ALARC Highlights

Summer 2017

What's happening at the USDA-Agricultural Research Service, Arid-Land Agricultural Research Center in Maricopa, Arizona?

In this issue

Featured Accomplishment

Supporting global collaborations to strengthen crop modeling

Use of computer models to study and predict crop growth and yield has seen rapid expansion in recent years. Applications range from guiding research strategy and policy decisions to assisting producers with in-season crop management. Drawing on relations established from field and laboratory research, the models quantify processes affecting crop growth and development with the goal of estimating yield, net growth and changes in the soil environment.

As with any predictive model, questions arise concerning model accuracy and appropriate model use. Scientists at the Arid-Land Agricultural Research Center (ALARC) in Maricopa, AZ have long sought to strengthen crop models and to ensure that these tools are used appropriately. The global Agricultural Modeling Intercomparison and Improvement Project (AgMIP, www.agmip.org) was recognized as a key partner for improving crop models and their applications, especially as related to climate uncertainty. Through AgMIP, we collaborate with scientists not only in the US but in Canada, France, Germany, Italy, the Netherlands, the United Kingdom, China, India, Australia, Mexico and elsewhere. Sharing data and modeling approaches enables us to jointly advance our work more rapidly and to ensure that our research outputs are as robust as possible.

ALARC's global collaboration to strengthen crop modeling involves three main activities:

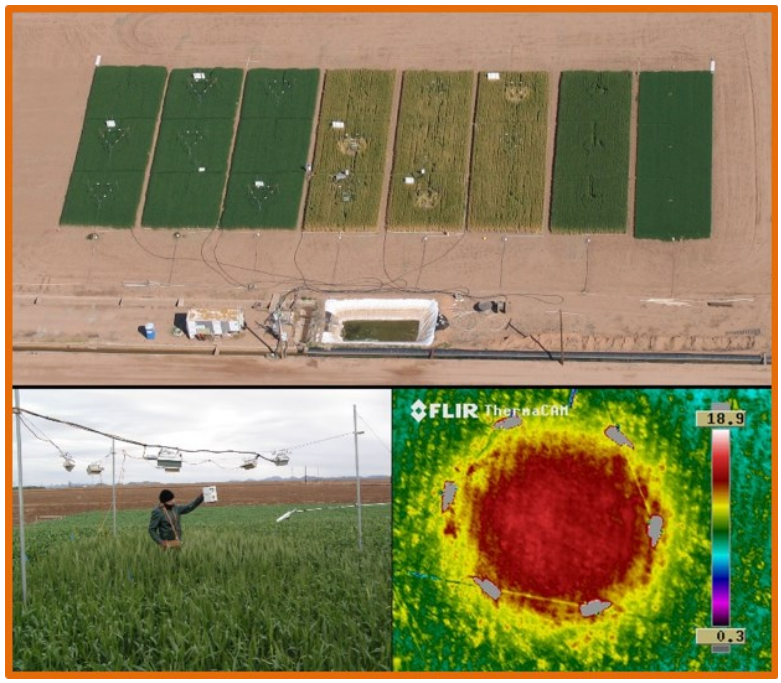
1. Direct participation in model intercomparisons
2. Improving the science of widely used models
3. Supporting improved data management

1. **Participating in model intercomparisons**

Providing high quality datasets for model intercomparisons: Comparisons of individual models are vastly more informative when related to real world results from field experiments. ALARC has provided three datasets to the AgMIP wheat modeling team:

- Hot Serial Cereal (see Figure 1): Monitored changes in spring wheat growth and yield for a range of air temperatures considerably wider than experienced in commercial production.
- FACE Wheat: Compared growth and yield of spring wheat under ambient and elevated atmospheric CO_2, as well as interacting effects of water or nitrogen.
- China Wheat: Compared growth and yield of winter wheat at five locations from Texas to Canada, providing four levels of nitrogen inputs and three levels of water. [Conducted from 1984 to 1986, this trial was coordinated by one of our predecessor laboratories, the US Water Conservation Laboratory, but was executed by researchers at other ARS and university locations.]

Figure 1. *Three images from the Hot Serial Cereal experiment conducted in Maricopa from 2007 to 2009. The top frame is an aerial view when four planting dates were in the field, including two with the infrared heating treatments. The lower left shows a single heated plot, where an effect on wheat heading is seen, and the lower right shows the temperature "footprint" from the heating system over a single plot.*



These datasets are prized by modelers not only for their detail and quality of information on crop responses but because they contain sufficient information on crop management and environmental conditions to allow simulations to be run with a minimum of guess work in defining the growth conditions.

Conducting simulations as part of model intercomparisons: An ALARC scientist collaborating with a retired researcher at the Univ. of Guelph (Canada) simulated spring wheat performance at four locations and for a series of temperature scenarios. AgMIP collaborators combined our results with simulations from 26 other models to examine how uncertainty was affected by differences in models vs. differences in sources of climate data (Asseng et al., 2013). Differences among models had a large effect on outcomes than did the different global circulation models used to create scenarios for future climates, thus highlighting the need for examining the different assumptions used by models.

Coordinating specific AgMIP intercomparisons: A retired ALARC scientist leads ongoing evaluations of modeled estimates of water use (evapotranspiration or "ET") for an Iowa maize crop. Results to date show larger than expected differences among models and have highlighted the importance of pre-plant soil moisture in determining crop performance.

Participating in analyses of results from intercomparisons: A potentially large source of error in simulations, especially in drier regions, arises from whether a given model assumes that air temperature (T_{air}) controls plant responses or whether the modeling the temperature of the canopy (T_{can}) results in more accurate simulations. Scientists at ALARC are currently assisting researchers at the University of Bonn and elsewhere in analyzing simulations of T_{can} for the FACE Wheat and China Wheat datasets.

2. Improving the science in widely used models

In a comparison of nine wheat models and using data from the Hot Serial Cereal experiment, considering variation in T_{can} improved simulation of heat stress as compared to simply using T_{air} (Webber et al., 2015). Thus, a first step to improve simulation of heat stress is to ensure that T_{can} is considered.

In the same study, the most accurate estimates of T_{can} were obtained from models that calculated the energy balance of the crop and considered effects of stability conditions of the atmosphere over the crop (relating to the vertical movements of air and hence affecting transfers of energy above and within a crop). Of models that use a strictly empirical approach to estimate T_{can}, calculate an energy balance but assume neutral stability, or calculate an energy balance with a stability correction, the latter class of models showed the highest predictive power (Fig. 2), here judged by the difference between canopy and air temperatures (ΔT).

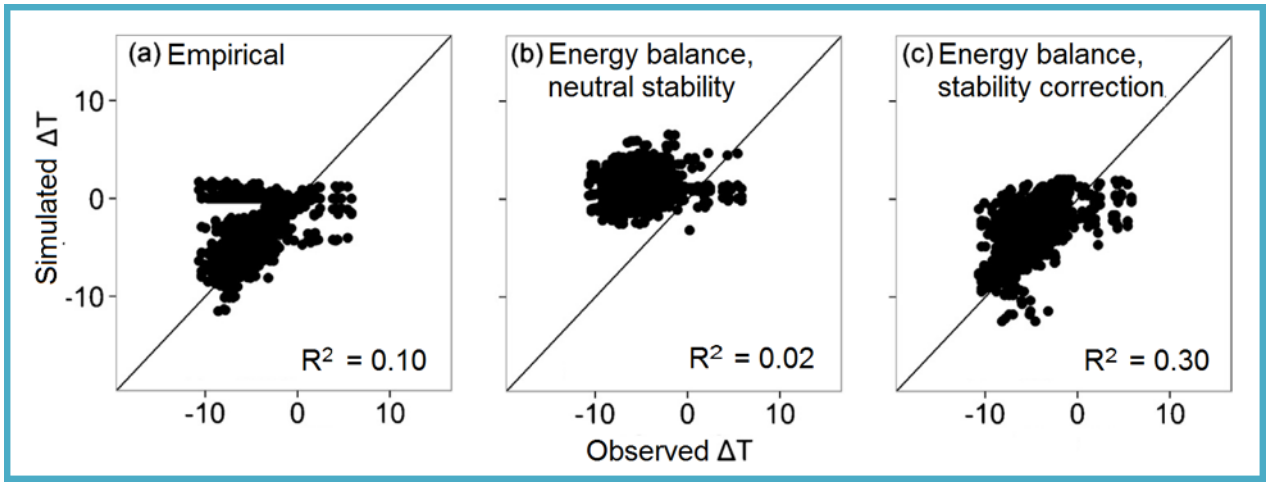


Figure 3. *Comparisons of simulated vs. observed ΔT, the difference between canopy and air temperature, for nine models using data from the Hot Serial Cereal experiment. A. Empirical models. B. Models with energy balance but assume neutral stability. C. Models with energy balance that considers atmospheric stability. Redrawn from Webber et al. (2015).*

3. **Supporting improved data management**

Too often, a large gap exists between the potential value of data from field experiments and the value obtained through use of those data. Data from a given experiment are used for a planned objective, but the data see no further use. Much greater value is obtained when datasets are combined across locations, time, and management conditions, allowing for development or evaluation of models or for conducting broader analyses ("meta-analyses") that examine how results may vary under different environments, management practices or other factors.

As part of the AgMIP IT Team, an ALARC scientist helps maintain the dictionary of terms that AgMIP uses to harmonize data across different field experiments and crop modeling groups (Porter et al., 2012). The dictionary includes a hierarchical classification of data types that has evolved over more than 30 years of crop modeling experience and is described as part of the ICASA data standards (Hunt et al., 2001; White et al., 2013). We continue to develop the dictionary and ICASA standards as new types of data are reported and models evolve to require more detailed inputs, especially with respect to data recorded at hourly or shorter intervals.

References relating to ALARC's efforts in model intercomparisons and improvement

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(Contact: Jeffrey.White@ars.usda.gov)

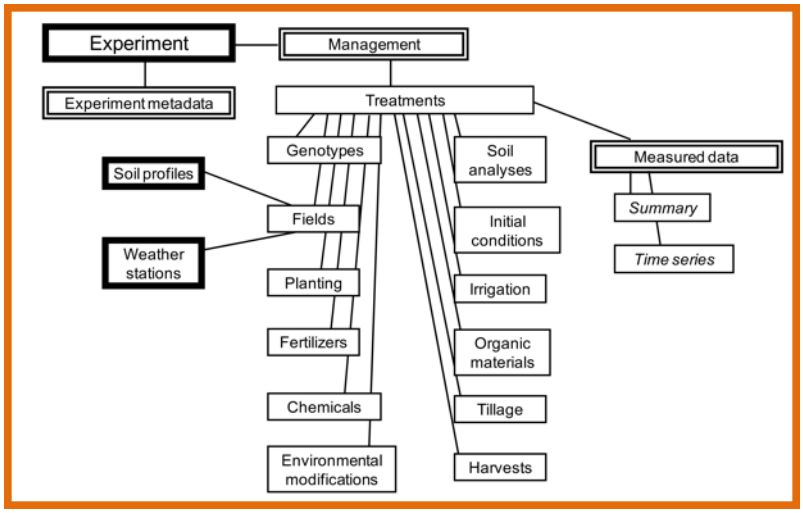


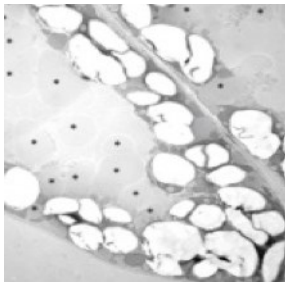
Figure 3. *Simplified diagram showing how data describing an experiment are assigned to hierarchical categories of the ICASA data standards. The system is used by AgMIP in organizing data from field experiments that are used in model comparisons (Porter et al., 2014).*

Other Accomplishments

"Blind" test of twenty-four maize growth models reveals huge range of water use predictions. To simulate the growth of maize now and in the future, growth models must be able to predict water use rates to account for how many days of growth can occur following a rain or irrigation event. As part of the Agricultural Model Inter-comparison and Improvement Project (AgMIP), an inter-comparison test was organized using eight years of water use (evapotranspiration, ET) measurements collected by an ARS scientist in Iowa. An ALARC collaborator compiled initial "blind" (blind because the modelers received no prior growth or water use information) ET predictions of 24 models from 16 research groups around the world (including ARS Maricopa, and Beltsville, Maryland). Water used varied by almost a factor of 4 and differed from measured water use. Research should contribute to improvements in crop models and ultimately in estimations of crop water use for improved management and policy decisions by stakeholders ranging from producers to national leaders. (Bruce.Kimball@ars.usda.gov)

Characterization of the genetic diversity in *Brassica napus*, a valuable oilseed crop used for food, feed, and biofuel purposes. To expand the resources available for breeding of *B. napus,* ARS scientists in Maricopa, Peoria, Illinois, Morris, Minnesota, Sidney, Montana, Mandan, North Dakota, Temple, Texas, Ames, Iowa, Akron, Colorado, Pendleton, Oregon, and scientists from Idaho State Univ. and Cornell Univ., collaborated to collect and genetically characterize a global population of *B. napus* plants. Eight hundred *Brassica* lines were genotyped by sequencing. Comparison of DNA sequences revealed three distinct and diverse groups distinguished by growth habit and geographical origin including spring, winter-European and winter-Asian subgroups. Each subgroup had a different historical evolutionary path, which was also reflected in the traits and genes that each subgroup possessed. This work provides insight to the diversity of plants available within the *B. napus* population and also provides genetic markers that can be used to identify genes and genomic regions that are associated with traits of interest. This work will be of greatest interest to those scientists improving the agronomic performance of *B. napus* using genome-assisted techniques. (John.Dyer@ars.usda.gov)

New roles for lipid droplets in carbon/energy balance and stress response in plants. Lipid droplets are subcellular organelles that store oil, and in oilseeds, they accumulate to high levels for the storage of triacylglycerols (carbon and energy reserve for germinating seedlings). Lipid droplets are also present in vegetative cell types, where their roles are less understood. ALARC scientists collaborated with scientists at the University of Guelph, Canada, and the University of North Texas to characterize a group of proteins called Lipid Droplet-Associated Proteins, or LDAPs, that are abundant proteins that coat the surface of non-seed lipid droplets. Studies revealed that LDAPs were required for regular changes in lipid droplet abundance throughout the day/night cycle, as well as rapid increases in lipid droplet abundance during heat and cold stress response. These and other findings reveal new and unexpected roles for lipid droplets in plant biology and will be of greatest interest to other scientists working to characterize the molecular mechanisms of carbon/energy balance and stress response in crop plants. Olga.Yurchenko@ars.usda.gov)



Accumulation of four pharmaceuticals in wheat irrigated with reclaimed municipal wastewater. Rising demands on fresh water has resulted in the need to increase water supplies by reuse of municipal effluent for irrigation. Pharmaceuticals are frequently found in effluent due to limited removal during wastewater treatment. An ALARC scientist, in collaboration with Penn State University, measured the uptake sulfamethoxazole, trimethoprim, ofloxacin and carbamazepine by wheat plants irrigated with reclaimed water. Residues of all compounds were found on plant surfaces with trimethoprim being found only on external surfaces. Ofloxacin had the highest average concentration (10.2 ng g^{-1}, straw; 2.28 ng g^{-1}, grain) with carbamazepine and sulfamethoxazole at much lower concentrations. Results will be used to safely increase water supplies by showing that drugs found in wastewater used for irrigation accumulate predominantly in the non-edible portions of wheat. (Clinton.Williams@ars.usda.gov)

Optimal nitrogen and irrigation inputs for high-yielding, high-protein durum wheat. Durum wheat is an important, high quality, high value row-crop from Arizona, that requires ample irrigation and nitrogen fertilizer inputs. ALARC scientists completed a two-year field study under an overhead-sprinkler irrigation system with ten levels of irrigation and five rates of nitrogen fertilizer with durum wheat. It was concluded and recommended that Arizona durum wheat growers should apply 200 kg nitrogen fertilizer/ha and maintain soil moisture depletion below 45 %. This practice will help ensure, high yields, high grain protein, low yellow berry incidence and maximum profits for producers. (Kevin.Bronson@ars.usda.gov)

New mode of action for Bacillus thuringiensis (Bt) toxins discovered. Resistance to Bt transgenic crops is increasing globally, threatening the benefits of these effective and environmentally-friendly crops. An ALARC scientist collaborating with a team of university collaborators discovered a new model of Bt intoxication (the "dual" model) in which Bt protoxins and activated toxins kill insects via different pathways. The research demonstrated that protoxins killed some Bt resistant insects better than the corresponding activated toxins. This suggests that a previously unknown mode of action for Bt toxins exists and that there may be utility in using protoxins in transgenic Bt crops to enhance and/or sustain their efficacy. (Jeff.Fabrick@ars.usda.gov)

Novel method for identifying predators in agroecosystems. Arthropod predators provide valuable ecosystem services in agriculture settings, however, identifying the predators of pests by direct observation is difficult because arthropods are small and elusive. The most popular indirect method to assess predation is by examination of a predator's stomach contents for the presence of prey-specific DNA, but these assays are complex, expensive, and labor intensive. An ALARC scientist developed an alternative approach that uses generic immunological assays designed to detect unique protein marks applied to the prey and subsequently transferred to the predator during feeding. The generic assay was more sensitive and reproducible than the DNA assay for detecting predation while being less expensive and time consuming. The generic gut assay procedure has been adopted by researchers throughout the world to study various aspects of predation. Using this method to pinpoint the main predators in an agroecosystem setting will lead to better conservation biological control practices. (James.Hagler@ars.usda.gov)

Long-term dynamics of insect parasitoids attacking sweetpotato whitefly. Sweetpotato whiteflies are a pest of global significance and negatively impact many field and horticultural crops. Whiteflies are attacked by a broad range of natural enemies, including insect parasitoids. An ALARC scientist conducted a long-term 15-year study to examine interactions between sweetpotato whitefly and several parasitoid species that specialize on whiteflies. This time period coincided with a USDA led program to introduce exotic parasitoid species for biological control of sweetpotato whitefly. Introductions dramatically changed parasitoid species composition in the cotton system by replacing three native species with two exotic species. However, the introductions have not contributed to increased biological control of the pest in Arizona cotton. Results are of interest to scientists studying introductory biological control and pest management and should help to inform future large-scale biological control programs. (Steve.Naranjo@ars.usda.gov)

Field validation of insecticide efficacies against Cucurbit Yellow Stunting Disorder Virus (CYSDV) in cantaloupes. Cantaloupe production in the southwestern U.S. has been severely impacted by epidemics of CYSDV since 2006 when it was first detected in Arizona. Infection causes yield reduction and poor fruit quality, especially when plants are infected early in their development. Through greenhouse studies an ALARC scientist demonstrated the capacity of certain insecticides to prevent transmission of CYSDV to cantaloupe plants by viruliferous whiteflies. Follow-up field studies on cantaloupes showed that under heavy whitefly pressure two of the five systemic insecticides significantly reduced the number and rate of plant infections. These findings will provide critical guidance to growers and pest consultants seeking to both reduce and delay the incidence of CYSDV in cantaloupe fields. (Steven.Castle@ars.usda.gov)

Recent Professional Awards and Recognition

Mike Roybal was named a winner in the 2016 Federal Customer Service Award Program. The award recognizes the exceptional effort of Federal employees in providing customer service in the federal sector. Mike has been providing excellent IT support at ALARC since 2010 and also has recently provided exceptional IT service to ARS locations in Corvallis and Burns, OR. Mike was recognized by the REE Under Secretary at the REE Mission Area Merit Awards ceremony that took place in September, 2016

Dr. Jeff White was elected Fellow of the Crop Science Society of America in 2016. The designation of Fellow recognizes significant contributions to science and agriculture. He is internationally recognized as an authority on simulating crop response to environment with emphasis on representation of genetic mechanisms of adaptation. His research interests also include model evaluation, data management, and field phenomics. Jeff was recognized during the 2016 Annual Meeting of the Society in Phoenix, AZ.

Dr. Eduardo Bautista is the 2017 recipient of the Award for the Advancement of Surface Irrigation for his contributions to the development of scientific concepts and technologies for modeling surface irrigation systems. He has advanced surface irrigation through his research on hydraulic modeling of surface irrigation systems, software development, publications, and outreach. Eduardo will be recognized in July at the 2017 American Society of Agricultural and Biological Engineers Annual Meeting in Spokane, Washington.

ALARC was recognized by Central Arizona College for their dedicated commitment to mentoring high school and undergraduate students, and inspiring them to pursue careers in STEM related disciplines as part of Project Puente (Bridge).

Current Grant Awards (*new)

*Sustainable Bioeconomy for Arid Regions, USDA-NIFA (PI Kimberly Ogden, Co-PIs Dennis Ray, Peter Waller, Raina Maier, Istvan Molnar, Meghan Downes, William McCloskey, Trent Teegerstrom, Omololu Idowu, Paul Gutierrez, Kulbhushan Grover, F. Omar Holguin, Catherine Brewer, Sangamesh Angadi, **Hussein Abdel-Haleem**, Colleen McMahan, David Dierig, Amy Landis, Jason Quinn, Xianglan Bai, Karl Seck) 2017-2022

*Root Genetics in the Field to Promote Drought Adaptation and Carbon Sequestration, Dept. Energy, ARPA-e Program (PI John McKay, Parker Antin, Randy Bartels, Thomas Borch, Pedro Andrade Sanchez, Francesca Cotrufo, **Andrew French**, Michael Ottman, Sangmi Palickara, Keith Paustian, Patrick Schnable, Chris Topp, Chris Turner, Matthew Wallenstein, Jianming Yu) 2017-2020.

*Eco-hydrological Modeling Using Field-based and Earth Observations to Assess H_2O Use Efficiency and Support Agricultural Water Resources Management, NASA (PI Pierre Guillevic, CO-PIs Inbal Becker-Reshef, Alissa Coffin, Jan Dempewolf, **Andy French**, Jerry Hatfield, Matthew Hansen, Roberto Cesar Izaurrlade, Jaehak Jeong, Catheriine Nakalembe, Brian Thomas, Eric Vermote) 2017-2018

*Quantitative Assessments of Water and Salt Balance for Cropping Systems in Lower Colorado River Irrigation Districts, Dept. Interior, Bureau of Reclamation (PI **Andy French**, CO-PIs Charles Sanchez, Paul Brown, Dawit Zerihun, **Eduardo Bautista, Clinton Williams**) 2016-2019

*Monitoring Evapotranspiration, Crop Growth and Nutrient Stress over Irrigated Crops in Central Arizona, NASA (PI **Andrew French**, Co-I **Kevin Bronson, Kelly Thorp**, Pedro Andrade-Sanchez) 2017-2020

*High-Throughput Phenotyping Using Portable LIDAR, Cotton Incorporated (PI **Andy French** with Co-PIs Michael Gore, Alison Thompson) 2017

*Genomics and Phenomics to Identify Yield and Drought Tolerance Alleles for Improvement of Camelina as a Biofuel Crop, USDA-NIFA. (PI **John Dyer**, Co-PIs **Hussein Abdel-Haleem**, Daniel Schachtman, Yufeng Ge, Toni Kutchan, Noah Fahlgren) 2016-2019

*Characterization of *Lygus hesperus* Salivary Gland Nucleases – Inhibiting the Inhibitors of RNAi, Cotton Incorporated (PIs **Colin Brent Joe Hull, Jeff Fabrick**) 2017.

*Targeting Water Homeostasis in Hemipteran Pests Using Novel Botanical Extracts, Bayer CropScience (PI **Jeff Fabrick**) 2016-2017

*Field Scale Movement of Pest & Beneficial Insets in Arizona Cotton, Arizona Cotton Growers Association (PI Ayman Mostafa, Co-PIs, Peter Ellsworth, **James Hagler, Steve Naranjo**) 2017

*Applying Proximal Sensing to Enhance Upland Cotton Yield Trials, Cotton Incorporated (PI **Alison Thompson**) 2017

*Improving Nitrogen Fertilizer Management in Subsurface Drip-Irrigated Cotton, International Plant Nutrition Institute (PI **Kevin Bronson**) 2017

*Evaluation of the Cotton2K model for Arizona cotton production systems, Cotton Incorporated (PI **Kelly Thorp**) 2017.

Energy Sorghum Reference Phenotyping System, DOE-ARPA-E (PI Todd Mockler, CO-PIs Noah Fahlgren, Erica Fishel, Stephen Kresovich, Jeremy Schmutrz, Jesse Poland, Geoff Morris, William Rooney, Pedro Andrade, Mike Ottman, **Jeff White**, David LeBauer, Robert Pless, Roman Garnett) 2015-2019

Elucidating the Cellular Machinery for Lipid Storage in Plants, DOE-BES (PI Kent Chapman, CO-PIs **John Dyer**, Robert Mullen) 2016-2019

Prospective Resistance Management: Empowering Growers to Understand and Exploit Refugia (PI Peter Ellsworth, Co-PIs **Steve Castle**, Nilima Prabhaker, Yves Carrière, John Palumbo, Al Fournier, Wayne Dixon, Lydia Brown) 2015-2017

Selecting and Using Bt-Resistant Strains of Two Key Pests to Understand Resistance and Characterize Responses to Novel Toxins, CRADA Pioneer Hi-Bred International (PI **Jeff Fabrick**) 2013-2018.

Accelerated Development of Commercial Hydrotreated Renewable Jet (HRJ) Fuel from Redesigned Oil Seed Feedstock Supply Chains, USDA-NIFA/DOE Biomass Research and Development Initiative (PI T. Isbell, Co-PIs **John Dyer,** Mike Gore, D. Long, D. Archer, S. Frey, D. Galloway, T. Tomlinson) 2012-2017.

Securing the Future of Natural Rubber – An American Tire and Bio-energy Platform from Guayule, USDA-NIFA/DOE Biomass Research and Development Initiative (PI H. Colvin, Co-PIs Mike Gore, C. McMahan, **John Dyer**, A. Halog, J. Mitchell, P. Zorner, Collaborator**, Doug Hunsaker**) 2012-2016.

Impact of Bioenergy Crops on Pests, Natural Enemies and Pollinators in Agricultural and Non-Crop Landscapes, USDA-NIFA-AFRI (Co-PI **James Hagler** with T. Kring and R. Weidenman, University of Arkansas; B. McCornack, Kansas State University; K. Giles, Oklahoma State University) 2011-2017

ALARC IN THE NEWS

US and UK Scientist Network on High Throughput Phenomics. Scientists from ALARC, University of Arizona, Maricopa and several British universities meet in Maricopa to network and share knowledge on the growing field of phenomics. [Link]

World's Largest Field Scanner. Maricopa, Arizona is now home to the largest phenotyping robot on the planet. The device uses multiple state-of-the-art sensors to remotely assess the structure and health of crop plants as an avenue to more rapid crop improvement. The scanner is currently being used to accelerate plant breeding for energy sorghum and wheat. [Link]

Saving Water, Fertilizer in Arizona Wheat. Scientists at ALARC are conducting research to develop guidelines to help Arizona wheat growers optimize irrigation and fertilization activities [Link]

Improving Flood Irrigation Systems. ALARC scientists participated in a meeting with research, extension and industry representatives to discuss ways to improve the efficiency of flood irrigation systems, the main approach to irrigation in the west [Link]


World's largest field scanner

Drip Irrigation for Cotton. An ALARC scientist talks about the advantages of drip irrigation for optimizing water use in cotton production [Link]

Uptake of Antibiotics by Crops. An ALARC scientists is working with colleagues at Penn State University to measure the uptake of commonly used antibiotics by wheat. [Link]

EMPLOYEE ENGAGEMENT

ALARC held its Annual Thanksgiving Potluck**.** This is a yearly tradition at the center, which brings together current, former, and retired employees, as well as family and friends. Everyone enjoyed wonderful food while catching up with friends and colleagues.

Andy French is the Center's representative on the **PWA Employee Engagement Committee**. The goal of the committee is to report engagement activities that can be featured on AXON, ARS' intranet, and to generate and share employee engagement ideas that could potentially be implemented at the Location, Area or even Agency level.

ALARC held its 2nd Annual **Safety Poster Contest** as a fun way to highlight the importance of safety in the workplace. Employees voted to determine the winners. All the posters are hanging in the laboratory building.

Special thanks *to Brenda Singleton for organizing the poster contest and Mike Roybal for printing the posters.*


1st Place – Colin Brent


2nd Place – Sarah Casey

2nd Place – Sharette Rockholt


3rd Place – Dan Langhorst


ALARC's phenotyping tractor


Big-eyed bug feeding on whiteflies


ALARC's linear-move

Recent Events and Outreach

July 2016, Project Puente students completed their summer internships and presented the research they were involved with during a poster session at ALARC. The students created amazing and informative posters showcasing the research they were involved with. There were 110 in attendance for this event. During the poster session, students, ALARC employees, and MAC employees enjoyed pizza and discussions with the students.

August 2016, ALARC hosted a visit by Ms. Blanca Varela, the Deputy District Director for Congresswoman Ann Kirkpatrick (Arizona, District 1). The Center Director and Research Leaders provided a tour of the facility and discussed current research projects in all three units.

September 2016, ALARC hosted visits by Mr. Mark Killian, Director of the Arizona Department of Agriculture and members of his staff. The Center Director and Research Leaders provided a tour of the facility and discussed current research projects in all three units.

October 2016, Andy French and other scientist from the Water Management and Conservation Research Unit participated in a Drone flight demonstration. The flight collected multispectral images over sorghum and cotton fields at the University of Arizona-Maricopa Agricultural Center (MAC). The sorghum trials are part of the TERRAref project (scientists from ALARC, the University of Arizona, and DOE and industry representatives). The cotton trials are led by Kelly Thorp and are for examining timing and amount of irrigation towards the goal of conserving water. Alison Thompson in the Plant Physiology & Genetics Research Unit led trials to measure performance of cotton relative to variety and planting date. Rick Ward at MAC has been sponsoring the flights with Phoenix Drone Service and Andy French has been working closely with Rick and Maria Newcomb to test the accuracy, repeatability, and information content in the multispectral cameras for phenomics and precision agriculture.

November 2016, scientist from the Plant Physiology and Genetics Unit and the Water Management and Conservation Unit attended and presented at the Tri-Societies (Soil Science Society, Agronomy Society and Crop Science Society) meeting held in Phoenix, AZ. Scientists from ALARC conducted tours of on-going research in linear move and drip irrigation technology, and in high throughput phenotyping. Attendees included university scientist and students, and scientists from other federal agencies and industry.

November, 2016, ALARC hosted National Program Leaders Drs. Roy Scott, Maureen Whalen and Jack Okamuro. They had an opportunity to tour laboratories and meet with scientists and technicians in the Pest Management and Biocontrol Unit and the Plant Physiology and Genetics Unit.

December 2016, Students and faculty from the University of Chapingo, Mexico, made their annual visit to ALARC. The group consisted of 89 undergraduate Irrigation Engineering students and 4 faculty members. ALARC scientists Eduardo Bautista and Kelly Thorp, and Dr. Pedro Andrade (University of Arizona) discussed ongoing research at ALARC and MAC in the areas of irrigation modeling, irrigation management, and remote sensing in irrigated agriculture. The group toured a Linear Move Sprinkler Irrigation system and Field Scanner. The visit was coordinated with the Agricultural and Biosystems Engineering Department at the University of Arizona.

February 2017, ALARC held their annual Farm Science Day as part of the AZ SciTech Festival. This event brought in people from the Maricopa, Casa Grande and the Phoenix metro area to learn about agriculture and the science behind agriculture. Activities included an interactive insect zoo, cotton

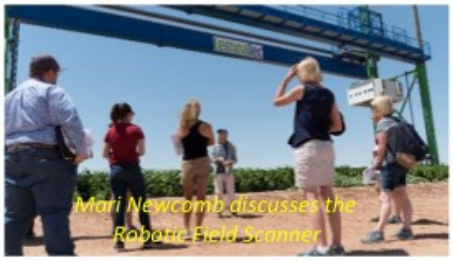
101, auto-steer tractor-ride along, field scanner, photosynthesis, natural rubber from guayule, remote sensing, drones, hayrides, cricket spitting, face painting, and lots more. We were joined by AZ Farm Bureau, Phoenix Drones, Future Farmers of America, CALS Ambassadors, and Wild at Heart. The event was a success even with inclement weather throughout the day. The event was attended by about 500 people.

November 2016, April, 2017, ALARC held Stakeholder Group semi-annual meetings in 2016 and 2017. Stakeholders learned about the research going on at ALARC from research leaders and individual scientist on topics ranging from molecular biology of insects and plants to remote sensing of crop fields to enhance productivity and crop improvement. Importantly, the meetings also provide our stakeholders a venue to offer ideas and suggestions on the research direction. This meeting helps maintain a strong relationship among scientists and stakeholders at the local, regional, and national level. Members represent growers, industry, university and state and federal agency interests.

May 2017, the ALARC Equal Employment Opportunity (EEO) committee hosted an event to observe Asian American Pacific Islander Heritage Month. The event showcased "*Golden Rice and the Filipino Farmer*." Three short videos were played to learn about how Golden Rice is being received by farmers and the importance of rice to the Asian people. The videos portrayed the difficulty in making a living being a rice farmer.

June 2017, In partnership with Central Arizona College, 15 Project Puente high school students begin their internships with the ALARC working in all three research units. The program gives each student an opportunity to conduct their own research project while learning about lab safety, data entry, strategies for working in the field, and the importance of maintaining a good laboratory notebook. ALARC scientists have been actively involved in training and mentoring under-represented students since 2012.

June 2017, ALARC hosted the annual Summer Ag Institute visit (photo below). The SAI is a group of K-12 teachers, who embark on a week-long tour throughout Arizona. This adventure is designed to teach them about food and fiber production, so they can incorporate that knowledge in the classroom curriculum. This experience is a great opportunity for the teachers to see the vital role agriculture plays in rural communities and the importance of the research being conducted at our center. The group had the opportunity to tour various labs in our three research units, learning about plant breeding, genomics, molecular biology, pest management, and water conservation. They also toured Field Scanner and our Lateral Move Sprinkler Irrigation System. The tours were provided by scientist and technicians from all three units. The group always has a great time.



Recent Journal Publications

Entomology

Asiimwe, P., Ellsworth, P.C., **Naranjo, S.E.** 2016. Natural enemy impacts on *Bemisia tabaci* dominate plant quality effects in the cotton system. Ecological Entomology. 41:642-652. (PDF)

Blubaugh, C.K., **Hagler, J.R., Machtley, S.A.**, Kaplan, I. 2016. Cover crops increase foraging activity of omnivorous predators in seed patches and facilitate weed biological control. Agriculture, Ecosystems and Environment. 231:264-270. http://dx.doi.org/10.1016/j.agee.2016.06.045

Brent, C.S., Penick, C.A., Trobaugh, B., Liebig, J. 2016. Induction of a reproductive-specific cuticular hydrocarbon profile by a juvenile hormone analog in the termite *Zootermopsis nevadensis*. Chemoecology. 26(5): 195-203. (PDF)

Brent, C.S., **Wang, M.**, Miao, Y., **Hull, J.J.** 2016. Ecdysteroid and chitinase fluctuations in the western tarnished plant bug (*Lygus hesperus*) prior to molt indicate roles in development. Archives of Insect Biochemistry and Physiology. 91(5):108-126. (PDF)

Christie, A.E., **Hull, J.J.**, Richer, J.A., **Tassone, E.E.**, Geib, S.M. 2016. Prediction of a peptidome for the western tarnished plant bug *Lygus hesperus*. General and Comparative Endocrinology. 243:22-38. http://dx.doi.org/10.1016/j.ygcen.2016.10.008

Cui, J., Li, S., **Spurgeon, D.W.**, Jia, W., Lu, Y., Gouge, D. 2016. Flight capacity of *Sitophilus zeamais* Motschulsky in relation to gender and temperature. Southwestern Entomologist. 41:667-674. https://doi.org/10.3958/059.041.0309

Eisenring, M.A., Meissle, M., Hagenbucher, S., **Naranjo, S.E.**, Wettstein, F., Romeis, J. 2017. Cotton defense induction patterns under spatially, temporally and quantitatively varying herbivory levels. Frontiers in Plant Science. 8:234. doi: 10.3389/fpls.2017.00234

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Guo, Y.Y., Tian, J.C., Shi, W.P., Dong, X.H., Romeis, J., **Naranjo, S.E.**, Hellmich, R.L., Shelton, A.M. 2016. The interaction of two-spotted spider mites, *Tetranychus urticae* Koch, with Cry protein production and predation by *Amblyseius andersoni* (Chant) in Cry1Ac/Cry2Ab cotton and Cry1F maize. Transgenic Research 25:33-44. DOI: 10.1007/s11248-015-9917-1

Hagler, J.R. 2016. A false positive food chain error associated with a generic predator gut content ELISA. Entomologia Experimentalis et Applicata. 161(3):187-192. (PDF)

Hagler, J.R., Tassone, E.E., Coffelt, T., Lipka, A.E. 2016. Host plant preference of *Lygus hesperus* exposed to three desert-adapted industrial crops. Industrial Crops and Products. 89:363-367. (PDF)

Katayama, Y., Suzuki, T., Ebisawa, T., Ohtsuka, J., Wang, S., Natsume, R., Lo, Y., Senda, T., Nagamine, T., **Hull, J.J.**, Matsumoto, S., Nagasawa, H., Nagata, K., Tanokura, M. 2016. A class-A GPCR solubilized under high hydrostatic pressure retains its ligand binding ability. Biochimica et Biophysica Acta. 1858(9):2145–2151. DOI: 10.1016/j.bbamem.2016.06.012

LeBoeuf, A.C., Waridel, P., **Brent, C.S.**, Goncalves, A.N., Menin, L., Ortiz, D., Koto, A., Privman, E., Soares, Z.G., Miska, E.A., Benton, R., Keller, L. 2016. Oral transfer of chemical cues, growth proteins and hormones in social insects. eLife. 5:e20375. (PDF)

Li, J., Zhu, L., **Hull, J.J.**, Liang, S., Daniell, H., Jin, S., Zhang, X. 2016. Transcriptome analysis reveals a comprehensive insect resistance response mechanism in cotton to infestation by the phloem feeding insect *Bemisia tabaci* (whitefly). Plant Biotechnology Journal. 14:1956-1975. doi: 10.1111/pbi.12554

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Spurgeon, D.W., Brent, C.S. 2016. Development, survival and hatching periodicity of *Lygus hesperus* (Hemiptera: Miridae) eggs under constant and variable temperatures. Journal of Entomological Science. 51(4):292-304. (PDF)

Traynor, K.S., Wang, Y., **Brent, C.S.**, Amdam, G., Page, R.E. 2017. Young and old honey bee (*Apis mellifera*) larvae differentially prime the developmental maturation of their caregivers. Animal Behaviour. 124(1):193-202. https://doi.org/10.1016/j.anbehav.2016.12.019

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