ALARC Highlights

Summer 2021

USDA-Agricultural Research Service
Arid-Land Agricultural Research Center
Maricopa, Arizona

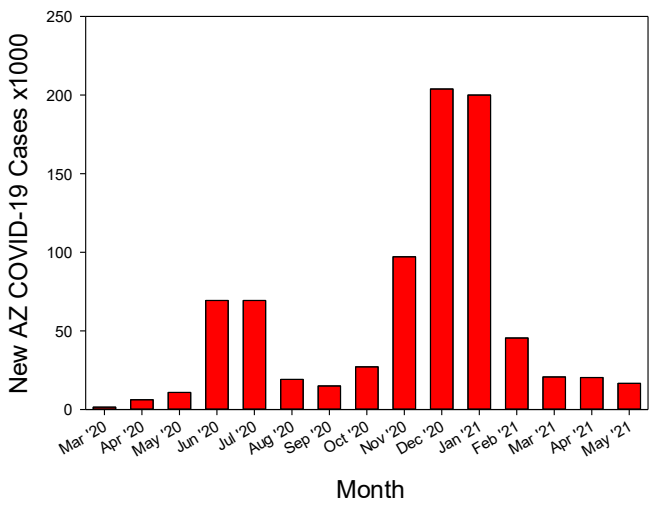
ALARC's mission is to develop sustainable agricultural systems, protect natural resources, and support rural communities in arid and semi-arid regions through interdisciplinary research.

IN THIS ISSUE

ALARC Pandemic Response

At this time last year, the United States was already months into a lockdown posture in response to the surging COVID-19 pandemic. USDA employees followed safety directives from local, state, and federal governments intended to minimize the risk to employees as the virus swept across the world. A year later and we are seeing some definite signs of recovery: new cases and deaths are down dramatically, hospitals are no longer overwhelmed, and more than a third of the Arizona population has been fully vaccinated. However, there is no doubt as to the severe impact wrought by this disease. Our daily lives have been disrupted on a scale and duration none of us could have imagined before this began. While ALARC has been fortunate in not having lost any staff members to the pandemic, a number of our personnel have been sick or had to provide care for ailing family members. Most troubling, numerous staff have lost family and friends.

It should not be surprising that research at ALARC has also suffered during this period. Our initial response was to restrict facility access to only those personnel needed to ensure the survival of living organisms and to maintain the function and security of the buildings. Everyone else became intimately acquainted with teleworking. With time and a better understanding of how to manage COVID, onsite work has gradually resumed. Field research is in full swing and we have reopened our laboratories to a limited extent using social distancing, staggered schedules, masks and other sanitary practices. As vaccinations climb and infections ebb, we look forward to becoming fully operational and continuing to deliver scientific solutions to regional, national and global agricultural challenges.



Featured Accomplishment

Measuring Cottonseed Size: Finding A Simple Solution For A Big Problem

Cotton production in the United States (US) supports a multi-billion-dollar industry that reaches far beyond textile and fabric production. Most consumers do not realize that cotton is in fact two crops, fiber and seed. Cottonseed (Figure 1) is primarily used by the cattle industry as a feed source, with more than 50% of the annual supply going towards dairy cattle consumption. Approximately 5% of cottonseed is used to plant the next years' crop and the remaining seed is crushed for oil. Cottonseed oil is used in the food industry for cooking, and small quantities of oil are used in pharmaceuticals and cosmetics among other products.

While cottonseed is considered an important by-product of cotton production, it has largely been ignored by cotton breeders and producers over the last 20 years. However, in 2018 the National Cotton Council urged breeders to begin using a "seed index", an estimate of seed size, as a selection criterion when developing new cotton varieties and germplasm. The reason for the request was two-fold; first, producers were noticing poor seed germination and stand establishment in the field from bags containing smaller seed; second, small cottonseed contamination was found in ginned fiber exported for textile production and lowered the US price per bale of cotton.

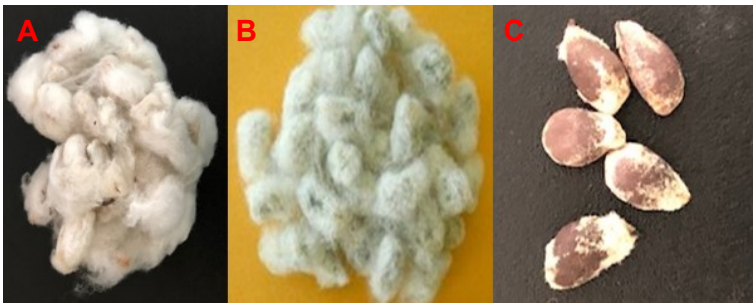


Figure 1. After the cotton is picked from the field (A) cottonseed must go through two stages of processing. The first stage is ginning, which separates most of the fiber from the seed leaving behind a fuzzy seed (B). The second stage is delinting, which removes any remaining fiber (C) and leaves the seed ready for meal production.

The request by the National Cotton Council prompted University breeding programs to conduct several studies examining cottonseed size in their breeding stock inventory. Many found that seed size had been reduced over the years but quickly pointed out "seed index" is a time-consuming trait to measure and is prone to human error which makes it unreliable for breeding. Studies also found that "seed index" might not be the best trait to use as it was consistently negatively associated with fiber yield. To help the cotton community breed for larger cottonseed and maintain fiber yields, a new phenotyping method was needed.

Cotton Fuzzy Seed Imaging

The priority of the cotton fuzzy seed imaging project was to quickly develop a solution for breeders focused on the seed size problem. Therefore, inexpensive off-the-shelf imaging equipment was utilized (Figure 2), and custom open-source processing software was developed. Image analysis of the fuzzy seed was undertaken with funding provided by Cotton Incorporated, and twenty-four cotton germplasm lines provided by eight public breeding programs. Image analysis was conducted on fuzzy seed rather than delinted seed for two reasons. First, delinting is a time-consuming and expensive process that breeders want to avoid when possible. Second, improper delinting can damage seeds affecting estimates of their area. While using fuzzy seed eliminates the extra time, expense, and potential damage to seed, it also creates some challenges for capturing "true" seed size. The remaining lint (linters) on the seed has the potential to be incorporated into the size estimates. To avoid incorporating the linters, the developed software utilizes a dynamic threshold and a size and circularity range to identify the seed on the tray in the image (Figure 3). Appropriate size and circularity ranges were determined after measuring more than 5,000 seeds by hand with a micrometer. Once the seeds are identified, the program counts the total number on the tray and assigns each a unique identification number. It then measures circumference (perimeter), height, and width for each seed, calculates seed area, and outputs the collected information in an Excel file.

Figure 2. Low-cost, off-the-shelf equipment used for imaging cotton seed.

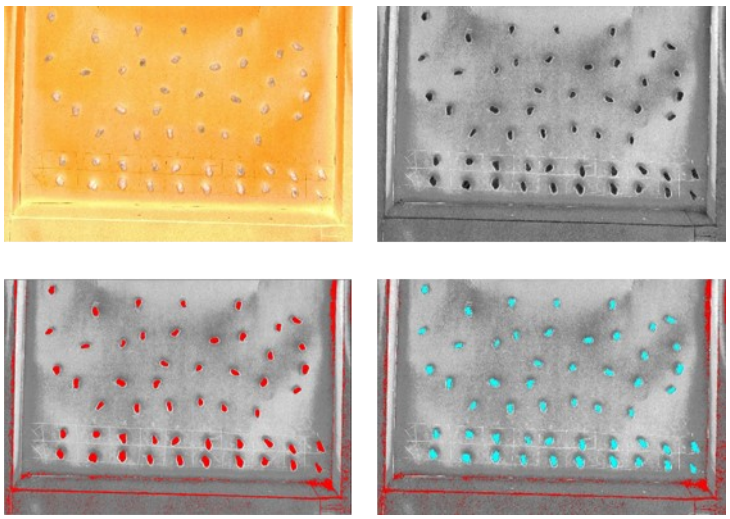


Figure 3. The image analysis workflow showing a scan of the tray with fuzzy seed (A), the saturation layer of the image (B), the dynamic pixel thresholding (C), and the particle (seed) identification (D).

Analysis of the test data showed that the outputs from the imaged seed were more consistent than the traditional "seed index" method and faster by ~1 minute for each sample. More importantly the image analysis enabled a new trait to be calculated, lint density, using the imaged seed area and the lint percentage provided by each cooperator. Lint density enables breeders to measure how many fibers are produced per given seed area (g/cm^2). With this information, breeders can select for germplasm based on lint-bearing surface potential, which will increase seed size without sacrificing fiber yield.

Seed size and germination

Another priority for the project was to determine if seed size has a significant effect on seed germination rates. If the traits are negatively associated, that could lead to poor stand establishment in the field. After imaging, the seeds were germinated under warm and cool conditions and the results compared to the imaged seed area and traditional seed index traits. The results from the twenty-four germplasm lines were mixed and could not provide a firm conclusion. However, results from a study of five commercial cultivars were much more conclusive. These cultivars were provided by Karen Geldmacher with Americot. The data indicate that imaged seed size (area) has a significant negative association with both warm and cool germination rates (Figure 4). As a result, Randy Norton (University of Arizona Extension) and Gaylon Morgan (Cotton Incorporated) are using the seed imaging method to conduct a nation-wide study on cotton seed size and stand establishment using cultivars provided by all the major US cotton seed companies.

Contact: Alison.Thompson@usda.gov

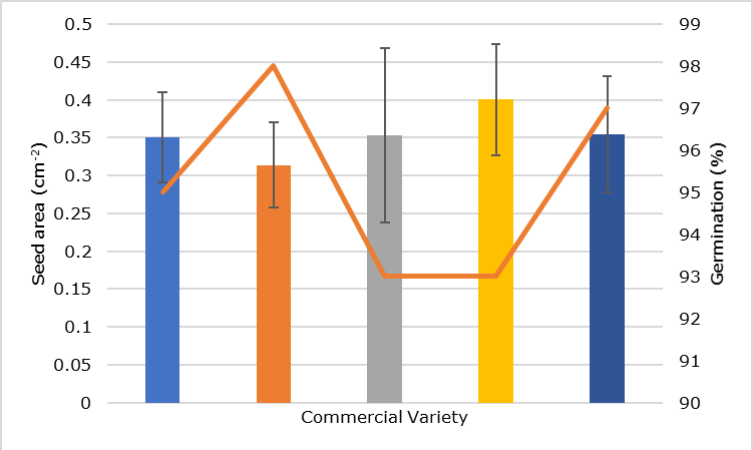


Figure 4. Average seed area (bars; ± standard deviation) of five commercial cotton varieties calculated by the imaging protocol and the percent germination (orange line).

Identifying genetic markers associated with seed size

To further aid breeding efforts to increase seed size, genetic markers associated with cotton seed size need to be identified. In collaboration with Duke Pauli (University of Arizona) and Vasu Kuraparthy (North Carolina State University), a genome wide association mapping panel is undergoing evaluation using the fuzzy cottonseed imaging method. The panel was grown in multiple years under well-watered and water-limited conditions, which will enable determination of environmental effects on seed size as well as identify genetic markers. Once genetic markers are identified, breeders can select germplasm lines with larger seed prior to growing them in the field. The use of genetic markers and the fuzzy seed imaging method will allow for the efficient and effective breeding of cotton seed to

Other Accomplishments

Identification of candidate genes controlling soybean canopy greenness. Nitrogen (N) plays a key role in plants because it is a major component of chlorophyll and dark and light reactions of photosynthesis. Genotypic variation in canopy greenness provides insights into the variation of N and chlorophyll concentration, photosynthesis rates, and N fixation in legumes. We collaborated with researchers from ARS in Colombia, Missouri and Stoneville, Mississippi and from universities of Arkansas and Missouri to map soybean canopy greenness using unmanned aerial imaging and dark green color index (DGCI) measurements. The study identified genomic regions associated with the intensity of greenness of the soybean' canopy, and genotypes with extreme DGCI values within the USDA soybean collection. Those genomic regions could be important resources for pyramiding favorable genes for improved N and chlorophyll concentrations photosynthesis rates, and N2 fixation ability in soybean breeding programs. **Contact:** Hussein.Abdel-Haleem@usda.gov

Identification of candidate genes controlling fatty acids profiles in rapeseed seeds. Finding environmentally responsible solutions to produce hydrotreated renewable fuels is an alternative path for carbon-based energy production. To meet market and user demands, current bioenergy feedstocks, such as rapeseed oil, must be optimized with respect to end-product composition and quality before these biofuels can be utilized for large-scale energy production. We collaborated with researchers from ARS in Peoria, Illinois, Morris, Minnesota, Sidney, Montana, Mandan, North Dakota, Temple, Texas, Ames, Iowa, Akron, Colorado, Pendleton, Oregon, and scientists from Idaho State University, University of Arizona and Cornell University, to identify candidate genes controlling rapeseed fatty acid synthesis. These candidate genes could serve as precise targets for genomics-assisted breeding to directly alter seed oil composition and quality to meet market criteria. The outcomes from this research provide information on how genomics can be leveraged to enhance the speed and effectiveness of rapeseed cultivar development for biofuel production. **Contact:** Hussein.Abdel-Haleem@usda.gov

Phenotyping of USDA guayule germplasm collection. Guayule, a plant native to semi-arid regions of Northern Mexico and Southern Texas deserts, is a potential domestic source of natural rubber. To date there is no research on phenotyping the global USDA guayule collection, including improved germplasm and wild accessions collected from natural habitats, and possibly using this collection in guayule genetic improvement programs. We explored the phenotypic diversity in traits related to rubber and resin production. The results summarized USDA guayule germplasm response and stability grown under different irrigation regimes. Water-stressed condition increased resin and rubber accumulation while well-watered condition increased dry weight biomass. This study lays the foundation for guayule breeding efforts to select parental candidates suitable for breeding programs to grow under different agricultural systems, to extend its growing areas into different geographical zones and to meet different end-user demands and goals. **Contact:** Hussein.Abdel-Haleem@usda.gov

High-throughput quantification of resin and rubber in guayule. Natural rubber (NR) is a critical industrial natural resource. However, the current production of NR, mainly harvested from Hevea rubber trees, is faced with many obstacles, including the shortage of supply due to increased demands, and the risks of fatal diseases in rubber-producing regions. Guayule is considered as a domestic source for NR in the U.S. semi-arid and arid regions and rapid screening tools are needed to identify guayule cultivars with high levels of rubber and resin. We have successfully adapted reliable high throughput prediction models for the determination of resin and rubber in guayule using near-Infrared spectroscopy. The established models might be useful to form a simple, low-cost and efficient pipeline to maximize the rubber/resin phenotyping efficiency in guayule. The established models will enable guayule breeders and researchers to efficiently screen large populations of genotypes at fairly short time compared to the wet chemistry protocols currently being used. **Contact:** Hussein.Abdel-Haleem@usda.gov

Development and testing of a portable HTP system. High throughput phenotyping (HTP) research is currently accomplished through numerous technologies. We developed and tested a low-cost wireless HTP system using a microcontroller (Arduino) and a single-board computer (Raspberry Pi) powered by a solar rechargeable battery for plant phenotypic metrics of vegetation index, canopy temperature, and height from a multispectral camera, an infrared (IR) thermometer, and mini LiDAR sensors, respectively. Use of this portable HTP system is of interest to plant breeding and phenotyping research with innovative features such as a portable plug-n-play feature providing quick mounting to outdoor ground\aerial platforms; easy adoption to indoor platforms such as vertical farms, growth chambers, and greenhouses; a wireless interface that allows end-users to remotely monitor and control the HTP system from smartphones or computers; and a self-powered feature offering simple cable-free installation. The HTP system was adopted for automated irrigation control and plant phenotyping in growth chambers, and enabled controlled water scheduling based on soil water condition and automated collection of phenotypic data months. This innovation will potentially enhance HTP research programs.

Fluctuations of CO2 in Free-Air CO2 Enrichment (FACE) depress plant photosynthesis, growth, and yield. Various techniques have been employed to provide a CO2 enrichment treatment to investigate plant responses. In collaboration with ARS researchers from Beltsville, Maryland, and Big Spring, Texas, and from the National Institute for Agro-Environmental Sciences, Tsukuba, Japan; and the University of Florida, Gainesville, Florida, we completed a review of the effects of fluctuating concentrations of CO2, such as exist in free-air CO2 enrichment plots, on plant growth and yield responses. It was concluded that it is likely that growth and yield responses in fluctuating CO2 are about 2/3 the size of the stimulations found using a corresponding steady CO2 enrichment. Therefore, even though FACE experiments are conducted under more natural open-field conditions than those using chambers, results likely have a bias, affecting projections of the likely effects of the increasing atmospheric CO2 concentration on future agricultural productivity. **Contact:** Gary.Wall@usda.gov

Sublethal insecticide effects on Bt soybean refuge strategy. High dose and deployment of a non-Bt (Bacillus thuringiensis) crop refuge are the key strategies for delaying resistance to the Bt proteins in target pests. However, insecticide sprays are often needed in the non-Bt refuge to manage the target and other pests. In collaboration with researchers at the University of Sao Paulo, Brazil we showed that sublethal doses of two common insecticides used in Brazilian soybean systems increased larval and pupal development times and reduced fecundity of a key soybean pest but only subtly affected the flight behavior of male moths. These biological effects could lead to asynchronous generations and the production of an insufficient number of susceptible moths coming out of refuge fields but should not alter the ability of moths to disperse between Bt and non-Bt fields. Results reinforce the value of using high dosage treatment and are of value to growers and regulators interested in sustaining the durability of this pest control technology. **Contact:** Steve.Naranjo@usda.gov

Selective control of cotton pests facilitates biological control. A fundamental component of integrated pest management (IPM) is maximizing biological control from natural enemies such as arthropod predators. This conservation is predicated on the use of insecticides that selectively kill the pests while leaving the natural enemies unharmed. In collaboration with scientists from the University of Arizona, we showed that four new insecticides registered for use in cotton selectively killed whiteflies and Lygus bugs but did not harm predatory arthropod communities. The favorable ratio of the abundance of these conserved predators relative to whitefly pests (predator to prey ratios) in cotton field enabled further biological control of the pest. Results allow cotton growers to continue managing pest populations in the most efficient way possible while having additional selective insecticide options that will facilitate biological pest control. **Contact:** Steve.Naranjo@usda.gov

Diapause induction in the western tarnished plant bug (Lygus) is primarily light-induced and comes at little cost. Management efforts focused on reducing overwintering populations of Lygus bugs have been attempted with little success, previously limited by an insufficient understanding of the diapause that facilitates overwinter survival. We found that temperature had a limited impact on diapause induction compared to daylength, and the sensitive period for exposure to short days that induces diapause starts during an early stage of development, the third nymphal instar. Further, despite redirecting resources to enhance overwintering survival, diapausing Lygus exhibit no negative impact in their development, post-diapause lifespan or lifetime egg production. In fact, the extra internal resources stored during adult diapause allows Lygus females to begin producing eggs more rapidly than if they were just newly emerged adults, which provides an advantage over non-diapausing females when environmental conditions become more hospitable. These findings provide new insights into the survival strategies of Lygus bugs, enhance the target value of diapausing individuals, and will be crucial for researchers developing improved management tactics targeting the overwintering population. **Contact:** Colin.Brent@usda.gov

Pink bollworm resistance to Bt cotton involves multiple genetic and biochemical mechanisms. Transgenic Bacillus thuringiensis (Bt) crops are critical for the control of important insect pests, but evolving resistance threatens their continued use. Pink bollworm is a global pest of cotton and multiple strains have developed resistance to Bt toxins. In collaborati0n with researchers from the University of Arizona, we found that in pink bollworm the primary mechanism is evolved mutations in the receptors that enable Bt toxin binding to the insect midgut. These mutations involve changes to the genetic sequence as well as to how the genes are translated into proteins. Reduced receptor expression and improper localization of those proteins on cell surfaces also can impair Bt toxin efficacy. These findings show the notable adaptability of pink bollworm to evolve resistance to Bt cotton and demonstrates the challenges for monitoring and managing resistance to Bt crops. The results are valuable for scientists concerned with understanding the mechanisms of resistance, for private industry for developing new commercial strategies to target pests, and for government authorities responsible for regulating transgenic crops. **Contact:** Jeff.Fabrick@usda.gov

Lygus transcriptomic data yield numerous potential control targets. The generation of transcriptomic datasets from Lygus exposed for set periods of time to different thermal environments has provided a better understanding of the molecular and cellular processes activated by Lygus in response to stress conditions. The datasets have provided crucial insights into the molecular basis of Lygus biology in general as well as that of other non-model agriculture insect pests. Dataset mining in conjunction with concurrent efforts to develop gene knockdown methods in Lygus to assess in vivo gene functionality has allowed researchers to identify numerous candidate genes for targeted disruption. More than 60,000 sequences have been made available via publicly accessible data repositories, which will facilitate the work of researchers looking for molecular targets for species-specific disruption that would support Lygus population control efforts in cotton and other commodity crops for which they are pests. **Contact:** Joe.Hull@usda.gov

RNA interference (RNAi) is effective in Lygus by injection but not ingestion of dsRNA. The ingestion of double-stranded RNAs to trigger RNAi-mediated knockdown of target genes has been promoted as a novel control strategy for agricultural pests such as Lygus. However, our studies of RNAi methods in Lygus have established that current methods for oral delivery of dsRNAs are ineffectual. Unlike other species, extraoral degradation of dsRNAs does account for the poor efficacy, indicating that the barrier is related to the persistence and uptake of the ingested dsRNAs. In contrast, injected dsRNAs have proven to be effective and have been used to assess the function of several candidate genes identified for targeted disruption. Negative physiological impacts were observed with the successful knockdown of genes involved in reproductive tissue development, desiccation tolerance, egg laying, and noxious odor detection. The results will facilitate developing highly targeted control approaches for Lygus using gene manipulation, which would make it possible to reduce pesticide application for cotton and other commodity crops for which they are pests. **Contact:** Joe.Hull@usda.gov

Development of a novel method to study arthropod feeding activity. While insect predators can provide biological control of pest species, they can undermine their efficacy by also engaging in intraguild predation (IGP) on other predator species and cannibalism. We developed a method for examining both IGP and cannibalism on a well-known predator, the green lacewing. The method entailed tagging young (third instar) and old (fifth instar) lacewing larvae with rabbit IgG and chicken IgY proteins, respectively. The uniquely marked lacewings were then introduced into caged arenas containing a cotton plant and an assemblage of predators. The predators were recaptured, and their gut contents examined for the presence of rabbit IgG- and chicken IgY-marked lacewing remnants by protein-specific immunological assays. The predator gut analyses detected incidences of both IGP and cannibalism, showing this technique to be useful for a variety of life stage-specific predation events. This method can be broadly applied to regions across the country, allowing researchers to identify which predators make substantial contributions to biological control so that their populations can be promoted to enhance pest population suppression. **Contact:** James.Hagler@usda.gov

Green lacewing (left) and the big-eyed bug eating whiteflies.

Alfalfa is an effective trap crop for strawberry fields. The Lygus bug is a major strawberry pest but prefer to feed on alfalfa. As such, embedding strips of alfalfa within large strawberry production fields can serve as a sink for both Lygus and its predaceous natural enemies. We examined the population dynamics and dispersal characteristics of the Lygus predator complex in strawberry fields embedded with one row of alfalfa for every 49 rows of strawberry. The data revealed that the minute pirate bug was the numerically dominant predator taxon, comprising 84% of the predator population. Predator movement from a centralized alfalfa trap crop row, using a protein mark-capture procedure, showed that most predators dispersed less than 2-m, indicating that the prey reservoir found in trap crops often produces a predator sink. This study suggests that alfalfa is a useful cultural (trap cropping) and biological (refuge for natural enemies) control tactic for managing Lygus in strawberries, leading to less insecticide use and greater production of organically grown strawberries. **Contact:** James.Hagler@usda.gov

Guayule, a perennial desert shrub, produces high-quality natural rubber that is suitable for use in commercial-grade tires. Presently, major tire companies in the US have revitalized interest in developing large domestic US supplies of natural rubber to alleviate dependency on imported and synthetic rubbers. Guayule is acclimated to hot, arid environments, however, to attain high rubber yields in the desert requires significant amounts of water when using traditional irrigation methods, such as flood irrigation. We conducted irrigation studies for two and a-half years to compare rubber yield and water use using both flood irrigation and the more efficient, subsurface drip irrigation (SDI) method. Key results were that rubber yields were nearly doubled using SDI over flood irrigation and that water savings can be greatly increased with SDI. This study provides irrigation technology that will greatly help future guayule growers attain high rubber yields while minimizing water use. **Contact:** Doug.Hunsaker@usda.gov

Modeling carbamazepine transport in wastewater-irrigated soil under different land uses. The reuse of sewage effluent for irrigation is an effective way to dispose of treated wastewater while protecting surface waters from contamination. Carbamazepine is a persistent anti-epileptic drug found in wastewater effluent. In collaboration with scientists from the University of Zagreb and Penn State University, we found that movement of carbamazepine in surface soils is related to organic carbon content, that models overestimated the observed mobility and that augmenting soil organic matter content could be used to limit carbamazepine mobility. Results will be used to better predict carbamazepine mobility and protect the environment where treated wastewater is used for irrigation. **Contact:** Clinton.Williams@usda.gov

Adsorption of pharmaceuticals from aqueous solutions using biochar derived from cotton gin waste and guayule bagasse. Current treatment processes in wastewater treatment plants are not designed to remove pharmaceuticals that are present, leading to concern when using treated wastewater for irrigation. Biochar produced from organic waste material can be a cost effective sorbant to remove pharmaceuticals from water. In cooperation with scientists at Penn State University, we evaluated biochar produced from cotton gin waste and guayule bagasse for efficacy at removing pharmaceuticals. It was found that cotton gin biochar was more effective at removing sulfapyridine, docusate, and erythromycin and that removal was also greater for biochars produced at higher temperatures. In addition, removal increased as pH increased from 7 to 10. Biochar produced from cotton gin waste can be effective at removing pharmaceuticals from water. Results will be used to provide low cost treatment for removal of pharmaceuticals from wastewater used for irrigation at the point of use. **Contact:** Clinton.Williams@usda.gov

Effects of sprinkler irrigation rate and timing on Arizona cotton production. Arizona agriculture faces several problems related to water: on-going regional drought, depletion of water in reservoirs, competition from cities, and climate uncertainty. Improving efficiencies of agricultural water use is imperative for the sustainability of Arizona row-cropping. We conducted a three-year field study on cotton irrigation practices, which revealed impacts of early-season and late-season irrigation levels on cotton yield, water use, and fiber quality. With improved scientific tools, irrigation could be reduced by 10% while maintaining acceptable cotton yield and fiber quality. The study provides valuable guidance for producers and water management planners in the region, specifically on irrigation practices for cotton using overhead sprinkler irrigation systems. **Contact:** Kelly.Thorp@usda.gov

High guayule rubber yield using subsurface drip irrigation (SDI). Guayule, a perennial desert shrub, produces high-quality natural rubber that is suitable for use in commercial-grade tires and major tire companies in the United States have revitalized interest in developing large domestic U.S. supplies of natural rubber to alleviate dependency on imported and synthetic rubbers. Guayule is acclimated to hot, arid environments, but to attain high rubber yields in the desert requires significant amounts of water when using traditional flood irrigation methods. We conducted irrigation studies for two and a-half years to compare rubber yield and water use using both flood irrigation and the more efficient, subsurface drip irrigation (SDI) method. Key results were that rubber yields were nearly doubled using SDI over flood irrigation and that water savings can be greatly increased with SDI. This study provides irrigation technology that will help future guayule growers to attain high rubber yields while minimizing water use. **Contact:** Kelly.Thorp@usda.gov

Nitrogen (N) management practices for subsurface drip irrigated (SDI) cotton. Declining water availability in the American Southwest continues to generate interest in efficient subsurface drip irrigation (SDI) for cotton production. Fertigating urea ammonium nitrate at low rates with high frequency is an important advantage of SDI, but nitrogen (N) fertilizer management guidelines, specific to SDI cotton are lacking. We conducted a 3-yr study to test a pre-plant soil profile NO3 algorithm and a canopy reflectance approach to manage in-season N fertilizer for SDI cotton. The key result of this study is that

Satellite-based remote sensing of evapotranspiration. Efficient irrigation management relies on timely information about crop water requirements and a practical and widely used method to estimate crop water requirements, "FAO56", estimates water use of a crop by multiplying a crop coefficient by reference water use value determined from weather station data. However, coefficients change over the season and are difficult to estimate every day. We determined the actual daily crop coefficient and water use of wheat crops using remote sensing information from satellites. The approach accurately estimates the daily measured water use, particularly during periods when the need for irrigation was the greatest. These results will lead to future development of this remote sensing technology for providing reliable guidance for efficient irrigation management. **Contact:** Andrew.French@usda.gov

Long-term simulations of site-specific irrigation management for Arizona cotton production. Engineering technologies are currently available for applying different irrigation rates at different locations in the field. However, further studies must identify cases where these technologies improve crop yield or save water. We conducted a comprehensive analysis of temporal weather patterns and spatial soil patterns. Assessments of irrigation requirements for cotton production among the different weather and soil patterns were performed. The results demonstrated little benefit for technologies that apply different rates of water at different spatial locations, because no improvements in crop yield or savings of water were shown as compared to spatially uniform irrigation management. The research is particularly useful for growers who are considering options for technologies to improve water management on their farms and for researchers in the area of irrigation science. **Contact:** Kelly.Thorp@usda.gov

Current Grant Awards (*new)

*Genomic resistance risk assessment for Vip3-producing transgenic Crops in Helicoverpa Zea, USDA-NIFA-Biotechnology Risk Assessment Grants Program. (PI Yves Carrière, Co-PIs **Jeff Fabrick**, Luciano Matzkin, Bruce Tabashnik) 2021-2023

*Optimization of Gene Modification Methods in *Lygus hesperus*: Further optimization and elucidation, Cotton Incorporated. (PI **Colin Brent**, Co-PIs **Jeff Fabrick, Joe Hull**) 2021

*Aflatoxin Mitigation in Sudan, International Institute of Tropical Agriculture. (PI **Kenneth Callicott**) 2020-2022

*Applying proximal sensing to enhance upland cotton yield trials, Cotton Incorporated (PI **Alison Thompson**) 2021

* Artificial intelligence ti oncrease sustainability of water, nutrient, salinity, and pest management in the Western US, USDA-NIFA(PI E. Scudiero, CO-PIs H. Ajami, R. Anderson, K. Bali, M. Cahn, N. Chaney, K. Chief, A. Eldawy, **Andrew French**, R. Khosla, M. McGiffen, C. Nugent, E. Papalexakis, A. Putman, M. Rivera, C. Sanchez, K. Schwabe, T. Skaggs, G. Vellidis) 2020-2026

*High-throughput phenotyping using portable LIDAR, Cotton Incorporated (PI **Andy French**) 2021

*Evaluation and improvement of crop simulation models to meet the data needs of modern cotton production systems, Cotton Incorporated (PI **Kelly Thorp**) 2021

*Temporal evaluation of CEC's in the effluent from the Norman Oklahoma water reclamation facility, Garver Engineering (PI **Clinton Williams**) 2021

Population genomics of Bt resistance in *Helicoverpa zea*, USDA-NIFA, (PI Bruce Tabashnik, Co-PIs Yves Carriere, Luciano Matzkin, **Jeff Fabrick**) 2020-2022

Utilizing genes from the soybean germplasm collection to mitigate drought stress, United Soybean Board (PI, Larry Purcell, CO-PIs **Hussein Abdel-Haleem**, Felix Fritschi, Jason Gillman, James Smith, Jeff Ray) 2018-2022

Sustainable bioeconomy for arid regions, USDA-NIFA (PI K. Ogden, Co-PIs D. Ray, P. Waller, R. Maier, I. Meghan Downes, W. McCloskey, T. Teegerstrom, O. Idowu, P. Gutierrez, K. Grover, F. Holguin, C. Brewer, S. Angadi, **Hussein Abdel-Haleem**, C. McMahan, D. Dierig, A. Landis, J.Quinn, X. Bai, K. Seck) 2017-2022

Understanding the potential for resistance and biological control impacts of thrips and plant bug active Bt deployment, USDA-NIFA, Biotechnology Risk Assessment Grant Program (PI Anders Huseth, Co-PIs G. Kennedy, P. Ellsworth, **Steve Naranjo**) 2018-2021

Molecular and environmental factors controlling aflatoxin reduction by non-toxigenic *Aspergillus* strains, Arizona Cotton Research and Protection Council (PI **Steve Naranjo**, Co-PI **Ken Callicott**) 2018-2023

Prevention of aflatoxin contamination of maize in pakistan with biological control based on atoxigenic strains of *Aspergillus flavus*, Ingredion [Pakistan] (PI **Steve Naranjo**, Co-PI **Ken Callicott**) 2018-2022

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**) 2016-2021

Securing water for and from agriculture through effective community & stakeholder engagement, USDA-NIFA (PI Kathy Brasier, CO-PIs **Clinton Williams**, Sarah Porter, Julia Bausch and others) 2017-2021

The nexus of agricultural & urban trade-offs: Interdisciplinary education & research to create emerging opportunities in urban agriculture, USDA-NIFA, (PI Rebecca Muenich, CO-PIs Otakuye Conroy-Ben, Peter Condon, **Clinton Williams**) 2018-2021

Occurrence and treatment of unregulated organic micropollutants in the San Jaun River, US Bureau of Reclamation (PI Anthony Kennedy, Co-PI **Clinton Williams**) 2019-2021.

Genetics and mechanism of pest resistance to second generation Bt crops, USDA-NIFA (PI Bruce Tabashnik, Co-PIs **Jeff Fabrick,** Yves Carriere) 2018-2021.

Recent Professional Awards and Recognition

Dr. James Hagler was the recipient of the **Senior Research Scientist of the Year Award from the Pacific West Area of USDA-ARS**. The award recognizes his career-long outstanding contributions to furthering the science and implementation of biological control. In particular, he was cited for "pioneering widely-used methods in the study of arthropod dispersal and feeding behavior." His techniques have been adopted by scientist around the world to track the impact of pest insects and their predators. A virtual ceremony honoring him and other awardees was conducted in Beltsville, MD.

Employee Engagement

Jeff Fabrick 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 Agency level.

ALARC Seminar Series. Each year, ALARC hosts scientific seminars on a variety of topics related to entomology, plant science and water management. The series runs from September through May on a biweekly schedule on Monday afternoons. Throughout the year, all presentations were made virtually due to the COVID-19 pandemic. If you are interested in getting advance notice of seminar speakers and topics, please email steve.naranjo@usda.gov.

Administrative Professionals Day. We used this national day of recognition to extend our thanks and appreciation to all ALARC employees, especially considering what they have had to contend with during the pandemic. Unfortunately, the event had to be held virtually this year.

Unit- and Center-Wide Meetings. Regular virtual meetings were used to provide guidance, formulate strategies and bolster a sense of cohesion and community. This became ever more important as staff felt increasingly isolated do to the protracted separation caused by the maximized telework posture.

June 2020. The ALARC EEO/Diversity Committee hosted a virtual event to celebrate Lesbian, Gay, Bisexual and Transgender Pride Month. **Brenda Singleton** and **Miles Casey** presented "Transgender Contributions to Science and Society."

September 2020. The ALARC EEO/Diversity Committee hosted a virtual event to celebrate National Hispanic Heritage Month. **Gary Wall** and **Laura Olivieri** presented "Hispanic American Heritage Month."

February 2020. The ALARC EEO/Diversity Committee hosted a virtual event to celebrate National African American History Month. **Brenda Singleton** presented "James Baldwin, Author, Activist, Playwright," and Damien Seay presented "The Brick Wall".

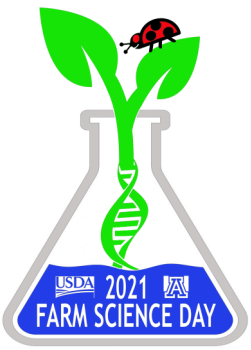
March 2021. The ALARC EEO/Diversity Committee hosted a virtual event to celebrate National Women's History Month. **Damien Seay** presented "Women in Agriculture."

May 2021. The ALARC EEO/Diversity Committee hosted a virtual event to celebrate Asian American and Native Hawai-

Recent events and outreach

December 2020. Using a virtual platform, ALARC hosted its semi-annual **Stakeholder Meeting**. Stakeholders learned about the research going from ALARC scientists on topics ranging from management of crop diseases and mycotoxins to developing molecular tools for use in integrated pest management. We also heard from Blase Evancho, one of our stakeholder members, who provided an update on the current state of the Pinal County Ag Extension Program. The meeting goals are to provide our stakeholders a venue to offer ideas and suggestions on research direction at the Center and to maintain strong relationships between scientists and the stakeholders they serve at the local, regional, and national level. Members represent growers, industry, university and state and federal agency interests.

February 2021. Due to various circumstances, our annual **Farm Science Day** had to be canceled in 2019 and 2020, but we were able to hold a virtual version of the outreach event in 2021 using a combination of live and prerecorded presentations. In addition to talks about ALARC and the research conducted there, a STEM career panel was hosted. The event was held over several days as part of the Arizona SciTech Festival. [Link]



Recent Publications

Plant Physiology and Genetics Research

Baslam, M., Mitsui, T., Hodges, M., Priesack, E., **Herritt, M.T.**, Aranjuelo, I., Sanz-Saez, A. 2020. Photosynthesis in a changing global climate: scaling up and scaling down. Frontiers in Plant Science. 11. https://doi.org/10.3389/fpls.2020.00882.

Doner, N.M., **Seay, D.**, **Mehling, M.**, Sun, S., Gidda, S.K., Schmitt, K., Braus, G.H., Ischebeck, T., Chapman, K.D., **Dyer, J.M.**, Mullen, R.T. 2021. *Arabidopsis thaliana* EARLY RESPONSIVE TO DEHYDRATION 7 localizes to lipid droplets via its senescense domain. Frontiers in Plant Science. 14. https://doi.org/10.3389/fpls.2021.658961.

Herritt, M.T., Long, J.C., **Roybal, M.D.**, Moller Jr, D.C., Mockler, T.C., Pauli, D., **Thompson, A.L.** 2021. FLIP: FLuorescence imaging pipeline for field-based chlorophyll fluorescence images. SoftwareX. 14:100685. https://doi.org/10.1016/j.softx.2021.100685.

Herritt, M.T., Jones, D., **Thompson, A.L.** 2020. Upland cotton (*Gossypium hirsutum* L.) fuzzy seed counting by image analysis. Journal of Cotton Science. 24:112-120.

Herritt, M.T., Mockler, T.C., Pauli, W.D., **Thompson, A.L.** 2020. Chlorophyll fluorescence imaging captures photochemical efficiency of grain sorghum (Sorghum bicolor) in a field setting. Plant Methods. 16. https://doi.org/10.1186/s13007-020-00650-0.

Herritt, M.T., Fritschi, F.B. 2020. Characterization of photosynthetic phenotypes and chloroplast ultrastructural changes of soybean (Glycine max) in response to elevated air temperatures. Frontiers in Plant Science. 11:153.

Luo, Z., Mullen, C.A., **Abdel-Haleem, H.A.** 2020. Pyrolysis GC/MS analysis of improved guayule genotypes. Industrial Crops and Products. 155. https://doi.org/10.1016/j.indcrop.2020.112810.

Luo, Z., Szczepanek, A.E., Abdel-Haleem, H.A. 2020. Genome-wide association study (GWAS) analysis of camelina seedling germination under salt stress condition. Agronomy. 10(9). https://doi.org/10.3390/agronomy10091444.

Thompson, A.L., Conley, M.M., Roybal, M.D. 2021. High-throughput phenotyping data from a proximal sensing cart. Ag Data Commons. https://doi.org/10.15482/USDA.ADC/1520740.

Thompson, A.L., **Thorp, K.R.**, **Conley, M.M.**, **Roybal, M.D.**, Moller Jr, D.C., Long, J.C. 2020. A data workflow to support plant breeding decisions from a terrestrial field-based high-throughput plant phenotyping system. Plant Methods. 16. https://doi.org/10.1186/s13007-020-00639-9.

Tomasi, P., **Herritt, M.T.**, Jenks, M., **Thompson, A.L.** 2021. Quantification of leaf wax and cutin monomer composition in Pima (Gossypium barbadense) and upland (G. hirsutum L.) cotton. Journal of Plant Physiology. https://doi.org/10.1016/j.indcrop.2021.113670.

Overhead sprinkler irrigation system at dusk.

Pest Management and Biocontrol Research

Bordini, I.C., **Naranjo, S.E.**, Fournier, A., Ellsworth, P.C. 2021. Novel insecticides and generalist predators support conservation biological control in cotton. Biological Control 154: 104502. https://doi.org/10.1016/j.biocontrol.2020.104502

Brent, C.S. 2021. Diapause termination and post-diapause in *Lygus hesperus* (heteroptera: miridae). Journal of Insect Science. 21(1):1-7.

Fabrick, J.A., Leroy, D.M., Mathew, L.G., Wu, Y., Unnithan, G.C., Yelich, A., Carriere, Y., Li, X., Tabashnik, B.E. 2021. CRISPR-mediated mutations in the ABC transporter gene ABCA2 confer pink bollworm resistance to Bt toxin Cry2Ab. Scientific Reports. https://doi.org/10.1038/s41598-021-89771-7.

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Fabrick, J.A., Yool, A.J., **Spurgeon, D.W.** 2020. Insecticidal activity of marigold Tagetes patula plants and foliar extracts against the hemipteran pests, Lygus hesperus and Bemisia tabaci. PLoS One. 15(5). https://doi.org/10.1371/journal.pone.0233511.

Guan, F., Hou, B., Dai, X., Liu, S., Liu, J., Gu, Y., Yang, Y., **Fabrick, J.A.**, Wu, Y. 2021. Multiple origins of a single point mutation in the cotton bollworm tetraspanin gene confers dominant resistance to Bt cotton. Pest Management Science. 77(3):1169-1177. https://doi.org/10.1002/ps.6192.

Gula, S.W., Lopez, V.M., Ray, A.M., **Machtley, S.A., Hagler, J.R.,** Ginzel, M.D. 2020. Protein self-marking by emerald ash borer: an evaluation of efficacy and persistence. Entomologia Experimentalis et Applicata. 168:678-687. https://doi.org/10.1111/eea.12941.

Hagler, J.R., Casey, M.T., Hull, A.M., Machtley, S.A. 2020. A molecular approach for detecting stage-specific predation on *Lygus hesperus*. Journal of Insect Science. 20(6):1-6. https://doi.org/10.1093/jisesa/ieaa136.

Hagler, J.R., Thompson, A.L., Machtley, S.A., Miles, C.T. 2021. Arthropod demography, distribution, and dispersion in a novel trap-cropped cotton agroecosystem. Journal of Insect Science. 21(1):1-10. https://doi.org/10.1093/jisesa/ieab010.

Naranjo, S.E., Hagler, J.R., Byers, J. 2021. Methyl salicylate fails to enhance arthropod predator abundance or predator to pest ratios in cotton. Environmental Entomology. 50 (2):293-305. https://doi.org/10.1093/ee/nvaa175.

Ortega-Beltran, A., **Callicott, K.A.,** Cotty, P.J. 2020. Founder events influence structures of Aspergillus flavus populations. Environmental Microbiology. 22(8):3522-3534. https://doi.org/10.1111/1462-2920.15122.

Singh, P., **Callicott, K.A**., Orbach, M.J., Cotty, P.J. 2020. Molecular analysis of S morphology aflatoxin producers from the United States reveals previously unknown diversity and two new taxa. Frontiers in Microbiology. 11. https://doi.org/10.3389/fmicb.2020.01236.

Tabashnik, B.E., Liesner, L.R., Ellsworth, P.C., Unnithan, G.C., **Fabrick, J.A., Naranjo, S.E.**, Li, X., Dennehy, T.J., Antilla,

L., Staten, R.T., Carriere, Y. 2021. Transgenic cotton and sterile insect releases synergize eradication of pink bollworm a century after it invaded the United States. Proceedings of the National Academy of Sciences(PNAS). 118(1). https://doi.org/10.1073/pnas.2019115118.

Wyckhuys, K.A.G., Lu, Y.H., Zhou, W.W., Cock, M.J.W., **Naranjo, S.E.**, Fereti, A., Williams, F.E., Furlong, M.J., 2020. Ecological pest control fortifies agricultural growth in Asia–Pacific economies. Nature Ecology and Evolution. https://doi.org/10.1038/s41559-020-01294-y.

Lygus hesperus *exhibiting premating behaviors that involve chemoperception.*

Water Management and Conservation Research

Ayankojo, I.T., **Thorp, K.R.**, Morgan, K.T., Kothari, K., Ale, S. 2020. Assessing the impacts of future climate on cotton production in the Arizona low desert. Transactions of the ASABE. 63(4):1087-1098. https://doi.org/10.13031/trans.13731.

Bautista, E., Schlegel, J.L. 2020. Modeling solute transport in the WinSRFR surface irrigation software. Journal of Irrigation and Drainage Engineering. 146(11). https://doi.org/10.1061/(ASCE)IR.1943-4774.0001507.

Barnes, E.M., Campbell, B.T., Vellidis, G., Porter, W., Payero, J., Leib, B., Sui, R., Fisher, D.K., Anapalli, S.S., Colaizzi, P.D., Bordovsky, J., Porter, D., Ale, S., Mahan, J.R., Taghvaeian, S., **Thorp, K.R**. 2020. Forty years of increasing cotton's water productivity and why the trend will continue. Applied Engineering in Agriculture. 36(4):457-478. https://doi.org/10.13031/aea.13911.

Bronson, K.F., Hunsaker, D.J., El-Shikha, D., Rockholt, S.M., Williams, C.F., Rasutis, D., Soratan, K., Venterea, R.T. 2021. Nitrous oxide emissions, N uptake, biomass, and rubber yield in N-fertilized, surface-irrigated guayule. Industrial Crops and Products. 167. https://doi.org/10.1016/j.indcrop.2021.113561.

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Jimenez, J., Leiva, L., Cardoso, J.A., **French, A.N.**, **Thorp, K.R.** 2020. Proximal sensing of Urochloa grasses increases selection accuracy. Crop and Pasture Science. 71(4):401-409. https://doi.org/10.1071/CP19324.

Lebauer, D.S., Burnette, M.A., Demieville, J., Fahlgren, N., **French, A.N.**, Garnett, R., Hu, Z., Huynh, K., Kooper, R., Li, Z., Maimaitijiang, M., Mao, J., Mockler, T., Morris, G.S., Newcomb, M.S., Ottman, M., Ozerksy, P., Paheding, S., Pauli, D., Pless, R., Qin, W., Riemer, K., Rohde, G., Rooney, W., Sagan, V., Shakoor, N., Stylianou, A., **Thorp, K.R.**, Ward, R., White, J., Willis, C., Zender, C., Lebauer, D. 2020. Terra-Ref, an open reference data set from high resolution genomics, phenomics, and imaging sensors. Dryad Digital Repository. https://orcid.org/0000-0001-7228-053X.

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Shamshiri, R.R., Hameed, I.A., **Thorp, K.R.**, Balasundram, S.K., Shafian, S., Fatemieh, M., Sultan, M., Mahns, B., Samiei, S. 2021. Greenhouse automation using wireless sensors and IoT instruments integrated with artificial intelli-

gence. Book Chapter. https://doi.org/10.5772/intechopen.97714.

Thorp, K.R., Marek, G.W., Dejonge, K.C., Evett, S.R. 2020. Comparison of evapotranspiration methods in the DSSAT Cropping System Model: II. Algorithm performance. Computers and Electronics in Agriculture. 177. https://doi.org/10.1016/j.compag.2020.105679.

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Wutich, A., Beresford, M., Bausch, J., Eaton, W., Brasier, K., **Williams, C.F.**, Porter, S. 2020. Identifying stakeholder groups in natural resource management: Comparing quantitative and qualitative social network approaches. Society and Natural Resources. 33(7):941-948. https://doi.org/10.1080/08941920.2019.1707922.

Study of pharmaceuticals uptake by leafy vegetables.

ALARC in the news

Pink Bollworm eradication. ALARC and other ARS scientists made substantive contributions the elimination of the pink bollworm from much of the U.S. and Mexico. A detailed history of this crucial effort is given. From National Public Radio, ARS, and Imperial Valley Press [Link] [Link] [Link]

Water and Salt Management in Yuma. An ALARC scientist has been working to update water usage guidelines for growers in Yuma to maximize yields while reducing consumption and salt accumulation. From the Maricopa Monitor [Link]

Integrated Pest Management in AZ Cotton. Overviews are given of an ALARC scientist's research efforts that have been integral to driving the adoption and improvement of integrated pest management practices in cotton. From Pinal Centra and Cotton Farming [Link] [Link]

Drip Irrigation in Cotton. Water conservation through usage of drip irrigation systems refined by ALARC scientists. From Western Farm Press [Link]

Reclaimed Wastewater for Irrigation. An ALARC scientist who s a wastewater specialists shares his views on solving water shortage issues. From USDA and ARS [Link] [Link]

ALARC Intern Wins Contest at Purdue. Working with an ALARC scientist, a repeat student intern was able to win a research competition that highlighted her work on plant fats. From Purdue University [Link]

Rapid Phenotyping Gantry System. An overview is given of the automated scanning platform shared by ALARC with other institutions. From Wall Street Journal [Link]

Rapid phenotyping gantry system with sensor array extended. Photo: Jesse Rieser for The Wall Street Journal.