step in the contaminant, clean your shoes prior to harvesting in other areas of the garden to avoid bringing contaminants into the previously non-contaminated areas.

Harvesting Containers & Equipment

- Hands should be washed before beginning to harvest the produce and again after using the restroom, touching the face, coughing or sneezing. Single-use non-latex plastic gloves are required by ADHS for harvesting produce.
- Food grade, reusable harvest containers should only be used for harvest. The containers should not be made from wood. They should be stored in a protected area during and after harvest and must be sanitized and in good condition. Clean the containers with hot soapy water, rinse then sanitize with chlorine or quaternary ammonia. New, clean paper or plastic bags are acceptable

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for one time use harvest containers. Knives, scissors, and other harvesting equipment must be cleaned prior to use and must only be used in the garden for their designated purposes. They should never be used for working with compost.

Receiving by Cafeteria Staff

- The harvested produce should not be washed by the garden workers. Shake off as much dirt as possible in the garden area and deliver to the cafeteria staff in the harvest container. The cafeteria staff must verify the harvest containers are clean. Cafeteria staff must not accept the product if there are odors or evidence of contamination. Produce from the school garden needs to be kept separate from the commercial produce.
- If possible, weigh the produce so the students can document their harvest. The cafeteria staff should record who, how, and where the school garden produce was harvested and cleaned.

These guidelines were adapted from:
AZ Department of Education (http://www.azed.gov/health-nutrition/school-gardens), AZ Department of Health Services (http://www.azdhs.gov/diro/admin_rules/guidance_PHS_BEDCS.htm), USDA's People's Garden Initiative, North Carolina State Cooperative Extension, Mountain Roots Food Project, National Farm to School Network, University of Maryland, University of Connecticut, USDA National Food Service Management Institute, Denver Urban Garden, and The Community Food Bank of Southern Arizona's Garden-to-Cafeteria Guidelines.

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The Arizona Department of Agriculture, Agricultural Consultation and Training has funded all or a portion of this Project, using Specialty Crop Block Grant funds provided by the USDA, Agricultural Marketing Service.

Garden Manager's Checklist

School Garden Food Safety

The purpose of this document is to help school Garden Managers create a simple, yet effective Risk Control Plan. A Risk Control Plan identifies any potential risk associated with microbial contamination that may cause foodborne illness or injury. This will need to be developed on an individual, garden-to-garden basis. Documentation of land history, soil and water tests, and composting sources needs to be in writing and made available to the Garden Manager.

The use of a Risk Control Plan for school gardens is essential and benefits students by:

- Creating a safe environment for students through the identification and management of microbial hazards associated with gardening.
- Creating a long-term, behavioral regimen that helps to increase safety and the likelihood of having a successful garden.
- Teaching how to follow policies and procedures.
- Teaching the relationship between effort and results, emphasizing success by implementing the most effective means to an end goal.

<u>Establishing the Garden</u>

- ☐ Locate garden(s) in an area that is away from potential contamination sources.
- ☐ Document the history of the land use.

  Description prior to school: _____

  _____

  Description since school: _____

  _____

- ☐ Test the soil for lead; levels are to be less than 300 ppm (*include information below and attach documentation to the back of this document*).

  Date: _____ Testing Agency: _____ Lead level:_____

- ☐ Optional: test and document soil's nutrient levels.

  Ca: _____ Mg: _____ Na: _____ K: _____

  NO_3: _____ PO_4: _____ Salinity: _____ pH: _____

- ☐ Call 811 before you dig.
- ☐ Document any soil amendments that will be utilized.

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- ☐ Document the commercial compost source to ensure that safety standards were met.
- ☐ Ensure that school prepared compost is downslope, away from the garden, contains only plant material, and is used only on non-edible plants.
- ☐ Use non-toxic, non-leaching materials for raised bed gardens.
- ☐ Document appropriate testing of water source (*record the testing date below and attach documentation to the back of this document*).

  Municipal (*yearly*) _____ Well (*once/growing season*) _____

  Irrigation (*planting,* _____ *peak,* _____ *& harvest* _____)

- ☐ Coordinate with the maintenance staff to ensure they use safe practices on the school grounds near the garden; i.e. chemicals for weeds or pests are not used in the vicinity of the garden.
- ☐ Extend the school's normal security measures to the garden, such as a sign-in sheet and posting no trespassing signs.
- ☐ Secure the perimeter of the garden with fencing, to the extent that it is practical.
- ☐ Keep allergenic types of food separate from other areas of the garden.

Maintaining the Garden & the Equipment

- ☐ Manage the planting area to avoid standing water and excess debris.
- ☐ Use organic pest control methods, such as non-synthetic controls and biological controls, and document its application.
- ☐ Document procedures intended to deter animals from entering the garden.
- ☐ Evaluate the garden for any contamination, document, and properly remove contaminate (including soil and plant).
- ☐ Monitor for and document the presence of animals, and properly remove contaminates.
- ☐ Sanitize water containers on a regular basis.

Training the Workers

- ☐ All adults help supervise youth workers
- ☐ What to do when a worker is sick or has recently been sick
- ☐ Proper use of sun protection
- ☐ Need for regular hydration
- ☐ Proper hand-washing techniques and hygiene procedures
- ☐ Proper bandaging of wounds

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- ☐ Proper use of machinery (only adults operate equipment with on/off switch; youth to know how to turn off in emergency)
- ☐ Use of closed-toed shoes during harvest.
- ☐ Proper use of equipment
- ☐ Proper sanitization of equipment
- ☐ Proper harvesting procedures
- ☐ Location of designated area away from garden for eating and smoking.
- ☐ Use of single-use, non-latex, plastic gloves for harvesting
- ☐ Proper clean-up procedures for when contamination occurs
- ☐ Proper preparation and transportation of produce to cafeteria staff

Harvesting

- ☐ Complete the pre-harvest assessment.
- ☐ Coordinate with adults to oversee youth and ensure that training instructions are being followed.
- ☐ Check that restroom facilities are clean.
- ☐ Review with workers the hygiene requirements and sun protection techniques.
- ☐ Confirm that workers are not sick, have washed their hands, and are protected to work in the sun.
- ☐ Oversee inspection of shoes (closed-toed and free from contamination).
- ☐ Review with workers the harvesting methods that minimize injuring produce.
- ☐ Review with workers the emergency clean-up procedures.
- ☐ Ensure that single-use, non-latex, plastic gloves are being used for harvesting.
- ☐ Ensure that produce is placed in proper harvest containers.

Receiving of Produce by Cafeteria Staff

- ☐ Reject any produce if there are odors or evidence of contamination.
- ☐ Store produce from school garden separately from commercial produce.
- ☐ Record who, how, and where the school garden produce was harvested and cleaned.
- ☐ If possible, weigh the produce so students can document their harvest.

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Training Log

School Garden Food Safety

Date: _____ Trainer: _____ Location: _____

Name	Adults supervise youth	Illness procedure	Sun protection	Hydration	Hand washing & hygiene	Bandaging wounds	Proper use of machinery	Proper use of equipment	Closed-toed shoes	Sanitization of equipment	Harvesting procedures	Eating & smoking areas	Harvesting gloves	Emergency contamination procedures	Preparation & transportation of produce

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Restroom & Hand Washing Facilities Maintenance Log

School Garden Food Safety

Date	Restroom & Hand Washing Facilities		Soap		Toilet Paper		Trash Can		Potable Water		Initials
	Checked	Cleaned	Checked	Filled	Checked	Filled	Checked	Emptied	Checked	Filled	

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Injury and Illness Reporting Log

School Garden Food Safety

Date	Name	Injury/Illness Reported	Action Taken*	Did student return?	Garden Manager's Initials

* Ex: ice applied, bandaged, sent to nurse

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Water Testing Log

School Garden Food Safety

Water Source*	Garden Location	Date Sampled	Testing Lab	Results

* Municipal water tests must be acquired on a yearly basis. Well water must be tested at least once during the growing season. Surface water must be tested three times during the growing season (first at planting, second at peak use, and third at or near harvest).

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Soil Amendments Log

School Garden Food Safety

Date	Location Applied	Rate/Ratio	Incorporated (Y/N)	Product	Supplier

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School Compost Log

School Garden Food Safety

Date	Location	Source of Compost*	Recorded Temperature

* i.e.: company's name if compost was purchased or what was used to create compost if made at the school (temperature records are essential if creating own compost)

At this time, school prepared compost can only be used on non-edible plants and must only contain plant products.

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Animal/Pest Deterrent Log

School Garden Food Safety

Date	Product	Location Applied	Supplier

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Animal Presence Log

School Garden Food Safety

Date	Location	Description of Sighting	Contaminates Removed	Determent Introduced

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Equipment Sanitization Log

School Garden Food Safety

Equipment*	Date	Cleaned By	Cleansing Agents

* i.e.: specific gardening tools, storages containers, etc.

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Pre-Harvest Assessment

School Garden Food Safety

Field or Production Area: _____ Date: _____ Harvest Date: _____

Questions	Yes	No	Action Taken	Initials
Has the garden been certified by the ADHS Sanitarian?				
Does the school district's liability insurance cover school garden produce?				
Is the equipment in safe working condition and free from defect?				
Have all knives, scissors, harvesting containers, and other harvesting equipment been cleaned and sanitized?				
Are there enough of the required harvesting gloves (single-use, non-latex, plastic gloves)?				
Is there enough potable water available?				
Are there enough new and clean, one-time use paper or plastic bags if not using reusable harvest containers?				
Are the restroom facilities accessible, well-stocked, and clean?				
Has the garden been inspected for evidence of contamination, including human and animal contaminates?				
Have contaminates plus affected plants and soil been removed and disposed of in a trash container?				

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Guidelines for School Gardens

This guidance document has been prepared to provide schools with recommended standards for on-site gardens in which produce is grown to be served by the school to individuals.

The Arizona Department of Health Services recommends that a school that wants to grow produce in a garden on school grounds to be served to students, teachers, parents, or guests of the school comply with the following:

The administrator of the school should:

- Designate an individual at the school who is knowledgeable about or trained in Good Agricultural Practices (GAP) and Food Safety, as it relates to the type of produce being grown, to be the Person In Charge (PIC) of the garden and be responsible for managing the garden and overseeing daily operations.
- Ensure that a written Food Safety Plan (describing Who, What, Where, How, and When) is developed to ensure GAP is implemented by the PIC and that the PIC maintains written documentation demonstrating that the Food Safety Plan is being adhered to.
- Ensure that an outdoor garden is not located:
  - Adjacent to a well, septic system, garbage dumpster, in ground storage tank, compost area, school animals (rabbits, tortoises, birds, etc.), or animal enclosure.
  - In a low-lying, poorly drained area.
  - In an area subject to any kind of chemical application: herbicide, fungicide, or pesticide.
- Ensure that toilet facilities and sanitary hand washing facilities, including dispensed soap, dispensed hand towels, and drainage collection are provided at, and in close proximity to, all garden areas. Signs should be posted in garden area to wash hands. Drainage collection, if not plumbed to a sanitary sewer, should include a holding tank that is larger than the water supply holding tank.
- Provide a first aid kit.
- Ensure that the produce harvested from the garden is:
  - Rinsed with clean potable water to further remove soil and particulate matter, prior to consumption.
  - Prepared under sanitary conditions, in accordance with local food code requirements, and overseen by a person trained in Food Safety with a food handler's card, if available.

The PIC for a garden at a school should ensure that:

- Water used for hand washing, harvesting, or cleaning of equipment or utensils is from a municipal source or meets the minimum drinking water quality standards.
- If well water is used for growing the produce, the well water is tested once during the growing season and treated if necessary to meet the GAP and Good Handling Practices Certification Program requirements.
- If irrigation (surface water) is used for growing the produce, the irrigation water is tested three times during the growing season and meets the microbial requirements of the EPA Recreational Water Standard.
- Collected rainwater shall not be used for edible plants.
- Unless using commercially produced soil in a container garden, the soil in the garden is tested for lead, and that the level of lead in the soil is less than 300 ppm.

- Any fertilizer or compost containing animal products such as manure, blood meal or dried blood must be from a commercially produced source and records from the supplier kept on the premise at all times.
  - School made compost shall not be used for edible plants.
- Weeds are controlled with mulches, hand-pulling, or weeding implements, not with herbicides.
- An outdoor garden is protected from animal intrusion by fencing or otherwise enclosing the garden area.
- Raised beds shall use only non-toxic, non-leaching materials for the frame.

When the produce is ready to be harvested, the PIC should ensure that:

- Individuals harvesting the produce shall
  - Wash their hands before beginning to work or returning to the garden,
  - Wear non-latex disposable gloves,
  - Avoid contact with animals,
  - Eat and drink in designated areas away from the garden,
  - Stay home if they are sick.
- All soil and particulate matter is manually cleaned from the produce before placing in the harvest container.
- The produce is stored in food-grade quality, reusable containers that has been washed, rinsed, and sanitized, or single service containers such as paper bags, during harvesting and post harvest.
- Produce with bird droppings on it is not harvested unless the produce item will be washed and cooked prior to consumption.

ARIZONA DEPARTMENT OF HEALTH SERVICES
OFFICE OF ENVIRONMENTAL HEALTH
150 N. 18th Avenue, Suite 140, Phoenix, Arizona 85007
REQUEST FOR SITE VISIT FOR SCHOOL GARDENS

Name of School Garden:		
Street address:		
City:	Zip code:	School phone:
Person In Charge (PIC):		
Email:	PIC phone:	Fax number:
Mailing address:		
City:	State:	Zip code:

Water source: Municipal ____ Well* ____ Irrigation* ____ Other*___

If other, please describe: _____

*Provide a copy of the most recent bacterial analysis

What produce will you be growing: _____

What is your growing season:_____

Type of produce beds: Flat _____ Sunken ___ Raised ___

If raised, what type of material will be used for the frame, describe: _____

Soil tested for lead: Yes____ No____ If yes, date tested: _____ and the amount of lead:_____

What type of fertilizer will be used, describe: _____

What is the distance, measured in feet, from the garden to the following areas:

Water source _____ Septic system _____ Garbage dumpster _____ Storage tanks _____ Feed lot _____

Parking lot _____ Bathroom _____ Hand wash sinks _____ Pest control applications _____

Composting area _____ and the method _____

Describe the desired location for the garden, include size, number of plots, fencing, harvesting equipment, pest control methods, does the area properly drain during and after rain, etc.
Please provide a map with the location of the beds, walkways, water source, fencing, and hand wash sinks.

_____

_____

_____

_____

_____

_____

Include a copy of your Risk Control Plan and garden map.

Print Name: _____ Signature: _____ Date: _____

ARIZONA DEPARTMENT OF HEALTH SERVICES
OFFICE OF ENVIRONMENTAL HEALTH
150 N. 18th Avenue, Suite 140, Phoenix, Arizona 85007
SCHOOL GARDEN RISK CONTROL PLAN

School Garden Name: _____ Date: _____

Did you attend the University of Arizona College of Agriculture and Life Sciences Cooperative Extension Course? Yes_____ No_____

1. What company will you use to test the soil? What will you do if the soil tests positive for lead?

_____

_____

_____

2. What type of water system will you be using? What company will you use to test the water, if necessary?

_____

_____

_____

3. What type of construction material are you using for your raised gardens, if applicable?

_____

_____

4. What source are you going to use to obtain your commercial fertilizer and/or compost?

_____

_____

_____

5. Where will gardeners wash their hands? How will you train gardeners in proper hand washing techniques?

_____

_____

6. How will you keep sick gardeners out of the garden?

_____

_____

7. How will produce be transported to the cafeteria and what type of containers will you be using?

_____

_____

_____

8. What cleaning and sanitizing process will be used for the harvest containers prior to use? Where will the cleaning process take place?

_____

_____

_____

Division of Public Health Services
Public Health Preparedness Services

150 N. 18th Avenue, Suite 130
Phoenix, Arizona 85007
(602) 364-3122
(602) 364-3146 FAX
Internet: www.azdhs.gov

JANICE K. BREWER, GOVERNOR
WILL HUMBLE, DIRECTOR

School Gardens Program Date: _____

Name: _____

School: _____

Mailing Address: _____

Phone: _____

Soil sampling protocol for lead testing.

Do:

1. Take samples only in the garden area,
2. Illustrate on the garden map where samples were taken,
3. Use clean sampling tools to avoid contaminating the sample (like a metal trowel or spade),
4. Take 5 to 10 subsamples in the garden area. Take thin, vertical slices of soil making sure to include the surface soil to about 4 inches deep in each subsample.,
5. Mix the subsamples in a clean, plastic container or bag with a clean, plastic utensil,
6. Place less than 1 cup of mixed soil in a clean container (like a sandwich size zip type plastic bag) and label,
7. Label your shipping box with "Soil Sample" on the top and sides,
8. Include your shipping label,
9. Include this form in the shipping box,
10. Include the garden map in the shipping box,
11. Email, call or fax when shipping your soil sample.

Don't:

1. Use paper bags, as they can't be sealed against the elements,
2. Use bronze instruments, can cause contamination,
3. Allow sample to sit out uncovered, to prevent contamination,
4. Include in the sample mulch, such as bark and wood,
5. Use contaminated sampling tools or container.

Submit soil sample along with this form and garden map to:

Kathryn Mathewson
150 N 18th Avenue, Suite 140
Phoenix, AZ 85007
(602) 364-3952
Fax: (602) 364-3146
Kathryn.Mathewson@azdhs.gov
Allow 4 to 8 weeks for processing.

School Garden Harvest Log

School Name:

	Item Harvested	Date Harvested	Date Used	ID/Field/Row	Quantity	Unit of Measure	Use in school
	EXAMPLE: Lettuce	1/1/2013	1/5/2013	8th grade	5	lbs	salad bar
	EXAMPLE: tomatoes	1/1/2013	1/6/2013	7th grade	10	pints	salad bar
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Maintain a copy in the cafeteria for inspector.

College of Agriculture and Life Sciences
Cooperative Extension
The University of Arizona

AZ1604 September 2013

School Garden Food Safety Guidelines

Monica Pastor, Ashley Schimke and Diane Eckles

The following are guidelines for the safe handling of foods grown in school gardens for use in the school cafeteria. Following these guidelines will help reduce contamination from pathogens and maintain a safe environment for children, volunteers, and teachers who work in the garden. Prior to using the food items in the school cafeteria, school gardens will need to implement these guidelines and have the garden certified by the Arizona Department of Health Services (ADHS).

> **Rationale:** *School kitchens fall under the jurisdiction of the Arizona Food Code, which states that kitchen facilities may only use foods from an "approved source." The Arizona Food Code leaves this definition up to the local health authority. In this instance, the local health authority is considered the county health department. Prior to the implementation of these guidelines, county health departments considered school garden produce to be an unapproved source for use in kitchen facilities.*

These general guidelines are designed to reduce the risk of microorganisms contaminating fresh produce grown in school gardens. They also provide information about high risk areas for contamination and how to avoid or minimize such contamination. It is important to recognize that these guidelines do not guarantee the product is free from microbial contamination but verify that the school has taken proactive measures to reduce the risk of contamination by adhering to generally recognized best practices for safe food production and harvest.

Microorganisms and pathogens are a natural part of the environment and can be a problem whether you choose to use organic or conventional gardening methods. It is essential to understand how these microorganisms are typically introduced into the gardening environment and the potential means by which they can contaminate fresh produce in order for school gardens to safely provide healthy foods grown by, and for, students.

In order to implement a successful school gardening program, it is critical to involve students, teachers, school administrators, facilities staff, food service staff, and the community throughout the planning process. The school district and the ADHS will need to approve the implementation of these guidelines as an acceptable safety measure. Information about the ADHS certification procedures can be found at **http://www.azdhs.gov/phs/oeh/fses/school-garden.**

General Guidance

Every school garden must implement a written Risk Control Plan and have it approved by the Registered Sanitarian with ADHS **(Kathryn.Mathewson@azdhs.gov)** prior to utilizing garden-grown food items in the school cafeteria. The Plan should document appropriate training of student and volunteer workers in proper hygiene and harvesting as outlined below. A designated Garden Manager (Person in Charge) must document and maintain all necessary records as well as document any corrective actions.

What is the right way to wash your hands?

- Wet your hands with clean running water (warm or cold) and apply soap.
- Rub your hands together to make a lather and scrub them well; be sure to scrub the backs of your hands, between your fingers, and under your nails.
- Continue rubbing your hands for at least 20 seconds. Need a timer? Hum the "Happy Birthday" song from beginning to end twice.
- Rinse your hands well under running water.
- Dry your hands using a clean towel or air dry.

Washing hands with soap and water is the best way to reduce the number of germs on them. If soap and water are not available, use an alcohol-based hand sanitizer that contains at least 60% alcohol. Alcohol-based hand sanitizers can quickly reduce the number of germs on hands in some situations, but sanitizers do not eliminate all types of germs.

Centers for Disease Control and Prevention
http://www.cdc.gov/features/handwashing

Figure 1 Proper Hand Washing

Worker Health and Hygiene

All workers (students, staff and volunteers) must be trained by the Garden Manager in proper hand washing techniques and hygiene procedures. The Centers for Disease Control and Prevention recommended procedure can be seen in Figure 1. Any wounds should be properly bandaged before working in the garden.

The Garden Manager needs to tell sick workers that they must not work in the garden. Anyone who is ill should not handle food within 24 hours of vomiting or diarrhea, or before being cleared by a medical professional (e.g., the school nurse) after experiencing a combination of fever and sore throat.

It is recommended that all workers should be trained on the use of machinery including the location of controls to safely start and stop the equipment. Equipment that requires an on/off switch should only be handled by an adult, but in case of emergency, the students should know how to stop the equipment.

Since workers will be out in the sun, they should be encouraged to wear hats and apply sunscreen while gardening. The garden is an ideal way to utilize the SunWise Skin Cancer Prevention School Program, which can be found at **http://www.azdhs.gov/phs/sunwise.**

Garden Review

Prior to implementing the garden, it is important to consider previous land use and determine if the soil contains lead or other contaminants. The ADHS lab will conduct free lead tests on samples submitted by a school. The Garden Manager needs to document the quality of the water source for the garden, any soil amendments that will be utilized, methods implemented for pest control, and procedures to deter animals from entering the garden. Shovels, rakes, and other field equipment must be cleaned with hot, soapy water on a regular basis. If there are students with allergies at the school, keep allergenic types of foods (wheat, strawberries, melons, tree nuts, and peanuts are the most common) separate from other areas of the garden.

Land Use and Land Use History

- Document the history of the land use prior to installing the garden. The school district should have record of the prior use of the land before the school was built. It is also important to note how the land was used after the installation of the school. If the garden is placed in an area that was previously used for parking or an area where chemicals may have been applied for weed and pest control, then it is important to have the soil tested by a lab. A list of soil testing laboratories can be found at http://ag.arizona.edu/pubs/garden/az1111.pdf.
- Avoid damaging underground utilities by calling 811 (AZ Blue Stake) before you dig.
- Position the garden away from potential contamination sources such as garbage containers, school animals (rabbits, tortoises, birds, etc.), septic systems, in-ground storage tanks, and water runoff from playgrounds, roofs, walkways, and/or parking areas. Do not place the garden in a low lying, poorly drained area or an area subject to any kind of chemical application. Manage the planting area to avoid standing water and excess debris.
- Use non-toxic, non-leaching materials for raised bed gardens. Cedar, redwood, cypress, pine, and oak are acceptable woods as well as masonry and/or composite materials.
- It is important to work with the maintenance staff to ensure they use safe practices on the school grounds near the garden. These safe practices would ensure chemicals for weeds or pests are not used in the vicinity of the garden. Also, equipment such as lawn mowers, weed whips, or blowers may kick up rocks and could harm workers and should only be used when no workers are present in the garden.

Water Source

- Only use potable water for the portion of the garden in which food is grown. Municipal water tests must be acquired by the Garden Manager from the local water provider on a yearly basis. Well water must be tested for microbial contamination at least once during the growing season. Surface water must be tested three times during the growing season (first at planting, second at peak use, and third at or near harvest).

Water Harvesting

The Garden Manager needs to keep documentation of the water test results.

- If using containers to transport water, they need to be sanitized on a regular basis and only used for water. Clean the reusable containers and harvesting equipment with hot, soapy potable water. Rinse with clean water. After rinsing, sanitize with either 50-100 ppm of chlorine solution (about 1 tablespoon of chlorine solution) or 200 ppm of quaternary ammonia (or per the manufacturer's specification). Your kitchen staff should have test strips available to ensure the solution is at the proper concentration.
- At this time, we recommend that water from rainwater harvesting can only be used on non-edible plants. It is extremely difficult to keep up-to-date, accurate records of the quality of the water harvested through rainwater harvesting techniques. We recommend that this water can still be captured but used on plants not grown for food such as flowers, trees, shrubs, and grass.

Soil Amendments

- Unless using commercially produced soil in a container garden, the soil in the garden should be tested for lead; lead levels must be less than 300 ppm. The lead test is required since many gardens could be near older buildings that might have lead based paint. Areas that have been flooded in the past may have increased risk of lead contamination. You may also want to test the soil to document nutrient levels, such as available calcium, magnesium, sodium, potassium, nitrate, phosphate, salinity, and pH.

School Compost

- Mulch made from wood chips is an excellent method to preserve soil moisture or fertilizers.
- It is recommended that the garden only use commercially available compost or fertilizer. Keep a copy of purchase records from the commercial source to document the product's content.
- Hands should be washed thoroughly after handling soil or compost.
- School prepared compost must contain only plant products and can only be used on non-edible plants. The compost must maintain a temperature of 130º – 150º for three days during the decomposition process. Proper decomposition of plant products for composting involves periodically turning the pile with a shovel. This process normally takes a minimum of 1-2 months under optimal temperature and moisture conditions. The compost pile should be kept in an area separate and down slope from the garden. Do not use manure in the compost. Manure that has not been composted completely is a safety hazard.
- The Garden Manager must document the source of compost as well as record temperature levels of school prepared compost.
- Composting nuisances and risks such as the presence of pathogens, odor, vectors (small animals or insects that carry disease), fires, and litter can be prevented or minimized through proper design and operation.

Pest Control

Use organic methods to minimize or alleviate pests such as insects, weeds, animals, and fungi. These methods include traps, mechanical controls, crop selection, and non-synthetic chemicals and biological controls.

Animal Intrusion: Wild and Domestic

Animals need to be excluded from the garden area. The Garden Manager should monitor for presence of animals by looking for animal prints or feces in the garden. Fencing is the most effective method of excluding animals. Additional ideas to deter or limit animal access to the garden include utilizing scare balloons, metallic tape, CDs, or tassels. These methods provide movement and flashes from sunlight that are disturbing to vectors.

Security

To the extent that is practical, secure the perimeter of the garden with fencing. Extend the school's normal security measures in the garden, such as a sign-in sheet.

Field Harvest and Field Packing

The Garden Manager should conduct a pre-harvest assessment that includes a review of hygiene requirements with the workers prior to harvest as well as making sure potable water is available to the workers. Workers should wear closed toe shoes and should check shoes prior to harvest to avoid bringing contaminants into the garden. These contaminants may include animal feces, food, gum, or phlegm. The Garden Manager needs to ensure toilets and wash facilities are clean. Adults should supervise when harvest begins. Avoid injuring the produce during harvest and handling.

Field Sanitation

It is recommended that the Garden Manager develop a clean-up procedure in case contamination occurs. During the pre-harvest assessment, the Garden Manager should determine if there is evidence of contamination (human or animal) in the garden. The contaminated area should be isolated and labeled as "no harvest" or pull the contaminated plants immediately. Discard all plants that are contaminated. It is important to periodically remove rotten produce.

Emergency Clean-Up Procedures

A clean-up procedure needs to be developed in the event of an accidental contamination incident. Accidental contamination could include a worker getting sick or blood from a cut getting on the ground, a plant or a harvest tool. Discard all plants and soil that are contaminated.

If you step in the contaminant, clean your shoes prior to harvesting in other areas of the garden to avoid bringing contaminants into the previously non-contaminated areas.

Harvesting Containers & Equipment

- Hands should be washed before beginning to harvest the produce and again after using the restroom, touching the face, coughing, or sneezing. ADHS requires the use of single-use, non-latex, plastic gloves when harvesting produce.
- Food grade, reusable containers should only be used for harvest. The containers should not be made from wood. Rigid containers that are made from plastic or stainless steel are generally acceptable. They should be stored in a protected area during and after harvest and must be sanitized and in good condition. One-time-use harvest containers, such as paper/plastic bags and cardboard boxes, must be new and clean. Knives, scissors, and other harvesting equipment must be cleaned prior to use and must only be used in the garden for their designated purposes. Harvesting equipment should never be used for working with compost. Clean the reusable containers and harvesting equipment with hot, soapy potable water. Rinse with clean water. After rinsing, sanitize with either 50-100 ppm of chlorine solution (about 1 tablespoon of chlorine solution) or 200 ppm of quaternary ammonia (or per the manufacturer's specification). Your kitchen staff should have test strips available to ensure the solution is at the proper concentration.

Receiving by Cafeteria Staff

- The harvested produce should not be washed by the garden workers. Shake off as much dirt as possible in the garden area and deliver to the cafeteria staff in the harvest container. The cafeteria staff must verify the harvest containers are clean. Cafeteria staff must not accept the product if there are odors or evidence of contamination. Produce from the school garden needs to be kept separate from the commercial produce.
- If possible, weigh the produce so the students can document their harvest. The cafeteria staff should record who, what, when, how, and where the school garden produce was harvested and cleaned.

These guidelines were adapted from:

AZ Department of Education **(http://www.azed.gov/health-nutrition/school-gardens)**, AZ Department of Health Services **(http://www.azdhs.gov/diro/admin_rules/guidance_PHS_BEDCS.htm),** USDA's People's Garden Initiative, North Carolina State Cooperative Extension, Mountain Roots Food Project, National Farm to School Network, University of Maryland, University of Connecticut, USDA National Food Service Management Institute, Denver Urban Garden, and The Community Food Bank of Southern Arizona's Garden-to-Cafeteria Guidelines.

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This information has been reviewed by University faculty.
cals.arizona.edu/pubs/health/az1604.pdf
Other titles from Arizona Cooperative Extension can be found at:
cals.arizona.edu/pubs

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APPENDIX Orchard Field Operations.

Each spring after growers had completed tillage operations, PI McCloskey and his staff used a tractor mounted sprayer to apply the preemergence and postemergence herbicide treatments. Postemergence herbicide treatments included ammonium sulfate (1% w/w) to enhance absorption. Weed populations in the experiments were monitored at various times over the two-year period of this study. The field operations conducted at Red Rock Pecans, Green Valley Pecans and Chase Farms are presented in Tables A.1 to A.6.

Table A.1. Operations conducted in 2011 by PI McCloskey & staff at Red Rock Pecans (Pinal County).

Site	Date	Operation	Treatment	Details/comments
Red Rock	2-18-11	Field 10 irrigated	1 to 5 (all)	Grower irrigated field for first time in 2011 after ground work.
	4-5-11	PREE & POST herbicides sprayed	1, 2, 3, 4	T1=Prowl H_2O @ 3qt/A + Alecto (glyphosate) @ 2 qt/A, T2=Prowl H_2O @ 2 qt/A + Chateau @ 6 oz/A + Alecto @ 2 qt/A, T3=Pindar GT @ 3 pt/A + Glyphomax @ 2 qt/A, T4= CropSmart 41 Plus, T5 not treated
	5-10-11	Counted weeds by species	1 to 5 (all)	Counted weeds by species in 0.5 m^2 subplots in pairs at 25 step intervals about 1/3 into panel from tree lines.
	5-12-11	Rated weed control, took pictures	1 to 5 (all)	Visually estimated % weed control.
	5-12-11	CropSmart 41 + AMS	5	Applied with Kabota/orchard sprayer; Crop Smart (glyphosate) @ 48 fl oz/A + 8.5 lb/100 gal AMS.
	6-24-11	PREE & POST herbicides sprayed	1, 4, 5	T1=Prowl H_2O @ 3qt/A + CropSmart 41 @ 48 fl oz/A, T4=Alion @ 5 fl oz/A + Rely 280 @ 4 pt/A, T5=CropSmart 41 @ 2 qt/A.
	8-15-11	Counted weeds by species	1 to 5 (all)	Counted weeds by species in 0.5 m^2 subplots in pairs at 25 step intervals about 1/3 into panel from tree lines.
	8-26-11	Sprayed CropSmart 41 + AMS or Rely 280	1 to 5 (all)	T1, T2 & T3=CropSmart41 @ 2 qt/A + AMS @ 8.5 lb/100 gal; T4 & T5 = Rely 280 at 4 pt/A
	11-17-11	Counted weeds by species	1 to 5 (all)	Counted weeds by species in 0.5 m^2 subplots in pairs at 25 step intervals about 1/3 into panel from tree lines (N & S).

Table A.2. Field operations conducted by PI McCloskey and staff during 2012 at Red Rock Pecans in Pinal County.

Site	Date	Operation	Treatment	Details/comments
Red Rock	6/15/2012	Sprayed pre-emergence herbicides tank-mixed with glyphosate	1 to 5 (all)	Plots sprayed with Kabota. T1= Prowl @ 3 qt/A (Spring) Prowl @ 2 qt/A (fall); T2= Prowl @ 3 qt/A + Chateau @ 6 oz/A; T3= Pindar GT @ 3 pt/A; t4= Alion @ 5 oz/A; T5= Untreated with pre-emergence. All treatments were sprayed with 48 fl. oz./A of Honcho (glyphosate).
	7/26/2012	Pictures and Visual % Control	1 to 5 (all)	11 pictures taken per side of panel between tree rows with camera mounted on pole. 40 steps taken between pictures. Visual weed control ratings ratings (0 to 100% with 0 indicating no control and 100% indicating complete control or no weeds).
	7/26/2012	Barry Armstrong sprayed 2% Glyphosate solution	1 to 5 (all)	Barry Armstrong sprayed 2% Glyphosate solution
	8/31/2012	Sprayed Glyphosate	1 to 5 (all)	Plots sprayed with the Mule/Weed Seeker system. Gallons sprayed per plot were recorded. Glyphosate (Honcho) sprayed at 64 oz/A.
	8/31/2012	Visual Rating	1 to 5 (all)	Visual weed control ratings (0 to 100% with 0 indicating no control and 100% indicating complete control or no weeds).
	10/24/2012	Weed Counts	1 to 5 (all)	All weeds in panel were counted in each plot.

Table A.3. Field operations conducted by PI McCloskey and staff during 2011 at Green Valley Pecans in Pima County.

Site	Date	Operation	Treatment	Details/comments
Green Valley	March to April	Soil preparation	1 to 5 (all)	Disked, irrigated, disked, ran ripper (20" depth) with cultipacker, irrigated, ran cultipacker with blade and roller.
	4-11-11	Preemergence herbicides applied	1, 2, 3	Applied with kabota/orchard sprayer. No glyphosate or adjuvants. T1=Prowl H_2O @ 3 qt/A, T2=Prowl H_2O @ 3 qt/A + Chateau @ 6 oz/A, T3=Pindar GT @ 3 pt/A.
	5-4-11	% ground cover was measured	1 to 5 (all)	Photographed 0.5 m^2 subsamples; 25 steps between pairs of subsamples, alternating sides of wheel track (N/S).
	5-4-11	Honcho Plus + AMS	4, 5	Applied with Kabota/orchard sprayer.
	5-23-11	% ground cover was measured		Photographed 0.5 m^2 subsamples; 35 steps between pairs of subsamples, alternating sides of wheel track (N/S).
	6-27-11	Preemergence herbicides applied	1, 4	T1=Prowl H2O @ 2 qt/A + Honcho Plus @ 48 fl oz/A, T4: Alion @ 6.5 fl oz/A + rely 280 @ 4 pt/A.
	7-13-11	% ground cover was measured	1 to 5 (all)	Photographed 0.5 m^2 subsamples; 25 steps between pairs of subsamples, alternating sides of wheel track (N/S).
	7-14-11	Honcho Plus + AMS	1 to 5 (all)	FICO sprayed all treatments for us.
	8-15-11	Firestorm (rows 1-36) or Honcho Plus	1 to 5 (all)	FICO sprayed all treatments for us.
	10-6-11	% ground cover was measured	1 to 5 (all)	Photographed 0.5 m^2 subsamples; 25 steps between pairs of subsamples, alternating near tree line with outside near berm (N/S).
	10-10-11	Honcho Plus, AMS and Sandea sprayed	1 to 5 (all)	Tree rows 25 to 35 sprayed with Honcho Plus @ 48 fl oz/A + Sandea @ 1 oz/A; tree rows 35 to 40 sprayed with Honcho Plus @ 48 fl oz/A. Middle of panels also sprayed with latter mixture (no Sandea).

Table A.4. Field operations conducted by PI McCloskey and staff during 2012 at Green Valley Pecans in Pima County.

Site	Date	Operation	Treatment	Details/comments
Green Valley	4/11/2012	Spray glyphosate	1 to 5 (all)	Plots sprayed by grower with glyphosate at approximately 32 oz/A with 3 lb ae/gallon formulation.
	4/27/2012	Pre-emergence herbicides applied	1 to 5 (all)	Plots sprayed with Kabota. T1= Prowl @ 3 qt/A (Spring) Prowl @ 2 qt/A (fall); T2= Prowl @ 3 qt/A + Chateau @ 6 oz/A; T3= Pindar GT @ 3 pt/A; t4= Alion @ 6.5 oz/A; T5= Untreated with pre-emergence.
	6/8/2012	% Ground Cover	1 to 5 (all)	% Ground cover estimated visually
	6/27/2012	Spray Glyphosate	1 to 5 (all)	Plots sprayed with Kabota tractor. Glyphosate was sprayed at 44 oz/A.
	9/1/2012	% Ground Cover	1 to 5 (all)	% Ground cover estimated visually
	9/1/2012	Spray Glyphosate	1 to 5 (all)	Plots sprayed with the Mule/Weed Seeker system. Gallons sprayed per plot were recorded. Glyphosate sprayed at 64 oz/A.
	9/24/2012	Pictures taken	1 to 5 (all)	11 pictures taken per side of tree row. 25 steps taken between pictures; camera was mounted on pole.

Table A.5. Field operations conducted by PI McCloskey and staff during 2011 at Chase Farms in Cochise County.

Site	Date	Operation	Treatment	Details/comments
Chase Farms	April/May	Tree middles were disked, dragged	1 to 6 (all)	Grower disked middles of panel (about 24 ft wide) to incorporate chipped tree trimming
	5/4/2011	Honcho Plus + AMS spray	1 to 6 (all)	Grower sprayed glyphosate to control emerged vegetation
	5-13-11	Preemergence herbicides applied	1, 2, 3, & 5	Applied with Kubota/orchard sprayer. No glyphosate or adjuvants; T1=Prowl H_2O @ 3qt/A, T2=Prowl H_2O @ 2 qt/A + Chateau @ 6 oz/A, T3=Pindar GT @ 3 pt/A, T5 GoalTender @3 pt/A + Chateau @ 6 oz/A
	7-8-11	% ground cover was measured	1 to 6 (all)	Photographed 0.5 m^2 subsamples; 16 steps between pairs of subsamples; tree-line first then middle.
	7-8-11	PREE & POST herbicides sprayed	1, 4	T1=Prowl H_2O @ 2 qt/A + Honcho Plus @ 64 fl oz/A (1.5 lb ae/A glyphosate), T4=Alion @ 5 fl oz/A + Rely @ 4 pt/A; T6=No PREE-Honcho Plus @ 64 fl oz/A
	8-30-11	% ground cover was measured	1 to 6 (all)	Photographed 0.5 m^2 subsamples; 16 steps between pairs of subsamples; tree-line first then middle.
	9-1-11	Honcho Plus @ 48 fl oz/A + AMS	1, 2, 3, 5, 6	Applied with Kubota/orchard sprayer; T4+Alion was not sprayed because there were no weeds in this treatment.
	11-4-11	% ground cover was measured	1 to 6 (all)	Photographed 0.5 m^2 subsamples; 16 steps between pairs of subsamples; tree-line first then middle.
	11-7-11	Honcho Plus + AMS	1 to 6 (all)	Grower applied ~4 qt/A glyphosate to kill weeds in preparation for harvest.

Table A.6. Field operations conducted by PI McCloskey and staff during 2012 at Chase Farms in Cochise County.

Site	Date	Operation	Treatment	Details/comments
Chase Farms	5/10/2012	Sprayed Pre-Emergence	1 to 6 (all)	Pre-emergence herbicides sprayed with Kabota. T1= Prowl @ 3 qt/A (Spring) Prowl @ 2 qt/A (fall); T2= Prowl @ 3 qt/A + Chateau @ 6 oz/A; T3= Pindar GT @ 3 pt/A; t4= Alion @ 5 oz/A; T5= Goal Tender @ 3 pt/A + Chateau @ 6 oz/A; T6= Untreated with pre-emergence. All treatments received 48 oz/A of Honcho (glyphosate) with the above treatments.
	7/20/2012	% Control Rating	1 to 6 (all)	Plots were visually estimated for ground cover on a 1-10 scale.
	8/2/2012	Spray Glyphosate	1 to 6 (all)	Sprayed with Kubota. Glyphosate sprayed at 2 qt/A (1.5 lb ae glyphosate/A; T4=Alion was sprayed with Rely 280 @ 4 pt/A.
	10/10/2012	Pictures and weed counts	1 to 6 (all)	Pictures were taken of 0.5 m^2 PVC square. If weeds present in square, they were counted. 20 pictures per plot.
	11/4/2012	Pictures	1 to 6 (all)	Pictures were taken of 0.5 m^2 PVC square. 28 pictures per plot.

Appendix J

referenced from pages 69 thru 86

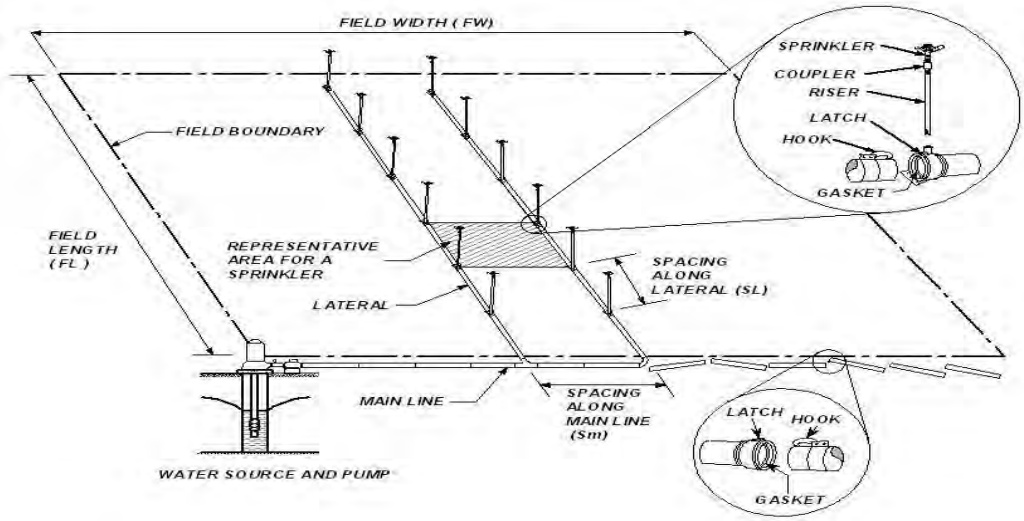


Figure 1. Layout and system components of a set sprinkler system (Martin et al., 2007a)

outlet discharge distribution)

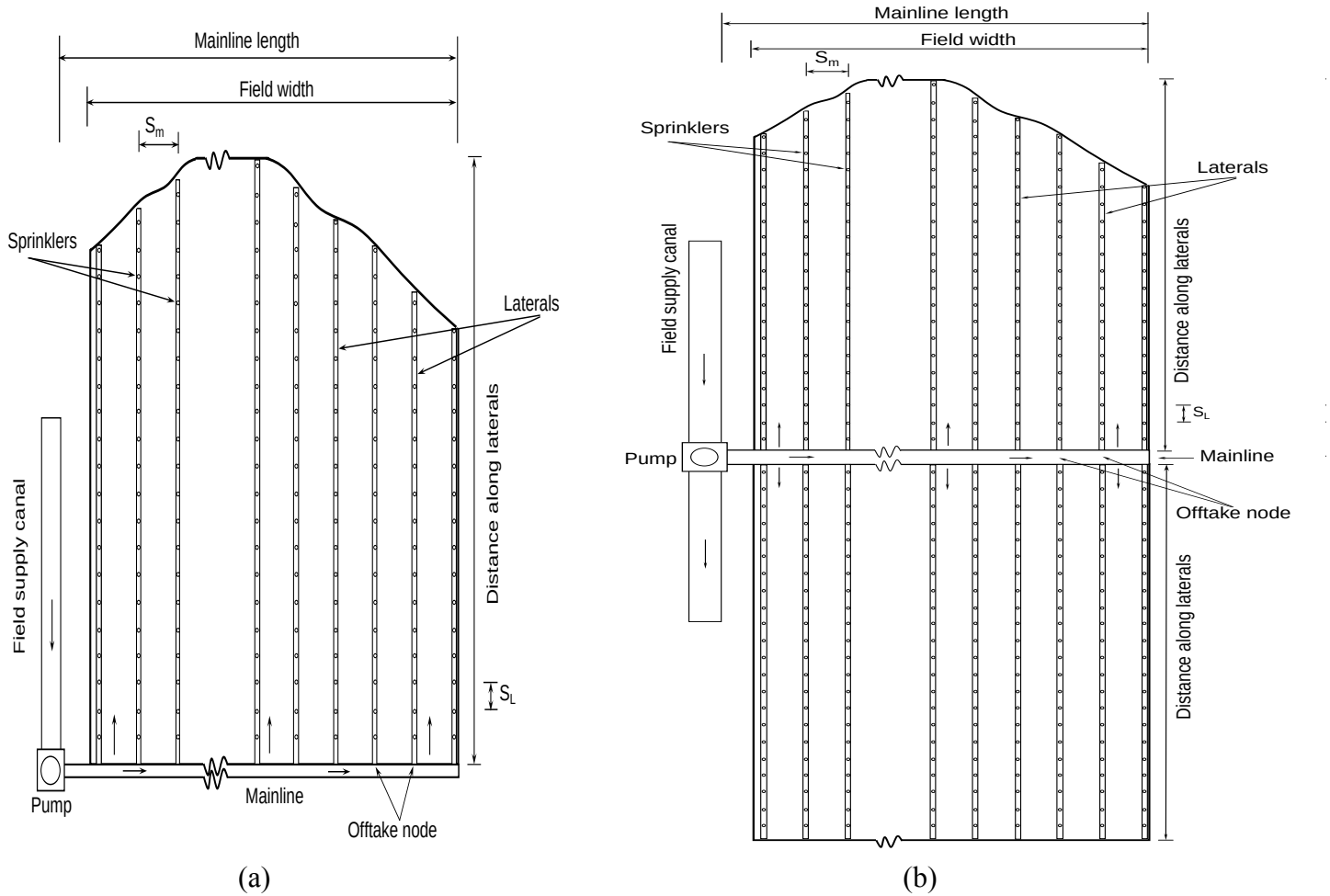


Figure 2 Field-scale solid set sprinkler system layout configurations (a) single-line laterals (b) double-line laterals (S_L = sprinkler spacing along laterals and S_m = lateral spacing)

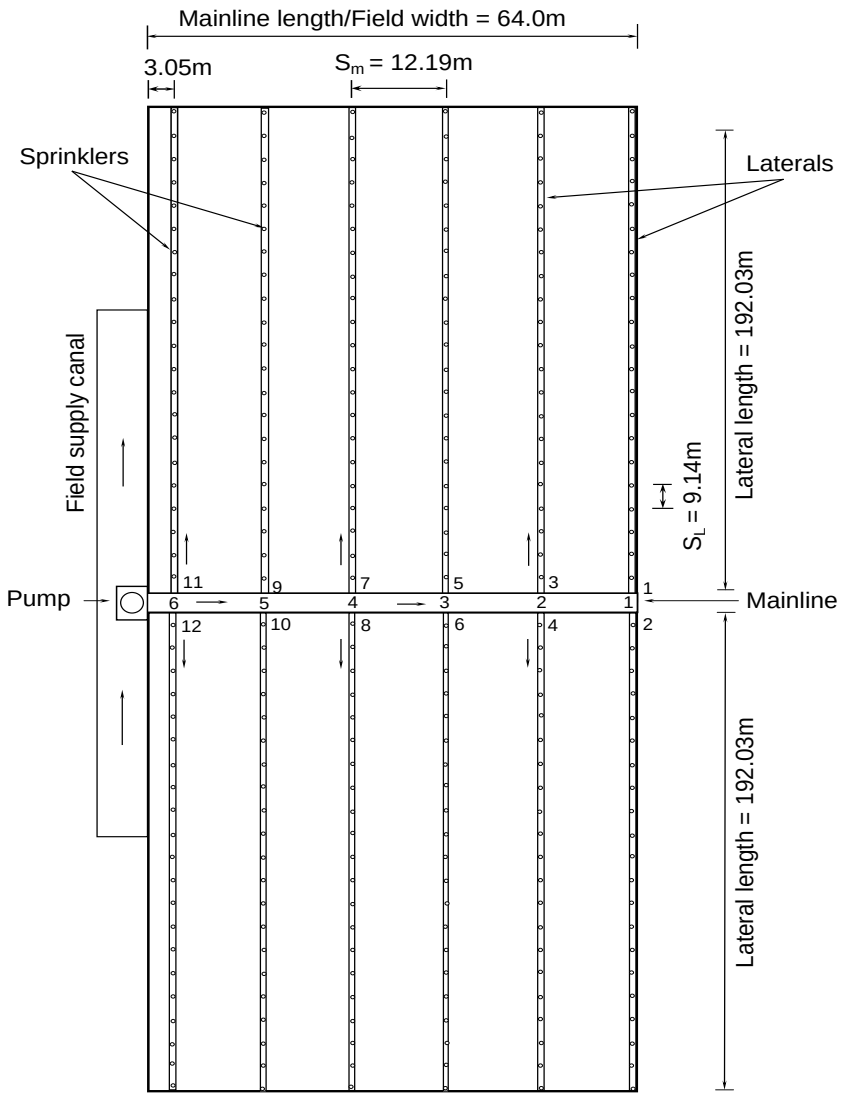


Figure 3 Layout of the sprinkler system used in the field study in the Maricopa Agricultural Center the University of Arizona

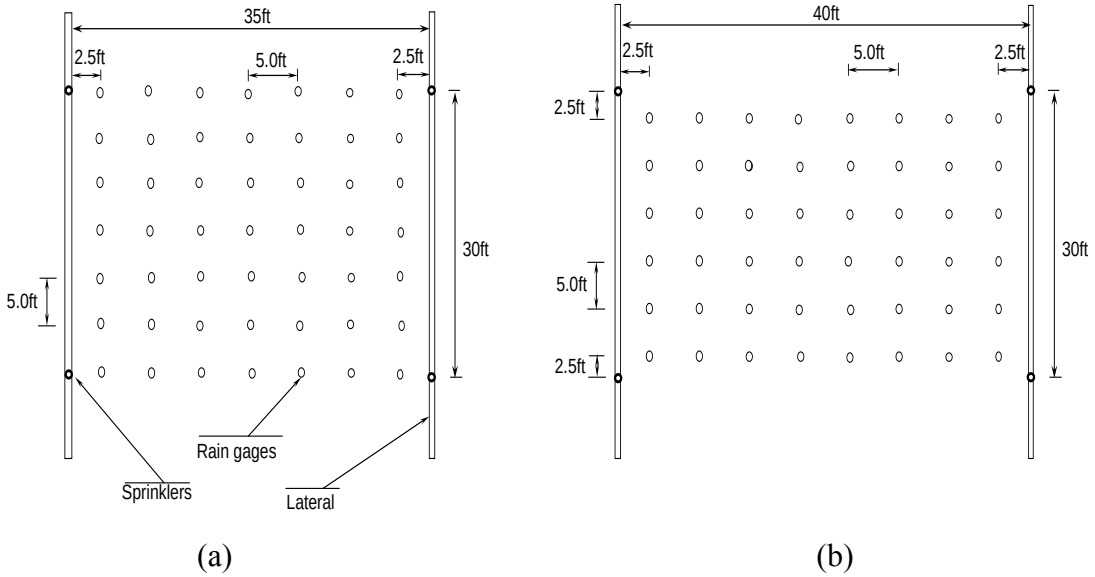


Figure 4 Layout of the irrigation uniformity test-plots used in: (a) The Yuma Valley field evaluation and (b) Maricopa Agricultural Center field evaluation

Table 1 Field data and uniformity computation for irrigation evaluation I, Yuma Valley Irrigation District

			Test-plot 1							Test-plot 2							Test-plot 3						
			Number of rain gages parallel to the laterals							Number of rain gages parallel to the laterals							Number of rain gages parallel to the laterals						
			1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
			Collected depth (mm)							Collected depth (mm)							Collected depth (mm)						
Number of rain gages parallel to the mainline		1	81	28	30	23	24	36	81	11	8	8	7	7	10	19	36	28	22	20	20	23	30
		2	38	28	25	25	30	30	30	10	8	8	8	8	10	13	25	24	24	30	24	25	25
		3	29	29	30	28	27	27	28	11	10	11	10	11	10	12	26	25	24	25	25	28	27
		4	30	32	33	29	25	27	28	16	15	15	15	20	15	15	27	28	28	28	29	30	30
		5	30	30	30	37	27	27	28	20	20	20	20	20	22	23	28	30	23	30	30	28	28
		6	29	28	28	26	24	25	28	34	25	23	25	23	26	30	30	30	30	25	25	27	28
		7	65	28	20	20	23	28	56	33	30	25	23	25	36	53	38	28	33	22	20	23	30
		Unit																					
Average wind speed during irrigation test		*m/s*	1.8																				
Duration of test irrigation event		*h*	7.0																				
Test-plot Scale	Test-plot size	*ft*	30.0×35.0							30.0×35.0							30.0×35.0						
	Farm block size	*ft*	430.0×490.0							430.0×490.0							430.0×490.0						
	Average depth collected	*mm*	32.0							18.0							27.0						
	UCC	-	0.78							0.58							0.89						
	DU_{lq}	-	0.76							0.48							0.84						
Field scale	Minimum depth collected	*mm*	7.0																				
	Maximum depth collected	*mm*	81.0																				
	Average depth	*mm*	26.0																				
	UCC	-	0.75																				
	DU_{lq}	-	0.69																				

UCC = Christiansen's uniformity coefficient, DU_{lq} = low-quarter distribution uniformity, and test-plots 1, 2, and 3 represent the upstream end, middle, and downstream end test-plots, respectively, generally arranged along the field diagonal starting from the inlet end.

Table 2 Field data and uniformity computation for irrigation evaluation II, Yuma Valley Irrigation District

			Test-plot 1							Test-plot 2							Test-plot 3						
			Number of rain gages parallel to the laterals							Number of rain gages parallel to the laterals							Number of rain gages parallel to the laterals						
			1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
			Collected depth (mm)							Collected depth (mm)							Collected depth (mm)						
Number of rain gages parallel to the mainline		1	13	18	20	20	20	20	20	18	18	19	20	20	22	25	18	-	-	-	-	-	15
		2	15	18	20	20	20	20	20	18	18	17	15	19	20	22	18	18	20	20	17	17	18
		3	20	20	20	20	23	23	20	18	17	18	18	20	20	20	19	18	18	19	20	20	20
		4	23	25	23	23	23	25	23	20	20	20	23	20	20	20	20	19	19	19	23	24	23
		5	23	23	23	23	23	20	23	25	20	22	22	23	20	20	24	18	18	20	23	28	27
		6	23	23	23	23	23	23	20	22	24	22	22	22	20	19	23	17	18	20	23	25	28
		7	20	20	20	18	15	20	20	28	28	23	25	19	22	20	20	17	20	18	23	27	26
		Unit																					
Average wind speed during irrigation test		*m/s*	1.2																				
Duration of test irrigation event		*h*	7.0																				
Test-plot Scale	Test-plot size	*ft*	30.0×35.0							30.0×35.0							30.0×35.0						
	Farm block size	*ft*	510.0×609.0							510.0×609.0							510.0×609.0						
	Average depth collected	*mm*	21.0							21.0							21.0						
	UCC	-	0.91							0.91							0.87						
	DU_{lq}	-	0.88							0.85							0.84						
Field scale	Minimum depth collected	*mm*	13.0																				
	Maximum depth collected	*mm*	28.0																				
	Average depth	*mm*	21.0																				
	UCC	-	0.90																				
	DU_{lq}	-	0.85																				

UCC = Christiansen's uniformity coefficient, DU_{lq} = low-quarter distribution uniformity, and test-plots 1, 2, and 3 represent the upstream end, middle, and downstream end test-plots, respectively, generally arranged along the field diagonal starting from the inlet end.

Table 3 Field data and uniformity computation for irrigation evaluation I, Maricopa Agricultural Center

			Test-plot 1						Test-plot 2						Test-plot 3					
			Number of rain gages parallel to the laterals						Number of rain gages parallel to the laterals						Number of rain gages parallel to the laterals					
			1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
			Collected depths (mm)						Collected depths (mm)						Collected depths (mm)					
Number of rain gages parallel to the mainline		1	12	11	10	8	8	10	12	11	9	7	8	9	15	11	9	10	10	12
		2	13	15	11	8	9	9	12	10	9	9	10	9	10	9	10	9	10	11
		3	14	12	10	9	11	10	11	10	10	11	10	10	9	9	10	10	11	12
		4	12	11	11	12	13	10	10	10	10	10	11	10	13	10	11	11	11	10
		5	14	13	11	12	11	12	10	11	11	11	10	11	10	11	11	11	11	11
		6	12	11	10	11	10	11	11	12	12	8	8	8	13	12	11	10	11	10
		7	12	12	10	9	10	14	11	12	10	7	7	8	12	11	10	10	9	9
		8	13	14	10	9	11	14	12	11	8	7	6	15	13	11	10	8	8	9
		Unit																		
Average wind speed during irrigation test		*m/s*	2.2																	
Duration of test irrigation event		*h*	3.0																	
Test-plot scale	Test-plot size	*ft*	35×40						35×40						35×40					
	Farm block size	*ft*	210×420						210×420						210×420					
	Average depth collected	*mm*	11.1						9.9						10.5					
	UCC	-	0.88						0.87						0.90					
	DU_{lq}	-	0.82						0.77						0.86					
Field scale	Minimum depth collected	*mm*	6.0																	
	Maximum depth collected	*mm*	15.0																	
	Average depth collected	*mm*	10.5																	
	UCC	-	0.88																	
	DU_{lq}	-	0.81																	

UCC = Christiansen's uniformity coefficient, DU_{lq} = low-quarter distribution uniformity, test-plot 1 is set in the field irrigated by the even-numbered laterals, test-plot 2 is installed in the field irrigated by the odd-numbered laterals but closer to the mainline, and test–plot 3 is set in the field irrigated by the odd-numbered laterals but further downstream from the mainline (Figure 6)

Table 4 Computed field-scale irrigation application uniformity and average applied depths, Maricopa Agricultural Center

	Christiansen's uniformity coefficient (-)				
	Test-plot scale				Field-scale
		Test-plot			
		1	2	3	
Irrigation evaluations	I	0.88	0.87	0.90	0.86
	II	0.90	0.89	0.92	
	II	0.84	0.89	0.88	
	IV	0.75	0.84	0.82	
	V	0.80	0.87	0.86	
	Low-quarter distribution uniformity (-)				
	Test-plot scale				Field-scale
Irrigation evaluations	I	0.82	0.77	0.86	0.78
	II	0.83	0.82	0.88	
	II	0.79	0.82	0.76	
	IV	0.69	0.73	0.72	
	V	0.71	0.78	0.75	
	Average application rate (mm/h)				
	Test-plot scale				Field-scale
Irrigation evaluations	I	3.7	3.3	3.5	4.3
	II	5.4	4.9	5.1	
	II	4.8	4.4	4.7	
	IV	4.5	4.0	4.1	
	V	3.8	4.0	3.8	
		Area weighing coefficient for each test-plot data (-)			Farm area, irrigated (*acre*)
		0.33	0.33	0.33	6.14

Area weighing coefficient for each test-plot is computed as the ratio of the area of the corresponding farm block to the total area of the field used in the study, irrigation evaluations I = data collected on June 27, 2012, II and III = data collected on June 28, 2012, and IV and V = data collected on June 29, 2012.

Table 5 Input data for model evaluation and simulation examples

Type of input data		Unit	Model evaluation	Data used in simulation examples	
				Single-line laterals	Double-line laterals
Sprinkler spacing[1]		*m*	9.14	9.14	9.14
Coefficient of sprinkler $q(h_s)$ function, α_1,[2]		$L/s/m^{\alpha 2}$	0.0258	0.0125	0.0125
Exponent of sprinkler $q(h_s)$ function, α_2,[2]		*(-)*	0.502	0.521	0.521
Lateral spacing[3]		*m*	12.19	10.67	10.67
Lateral length		*m*	192.03	374.8	374.8
Lateral diameter[4]		*mm*	76.2	76.2	-
Slope along laterals[5]		*(-)*	±0.0001	-	-0.00055
Mainline length		*m*	64.01	149.4	160.0
Mainline diameter		*mm*	152.4	203.2	203.2
Mainline slope		-	-0.0003	0.0	0.0
Total dynamic head (mainline inlet) [6]		*m*	139.0/144.0	158.0	158.0
Pipe absolute roughness, (aluminum pipe) *(e)*		-	0.127	0.127	0.127
Local head loss coefficient at lateral and riser pipe coupling	Branch flow	-	1.3	1.3	1.3
	Line flow	-	0.7	0.7	0.7
Local head loss coefficient at mainline and lateral coupling	Branch flow	-	1.0	1.0	1.0
	Line flow	-	0.5	0.5	0.5

[1]The first sprinkler is located at full spacing form the lateral inlet; [2]Coefficient and exponent of sprinkler pressure head-discharge function; [3]Considering the data used for model evaluation, the first lateral is installed at a distance of 3.05m from the pump; [4]Lateral diameter used in the simulation example with double-line laterals layout configuration vary along the laterals (between 0-128.0m is 76.2mm, between 128.0m-228.5m is 63.5mm, and between 228.5m-374.8m is 50.8mm); [5]Lateral slope used for system simulation with single-line laterals layout configuration vary along the laterals (between 0-128.0m is -0.3%, between 128.0-256.0m is 0.0%, and between 256.0-374.8m is 0.5%); and [6]Considering the data used for model evaluation, the total dynamic head imposed at the system inlet for data set I is 139.0m and for datasets II and III it is 144.0m.

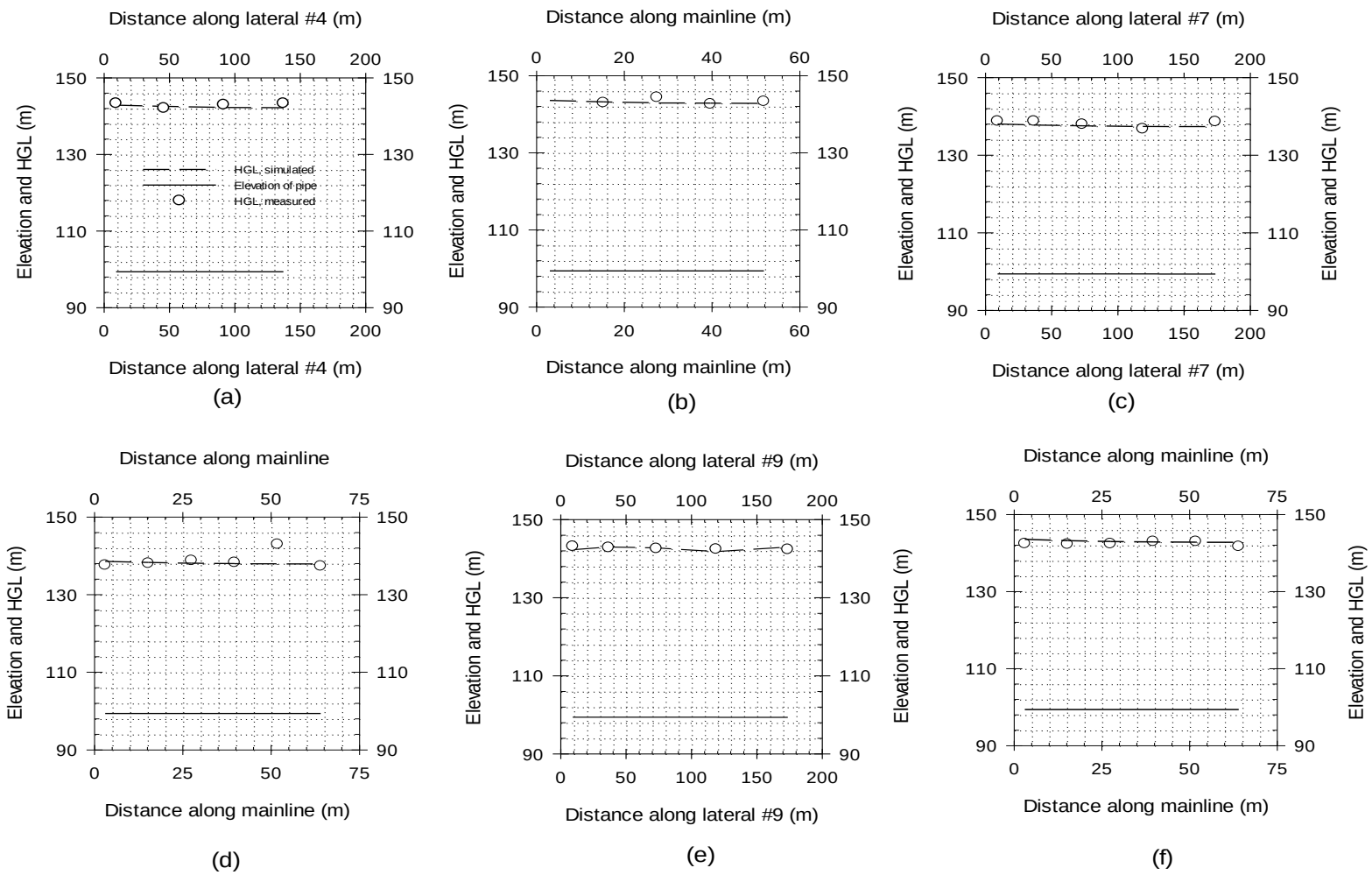
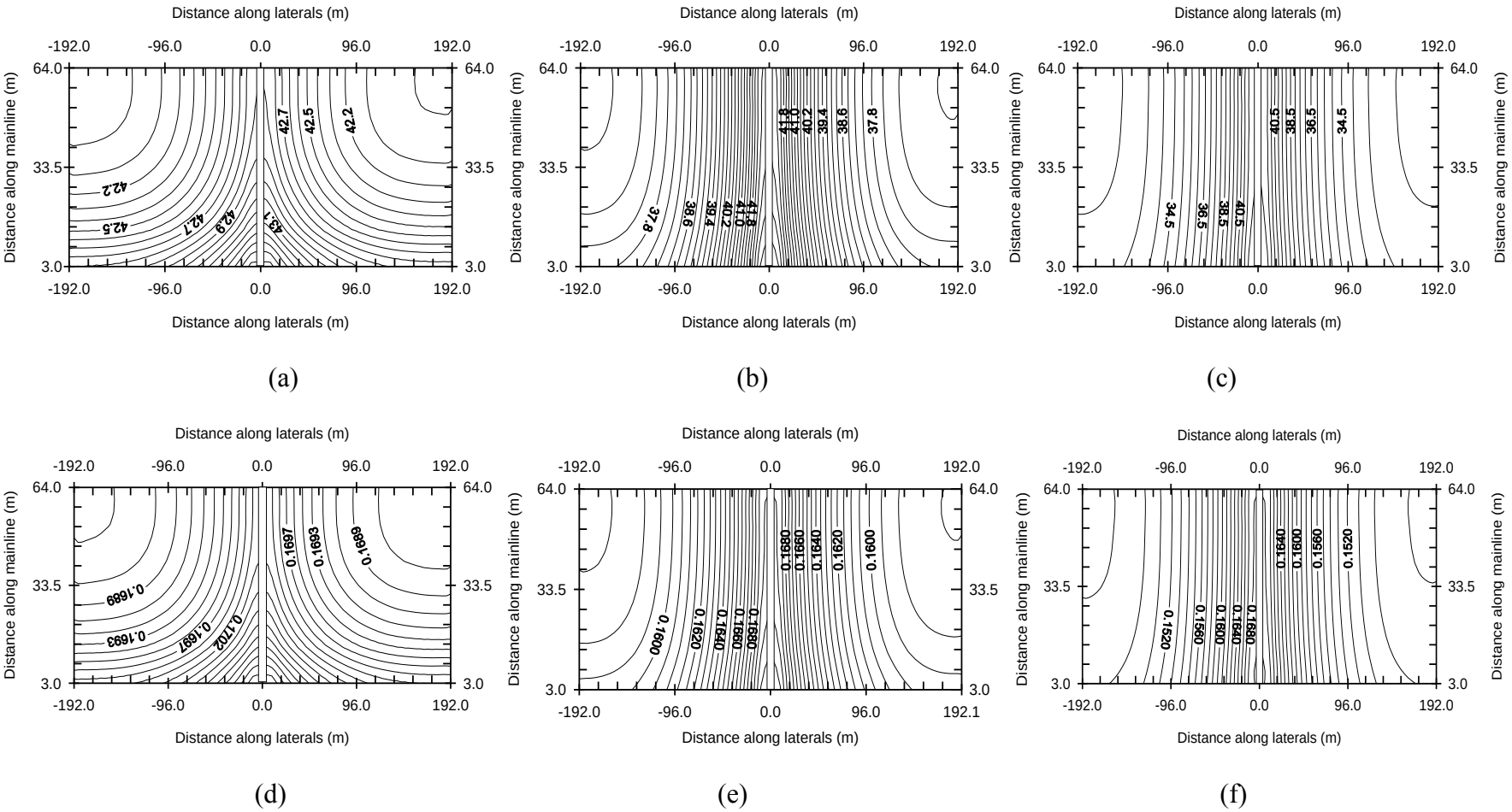


Figure 5 Comparison of model predicted and field observed hydraulic grade lines (HGL): (a) Along lateral #4, Dataset I; (b) Along mainline, Dataset I; (c) Along lateral #7, Dataset II; (d) Along mainline, Dataset II; (e) Along lateral #9, Dataset III; and (f) Along mainline, Dataset III



(a) (b) (c)

(d) (e) (f)

Figure 8 The sensitivity of field-scale spatial distribution of sprinkler pressure head to lateral diameter (D_l): (a) D_l = 76.2mm, (b) D_l = 50.8mm, (c) D_l = 44.45mm; and the sensitivity of field-scale spatial distribution of sprinkler discharge (L/s) to D_l: (d) D_l = 76.2mm, (e) D_l = 50.8mm, and (f) D_l = 44.45mm

Table 6 Comparisons of computed and measured pressure heads and discharges

Computed and measured pressure head along laterals and lateral inlet discharges

Lateral #	Error, nodal pressure head				Error, inlet discharge		
	Minimum (%)	Maximum (%)	Average (%)	Overall average (%)	Dataset I (%)	Dataset III (%)	Overall average (%)
4	0.75	2.96	1.71		9.9	10.9	
7	1.02	3.28	2.07		-	-	
9	0.31	1.98	1.10		14.9	11.5	
				1.49			11.8

Computed and measured pressure head along the mainline

Lateral #	Error, nodal pressure head				Error = |Measured –Computed|×100/ Measured; Average = arithmetic average of the errors computed for each measurement station along a lateral or the mainline; Overall average = the error averaged over all pertinent data sets
	Minimum (%)	Maximum (%)	Average (%)	Overall average (%)	
Data set I	0.47	3.17	1.34		
Data set II	0.57	11.59	3.14		
Data set III	0.32	2.68	1.58		
				2.02	

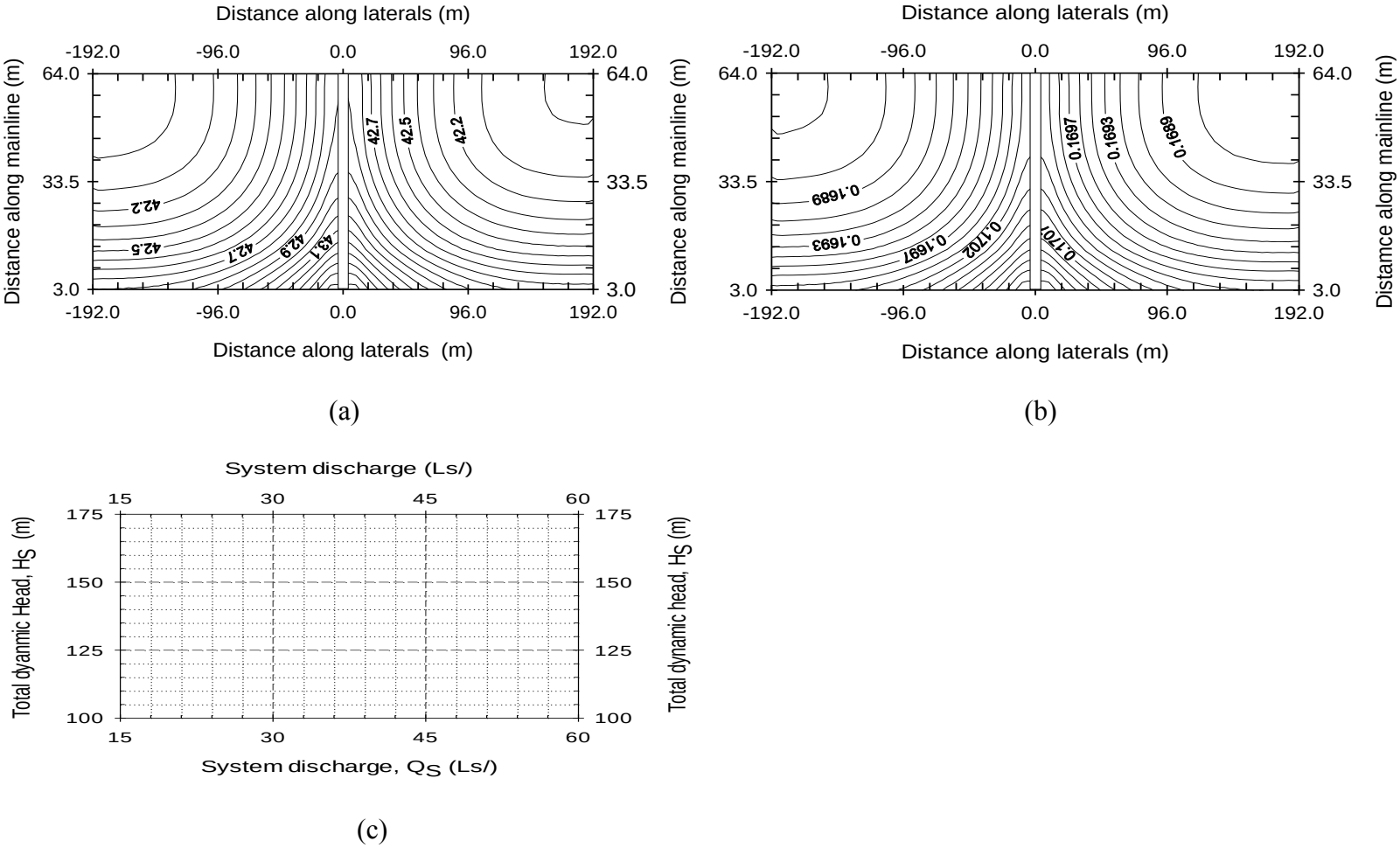


Figure 6 Hydraulic simulation of the field-scale sprinkler system with double-line laterals field layout configuration used in the Maricopa field study: (a) Spatial distribution of sprinkler pressure heads, (b) Spatial distribution of sprinkler discharges, and (c) System hydraulic characteristics (Note that the positive and negative algebraic signs in Figures 9a and 9b are meant to emphasize that distance measurement were made in opposite spatial direction with reference to the mainline)

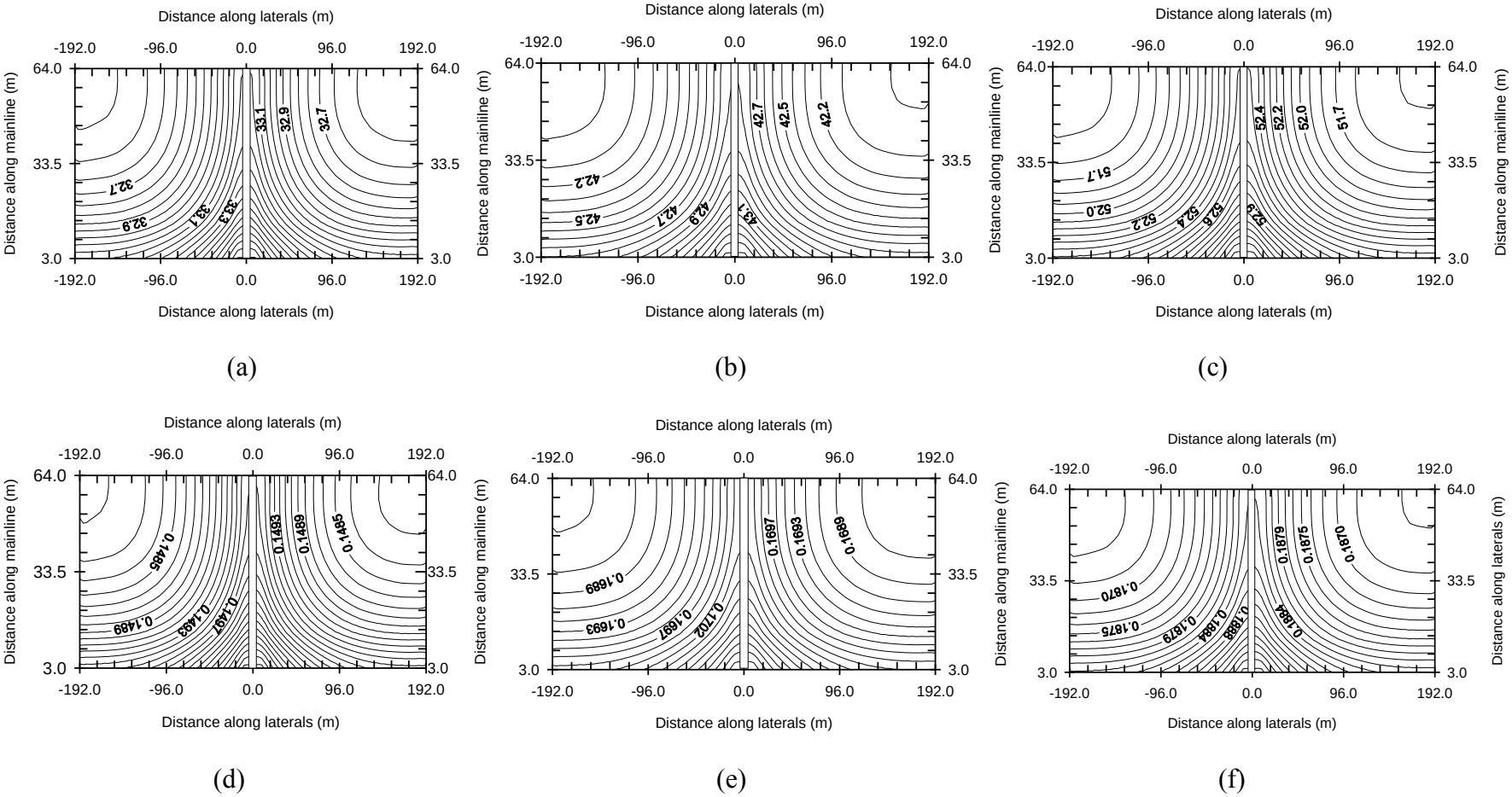


Figure 7 The sensitivity of field-scale spatial distribution of sprinkler pressure head (m) to total dynamic head (H_s): (a) H_s = 134.0m, (b) H_s = 144.0m, and (c) H_s = 154.0m; the sensitivity of field-scale spatial distribution of sprinkler discharge (L/s) to total dynamic head: (d) H_s = 134.0m, (e) H_s = 144.0m, and (f) H_s = 154.0m

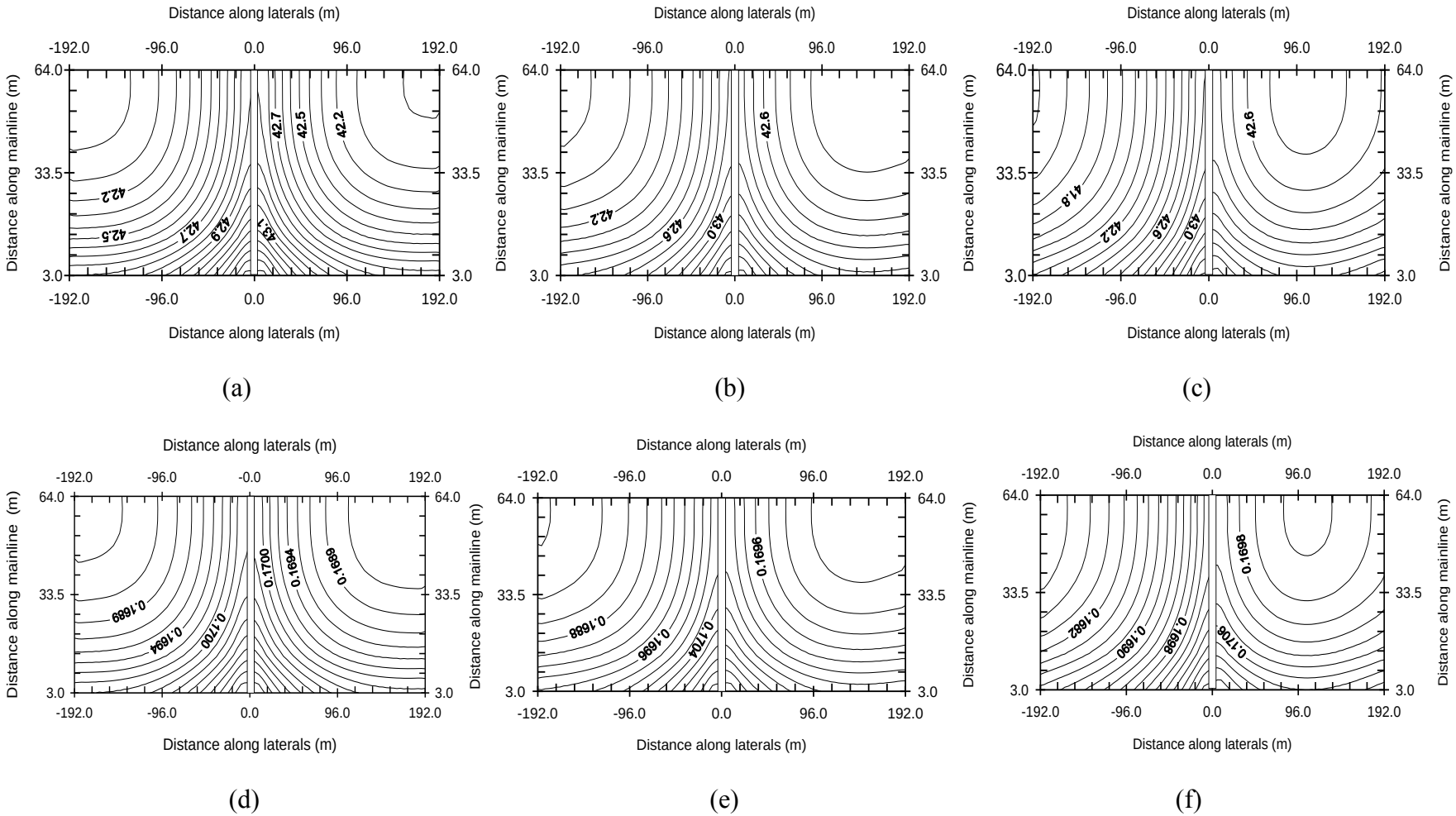


Figure 9 The sensitivity of field-scale spatial distribution of sprinkler pressure head (m) to lateral slope (S_o) : (a) $S_o = \pm 0.0001$; (b) $S_o = \pm 0.001$, (c) $S_o = \pm 0.003$; and the sensitivity of field-scale spatial distribution of sprinkler discharge (L/s) to lateral slope: (d) $S_o = \pm 0.0001$, (e) $S_o = \pm 0.001$, (f) $S_o = \pm 0.003$

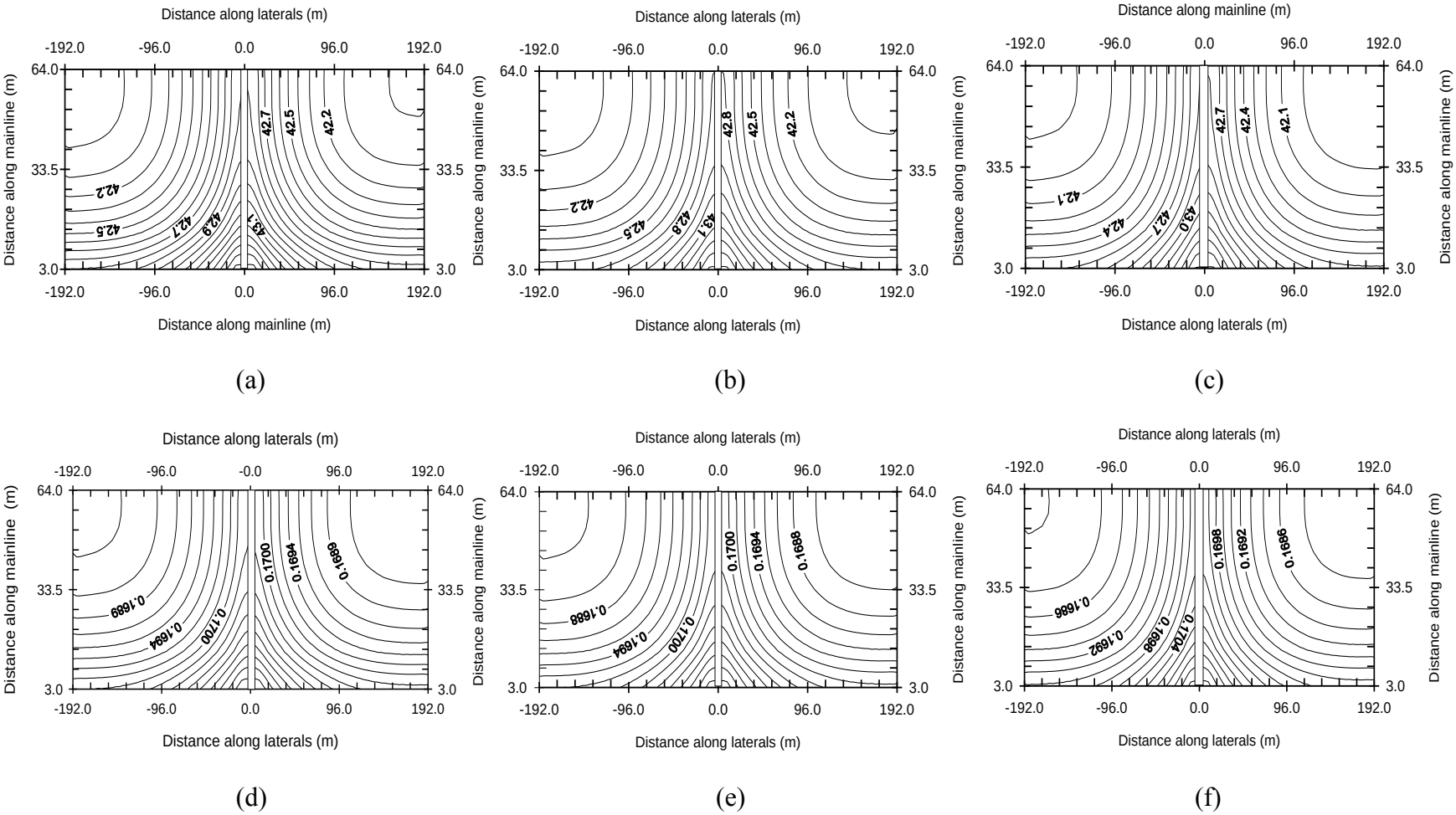


Figure 10 The sensitivity of field-scale spatial distribution of sprinkler pressure head (m) to pipe absolute roughness (*e*): (a) *e* = 0.127, (b) *e* = 0.254, (c) *e* = 0.381; and the sensitivity of field-scale spatial distribution of sprinkler discharge (L/s) to pipe absolute roughness: (d) *e* = 0.127, (e) *e* = 0.254, (f) *e* = 0.381

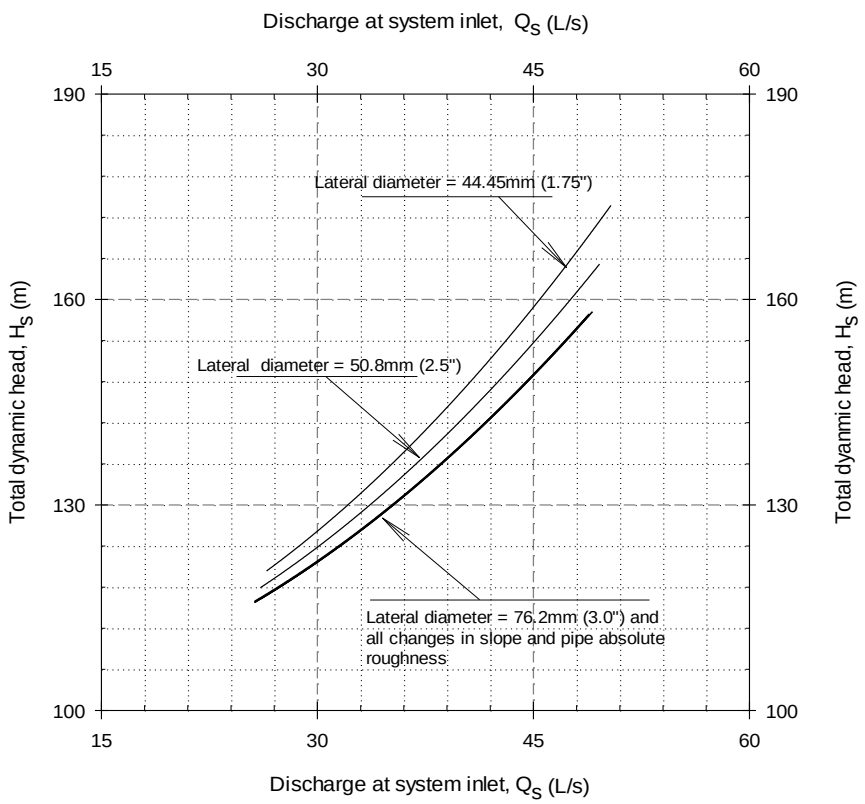


Figure 11 Sprinkler system hydraulic characteristics

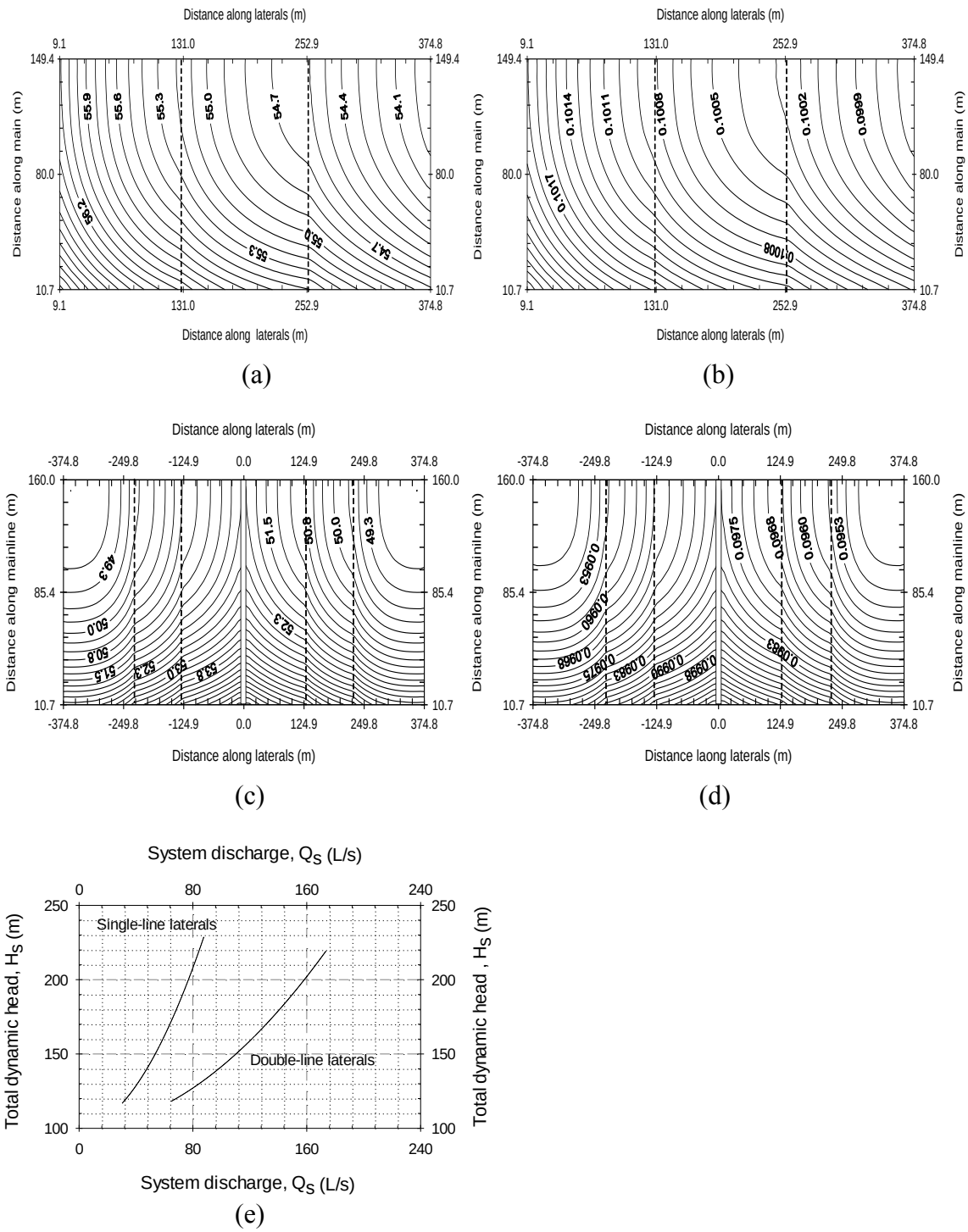


Figure 12 Hydraulic simulation example: (a) Sprinkler pressure head distribution (single-line laterals with variable slope), (b) Sprinkler discharge distribution (single-line laterals with variable slope), (c) Sprinkler pressure head distribution (double-line laterals with variable diameter), (d) Sprinkler discharge distribution (double-line laterals with variable diameter), and (e) System hydraulic characteristics for both single-line and double line laterals