SUSTAINABLE BIOECONOMY FOR ARID REGIONS (SBAR)

Summary Report – Quarters 1-2, 2021

Information submitted by project partners; synthesized by:
Alix Rogstad, Director of Operations

USDA Cover Page

Federal Agency and Organization Element to Which Report is Submitted	**United States Department of Agriculture – National Institute of Food and Agriculture**
Federal Grant or Other Identifying Number Assigned by Agency	**2017-68005-26867**
Project Title	**Sustainable Bioeconomy for Arid Regions (SBAR), Center of Excellence**
PD/PI Name, Title and Contact Information (email address and phone number)	**Kimberly L. Ogden, Ph.D.** **ogden@email.arizona.edu** **520.621.9484**
Name of Submitting Official, Title, and Contact Information (email address and phone number), if other than PD/PI	**Same**
Submission Date	
DUNS and EIN Numbers	**DUNS 94-336-0412** **EIN 74-2652689**
Recipient Organization (name and address)	**Arizona Board of Regents** **University of Arizona** **Tucson, Arizona 85721-0518**
Recipient Identifying Number or Account Number	
Project Grant Period (start date, end date)	**01 Sep 2017 – 31 Aug 2022**
Reporting Period End Date	
Report Term or Frequency (annual, semi-annual, quarterly, other) *USDA-NIFA Project Number*	**Annual** **ARZW-206-11192**
Name of Submitting Official	*Signature / Date*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

ACCOMPLISHMENTS
January 2021 – June 2021

INTRODUCTION AND MANAGEMENT

General Overview: Organization

The Sustainable Bio-economy for Arid Regions (SBAR) Center of Excellence continues under the direction of Dr. Kimberly Ogden, Executive Project Director, who leads the overall research effort and ensures adequate progress toward meeting goals. The SBAR Project Director of Operations (Alix Rogstad) continues to oversee operations and manage all of the day-to-day project administration and business affairs, as well as coordination, communication, and data sharing among partnering organizations and institutions.

A comprehensive project evaluation plan, approved in July 2018, continues to effectively capture detailed progress on the project's defined objectives. As a living document, the evaluation plan will change to reflect revised research questions, project goals and big-picture, overall objectives. An overall management review and update will be in December 2021.

Advisory Board

Mark DeDecker (Bridgestone Americas, Inc.) retired in December 2020, and he was replaced by Ron Shaffer (Bridgestone Americas, Inc.) starting in January 2021 (Table 1). John Holladay's affiliation changed in May when he transferred from PNNL to LanzaTech. All other Advisory Board members and their affiliations remained the same through June.

Table 1. *SBAR Advisory Board members.*

Advisory Board Member	Company/ Representation	Year Joined Board
Chris Cassidy	USDA, Rural Development	2018
Matt Chavez	Independent Grower, NM	2017
Steve Csonka	Commercial Aviation Alternative Fuels Initiative (CAAFI)	2017
Gary Deen	Double D Farms, AZ	2017
William Goldner	USDA, National Institute of Food and Agriculture	2017
John Holladay	Pacific Northwest National Laboratory LanzaTech	2019-2021 2021
Chris Kuzdas	Environmental Defense Fund	2018
Homer Marks	Southwest Indian Agriculture Association, Tohono O'odham Nation	2017
Newt McCarty	NMSU, Extension Educator	2018
Jaroy Moore	Texas A&M Agrilife Research & Extension Center	2017
Alex Muravijov	Guar Resources	2017
Paul "Paco" Ollerton	Tierra Verde Farms, AZ	2019
Matt Payne	West Water Research, Inc.	2018
Ron Shaffer	Bridgestone Americas, Inc.	2021
Bob White	Bridgestone Americas, Inc.	2017

The non-disclosure agreements (NDA) were updated during the second quarter to remain in effect through the duration of on-going SBAR research. As of the end of June, 6 NDAs have been extended, 4 Advisory Board members are subject to existing project NDA and confidentiality agreements, and 5 remain unsigned. Sensitive data is not shared with individuals until a signed NDA is on file, and because of the sensitive nature of current research, any Advisory Board member without a signed/activated NDA after 31 July 2021 will no longer be a part of the Board.

The Advisory Board meets frequently (4 times/year) so that (1) relevant research updates can be shared; (2) Advisors can drill down into specific Component work as it is underway; and (3) the researchers can solicit comments/suggestions for improving research direction or overcoming challenges. Ultimately, the goal for more frequent meetings is to ensure that SBAR can remain agile in addressing changing priorities and circumstances.

The Advisory Board met virtually during the previous two quarters on 20 January, 11 March and 6 May, where members were able to ask direct questions and work with the team to determine the best implementation strategy for ongoing research needs during a national pandemic. A future Advisory meeting will be hosted at the 2021 Annual Retreat scheduled for August 2021 to ensure that the research and outcomes remain on track.

Budget and Financial Management

No budget issues occurred during the last two quarters. Budget management activities continued to work effectively, and all project expenditures are on track. Rogstad continued to maintain sub-award agreements and sub-award modifications, non-disclosure agreements, and work with partners to ensure grant funds are spent according to the project plan and approved scopes of work.

Sub-awards are fully activated with all project partner institutions: Bridgestone Americas, Inc., New Mexico State University (NMSU), Colorado School of Mines (CSM), Colorado State University (CSU), and the USDA-Agricultural Research Service (USDA-ARS). All sub-awards are progressing appropriately.

Component Working Group Meetings

All five SBAR component working groups continued to participate in scheduled online meetings to ensure forward momentum on all project tasks. Smaller focus group meetings were scheduled and facilitated as necessary, including budget meetings and partnership development meetings. During the first quarter's reporting period, the virtual meeting space (via Zoom) was utilized 69 times for over 56 hours. During the second quarter's reporting period, the virtual meeting space was utilized 57 times for over 48.1 hours. The need for virtual working arrangements because of COVID-19 restrictions continues to require virtual meetings for SBAR research to continue. The total number of participants during the first quarter showed a marked increase from previous quarters for all working group meetings (n=690), which is likely the result of university and partner institution's office re-openings. The second quarter's participation numbers dropped (n=434) when another COVID-19 surge occurred and offices/labs were again temporarily closed or restricted.

LEADS Team Meetings

The component leaders and co-leaders (LEADS) continued to meet with Ogden and Rogstad during established fortnightly meetings held via SBAR's dedicated Zoom online meeting space. The LEADS provide guidance for project decisions, and assist with resolving internal conflicts that are brought for discussion. This has proven to be an effective way to communicate key issues requiring short turn-around times.

During the second quarter, the LEADS completed a full budget review and made recommendations for Year 5 spending and budget allocations. They also discussed follow-on research possibilities and opportunities that may be pursued in the future.

SBAR Annual Retreat

As in previous years, the SBAR Annual Retreat is being planned for hosting at the University of Arizona in Tucson from 12-13 August 2021. The Retreat will include updates from industry partners and visionaries, research highlights for each Component, Advisory Board meeting time, and open networking periods. There will also be multiple opportunities for student engagement through dialogue with colleagues and oral/poster presentations. We are tentatively planning for Component specific sessions during the retreat. Preparation and pre-planning are underway; a final agenda will be available by July.

Communication and Reporting

Rogstad continues to be the main point-of-contact for most SBAR communication. Various listservs are maintained that enable quick dissemination of pertinent and critical information. Rogstad also fields questions and liaises among project researchers, Advisors, partners, and students.

Reporting schedules for researchers are established and working well. Quarterly reports submitted are synthesized and made available to the research team and Advisory Board members. Summary reports are also posted to the SBAR website for wider dissemination. Each researcher is required to submit a self-evaluation score/rank with their report, and they are asked to describe all issues that may put them at risk for meeting annual goals (as articulated in annual scopes of work). A Task Tracker Report is provided to the LEADS, which gives a status update for each team member per component. The Task Tracker Report is a proactive management tool that allows the identification of issues before they become risks for overall project completion.

Website, Social Media and Digital Tools

The SBAR-specific website (www.sbar.arizona.edu) continues to be regularly updated and maintained, serving as the digital "face" of the SBAR Center. Updates this quarter included project highlights that showcased new work, and major updates and revisions for the research component pages. Portions of the Extension & Outreach pages have also been updated with guar-focused information. Other Extension & Outreach pages – including the guayule-focused pages and the Youth Development page – are currently under revision.

The SBAR webpage was visited by people in 41 different states of the USA during the first quarter and by 36 different states during the second quarter (Table 2). Since inception, the website has been viewed by people in all 50 states and the District of Columbia, which is an

indication of wide interest in the ongoing research as well as the broad dissemination of information implemented by project partners.

Table 2. *Web traffic to the SBAR Center webpage from within the United States since inception.*

	Time Period					
State	**Jul – Dec 2018**	**Jan – Dec 2019**	**Jan – Dec 2020**	**Jan – Mar 2021**	**Apr – Jun 2021**	**Jul – Sep 2021**
Alabama			X	X	X	
Alaska			X			
Arizona	X	X	X	X	X	
Arkansas		X	X	X		
California	X	X	X	X	X	
Colorado	X	X	X	X	X	
Connecticut			X			
Delaware		X	X	X		
District of Columbia	X	X	X	X	X	
Florida		X	X	X	X	
Georgia		X	X	X	X	
Hawaii			X	X	X	
Idaho		X	X	X		
Illinois	X	X	X	X	X	
Indiana		X	X	X		
Iowa	X	X	X	X	X	
Kansas	X	X	X	X	X	
Kentucky		X	X	X	X	
Louisiana			X		X	
Maine			X			
Maryland	X	X	X	X	X	
Massachusetts		X	X	X	X	
Michigan		X	X	X	X	
Minnesota		X	X	X	X	
Mississippi		X	X	X	X	
Missouri		X	X	X	X	
Montana		X	X	X		
Nebraska		X	X	X		
Nevada		X	X	X	X	
New Hampshire			X			
New Jersey			X	X	X	
New Mexico	X	X	X	X	X	
New York	X	X	X	X	X	
North Carolina	X	X	X	X	X	
North Dakota		X	X			
Ohio		X	X	X	X	
Oklahoma		X	X	X	X	
Oregon		X	X	X	X	
Pennsylvania		X	X	X	X	

State	Time Period					
	Jul – Dec 2018	Jan – Dec 2019	Jan – Dec 2020	Jan – Mar 2021	Apr – Jun 2021	Jul – Sep 2021
Rhode Island			X			
South Carolina	X	X	X	X	X	
South Dakota		X	X			
Tennessee	X	X	X	X	X	
Texas	X	X	X	X	X	
Utah		X	X	X	X	
Vermont				X		
Virginia		X	X	X	X	
Washington	X	X	X	X	X	
West Virginia		X				
Wisconsin		X	X		X	
Wyoming		X	X	X	X	
Total	**15**	**41**	**49**	**41**	**36**	**0**

There were 1,306 unique sessions from January – March 2021, and 1,096 unique sessions from April – June 2021. During the first quarter, page views occurred in 43 different countries (top three: USA, China, and Mexico), including 3 countries that have not visited the website previously (Afghanistan, Costa Rica, and Papua New Guinea). Visitors from the USA accounted for 84% of site visits during the first quarter reporting period, which was a decrease from previous quarters indicating a more world-wide interest in SBAR research. The first quarter also showed a high interest from Canada, Finland, Netherlands, India, Austria, Pakistan, and Spain which accounted for another 6% of site visits overall.

During the second quarter, page views occurred in 39 different countries (top three: USA, India, and China). Visitors from the USA accounted for 83% of site visits overall, and visitors from India, China, Canada, Germany, Mexico and the Netherlands made up another 7%. Overall, approximately 8% of the sessions are returning visitors to the site, while 92% are new/first-time visitors.

There have been 13,191 unique website sessions since July 2018. Since activation, the website has had visitors from 6 continents and 88 different countries around the world (Table 3). The highest visited website pages during the first and second quarters included those that describe the research conducted by the characterizations and co-products team, those that showcase youth development and 4H camps, those that describe our team and partnerships, those that describe the feedstock development research, and those associated with digital lessons and educational resources. Other highly visited pages included special award highlights and those that provide grower-focused information for guayule and guar. The website will continue to be updated regularly as the project unfolds.

Table 3. *International web traffic to the SBAR Center webpage since inception.*

Country	Time Period					
	Jul – Dec 2018	Jan – Dec 2019	Jan – Dec 2020	Jan – Mar 2021	Apr – Jun 2021	Jul – Sep 2021
Afghanistan				X		

Country	Time Period					
	Jul – Dec 2018	Jan – Dec 2019	Jan – Dec 2020	Jan – Mar 2021	Apr – Jun 2021	Jul – Sep 2021
Algeria			X		X	
Argentina		X	X	X	X	
Australia	X	X	X	X		
Austria	X	X	X	X	X	
Bahrain			X			
Bangladesh		X	X	X	X	
Belgium		X	X		X	
Belize			X			
Bolivia			X			
Brazil		X	X	X	X	
Cameroon			X			
Canada	X	X	X	X	X	
Chile		X	X		X	
China	X	X	X	X	X	
Colombia		X	X	X		
Congo-Kinshasa		X				
Costa Rica				X		
Côte d'Ivoire		X	X			
Cyprus		X				
Denmark			X		X	
Ecuador			X			
Egypt	X				X	
Estonia		X				
Ethiopia	X		X			
Finland			X	X	X	
France		X	X	X	X	
Germany	X	X	X	X	X	
Ghana		X	X	X		
Grenada			X			
Greece			X	X		
Honduras		X			X	
Hong Kong	X	X	X	X	X	
Hungary			X		X	
India	X	X	X	X	X	
Indonesia		X	X			
Iran	X	X	X	X	X	
Iraq			X			
Ireland		X		X		
Israel		X		X	X	
Italy	X	X	X	X	X	
Japan	X	X	X	X	X	
Jordan			X	X		
Kenya		X	X		X	
Kuwait	X	X	X			
Lebanon		X				

Country	Time Period					
	Jul – Dec 2018	Jan – Dec 2019	Jan – Dec 2020	Jan – Mar 2021	Apr – Jun 2021	Jul – Sep 2021
Libya			X			
Malaysia		X	X	X		
Mexico	X	X	X	X	X	
Morocco		X				
Namibia		X				
Nepal	X	X	X	X		
Netherlands		X	X	X	X	
New Zealand	X		X			
Nigeria		X	X	X	X	
Norway			X	X		
Oman			X			
Pakistan	X	X	X	X	X	
Papua New Guinea				X		
Paraguay		X				
Peru		X				
Philippines	X	X	X	X	X	
Poland		X	X			
Portugal		X				
Puerto Rico			X	X		
Qatar		X	X			
Romania			X			
Russia		X		X		
Saudi Arabia		X	X	X		
Serbia			X	X	X	
Singapore		X	X		X	
South Africa		X			X	
South Korea		X	X	X		
Spain		X	X	X	X	
Sri Lanka		X		X		
Sweden		X	X			
Switzerland			X		X	
Taiwan		X				
Thailand	X	X	X		X	
Tunisia			X			
Turkey	X	X	X	X	X	
Uganda			X			
Ukraine		X				
United Arab Emirates		X			X	
United Kingdom	X	X	X	X	X	
United States	X	X	X	X	X	
Vietnam		X	X		X	
Zambia		X				
Total	**22**	**60**	**65**	**43**	**39**	**0**

FEEDSTOCK DEVELOPMENT & PRODUCTION

Project Coordination: The Feedstock Development (FD) Team holds a single joint monthly meeting and periodically meets on an as-needed basis in between monthly meetings to address specific topics. The UA leads these meetings (Dr. Dennis Ray), which are leveraged to ensure all team members are on schedule and research work can seamlessly integrate between components. Questions related to planting or harvesting schedules are generally worked out during these monthly meetings, and data access and sharing has been a point of discussion during the last year. The FD team members also meet during weekly research team meetings (all-hands) hosted at the UA and monthly at New Mexico State University. These briefings provide an opportunity for open communication regarding on-going experiments, issues/challenges, and results for both guayule and guar research. Quarterly summary reports provide an opportunity to discuss relevant research topics and questions that may need further exploration.

Issues/Risks:
Abdel-Haleem: Even with COVID-19 pandemic situation and USDA policies of minimum essential operations and maximum teleworking, it is expected to meet the 2021 milestones.

Angadi: The COVID-19 pandemic has affected our research program. First part of deficit irrigation manuscript writing is delayed due to COVID-19, bad season in 2019 and my former student moving on to another university for a PhD.

Hoping to submit manuscript by the end of summer. We are also hoping to start trial assessing temperature requirement for germination and early growth of USDA germplasm by the end of the summer with the help of newly hired research assistant.

Dierig: Bridgestone Agro Operations partially shut down as a result of COVID-19 response. We anticipate to still meet the goals of our SOW. We completed most of the harvesting and processing of shrubs prior to shut down. The analytics were slightly delayed but are now up to date.

We now see that the space of the borders between plots for an irrigation experiment of this nature should have been wider. In cases where there is a frequent irrigation treatment next to a low (stressed) irrigation treatment, the first row and sometimes the second row (of 6 rows) show more growth than the middle row in the stress plot. We are now exclusively harvesting from these rows.

Grover: The COVID-19 lockdown has somewhat impacted the activities with restricted face-to-face interactions. The graduate student left the program due to medical and other issues, and is being replaced with other student and technical help to continue the project.

McCloskey: Obtaining adequate plant populations and field uniformity has been frustrating. To improve our chances of success at MAC in Spring 2021, I avoided field locations near alfalfa and planted only the center 8 rows of each 12-row border to maintain a dry strip between borders and planted coated seed treated with insecticide. MAC's broadcast sprayer will drive in the dry rows so that topical insecticides and bird repellent can be sprayed even while the field is

wet. In addition, two locations at MAC were planted in hopes of obtaining at least one good site. Planting at Bridgestone Eloy is proceeding as done in the past.

The seed quality during the spring plantings was good, and we obtained good plant populations in the fields. It turned out that it was not necessary to spray bird repellent at the spring study sites.

McMahan: The USDA-ARS-WRRC location was closed, except for essential work, in response to the COVID-19 pandemic on March 17, 2020. In 4Q20, due to the limited lab access, some genotype/phenotype evaluations did not take place (previously reported). We have been able to maintain plants with essential staff, however genotype/phenotype evaluations were delayed. Plants were maintained and grew in cultures and moved to greenhouse. Starting April 6, 2021, the laboratory was approved for non-essential work at 25% of the workforce. This has allowed us to begin rubber extractions and other phenotyping.

Neilson/Maier: The DNA extractions on soils sampled in 2018 and 2019 are still under progress by K. Brown. 202 of the 216 extractions are now complete. COVID restrictions have limited Brown's ability to work in the lab. K. Brown is using the time to complete the literature reviews described.

The bioinformatics analysis of the 2018 and 2019 soil samples from the guayule irrigation field trials will be completed when the DNA extractions and amplicon sequencing are completed. This delay affects Brown's research, but not the rest of the project.

DNA extractions from 2020 guayule sampling of MAC and Eloy fields will be started when Year 3 is complete. Lab work has been delayed due to COVID restrictions as mentioned above. The delay affects the harvest analysis of the irrigation field trial only.

Ogden: It has been a year where we are consistently adapting ourselves to working under the changing pandemic situation. It was very challenging to work effectively while minimizing the risk to be infected by the COVID-19. Therefore, there are some delays in the work progress. Vaccinations help. The work efficiency should be better with a safer environment.

Ray: Guayule inoculation project is on hold because fungal samples cannot be obtained.

Objective 1. Improve biomass quantity and quality through genetics and traditional breeding.

Task #	Description of Task	Deliverable	Target Completion Date
1 Dierig	Evaluate USDA germplasm lines	Ploidy analysis completed Harvest/Analysis of first growth cycle completed	31 Aug 19 30 Apr 22
2 McMah	Recover live plants from transformed calli (SEP3, FT, LEAFY)	Confirmed transformation for *in vitro* plants – 6 lines SEP3	30 Jun 21

		Confirmed transformation for *in vitro* plants – 6 lines FT Confirmed transformation for *in vitro* plants – 6 lines LEAFY	30 Jun 21 30 Jun 21
3 McMah	Determine effect of transgenes on rubber content by ASE (tissue culture)	% rubber data obtained for each construct line	30 Jun 21
4 McMah	Transfer plants to greenhouse/growth chamber for flowering phenotype	Transfer at least 2 lines to greenhouse	31 Dec 20
5 Ray	Evaluate growth and rubber/resin content in guayule germplasm lines	Rubber/resin content determined in 21 guayule germplasm lines	30 Apr 21
6 Ray	Compare root growth/architecture and water use in direct-seeded and transplant-established guayule	Compare root growth/top growth/water use	31 Mar 21

Evaluate Germplasm Lines (Variety Trials):
Nothing new to report at this time. A full analysis and interpretation of data will be coming soon with all the trials together.

Recover Live Plants from Transformed Calli – SEP3, FT, and LEAFY Genes:
Our project seeks to enhance natural rubber content in guayule by downregulation of flowering. We are evaluating 3 genes/approaches, all involving downregulation (by RNAi) of genes known to have a role in flowering: FT2, LEAFY, and SEP3. Thus, the rest of the project will focus on these 3 genes. In 1Q21, we concentrated on continued recovery of transformed plants from remaining calli (LEAFY and FT2). We have recovered one more putative transformation event for the LEAFY construct since the last report, for a total of 3, minimum needed for publishable results. However, explants have yet to root for LEAFY. Changes in media and/or protocol are under investigation. We have also recovered on additional putative transformed line for FT2 which has been moved to rooting media. The other two lines are propagating well in culture, so we anticipate at least 3 lines for phenotyping.

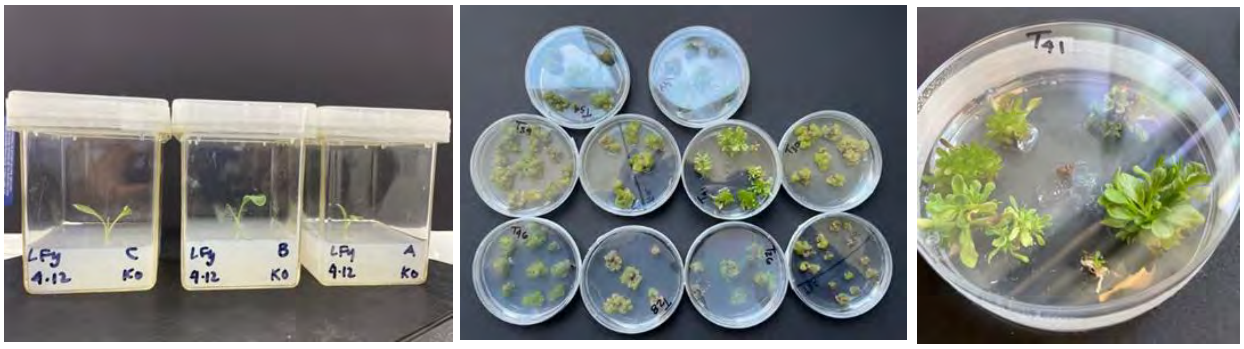


Figure 1. *Calli growing under selection pressure and putative LEAFY transgenic guayule A, B, and C.*

===

In Q2 for the FT2 construct, and additional putative transformed line has grown roots and others have been moved to rooting media. We anticipate having 3-5 lines for phenotyping. Methods development continues as we explore media and protocol optimization to limit transformation degradation during the explant recovery phase.

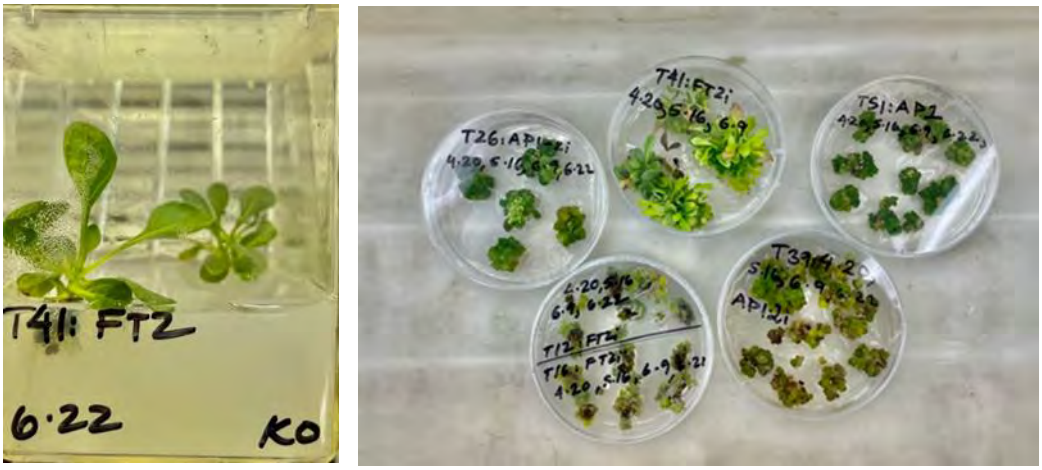


Figure 2. *Rooted FT2 putative transformant in rooting media (L) and the remaining calli under selection pressure (R).*

In 2Q21 we had more success with rooting for plants with a downregulated LEAFY gene. We now have a compelte set of 3 transformation events. These will be the next to move to soil/greenhouse.

Figure 3. *Complete set of putative LEAFY transgenics before soil transfer.*

<u>Effect of transgenes on rubber content by ASE (tissue culture)</u>:
Our first set of ASE data (below) showed % rubber at equal or lower values for experimentals vs. control lines. Interestingly, SEP3i -H had significantly lower stembark rubber. Recall this line previously showed a more upright architecture and other unusual characteristics (see below). % Resin, similarly, showed equal to lower values for SEP3i RNAi lines compared to the controls. We have revised the protocol to expose plants to longer greenhouse conditions (90d) before cold treatment and rubber/resin analysis.

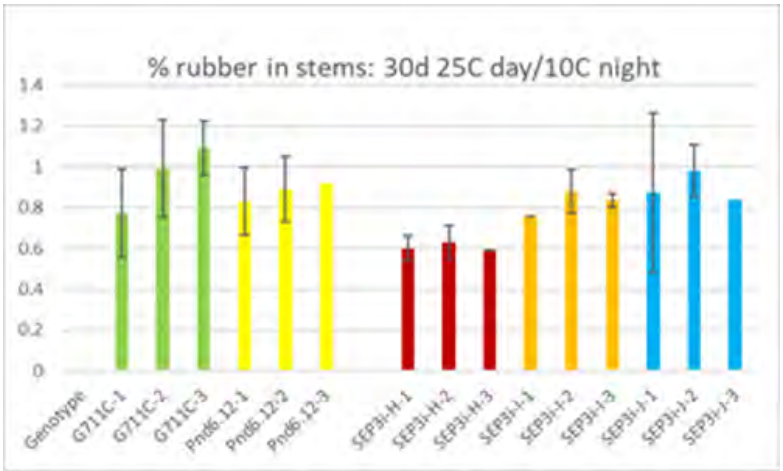


Figure 4. *Percent rubber in stems.*

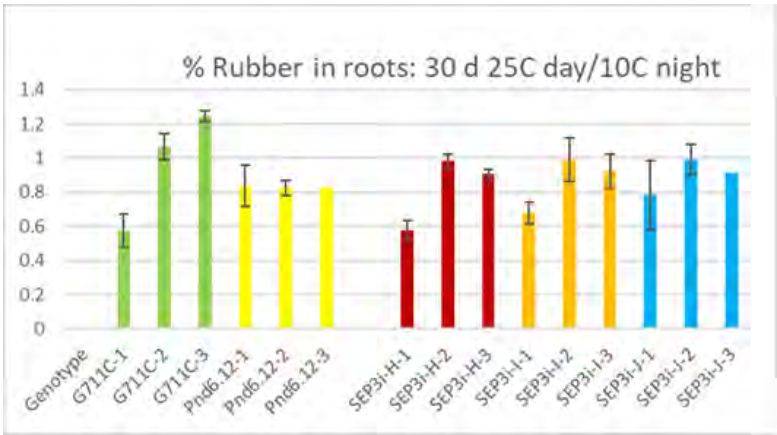


Figure 5. *Percent rubber in roots.*

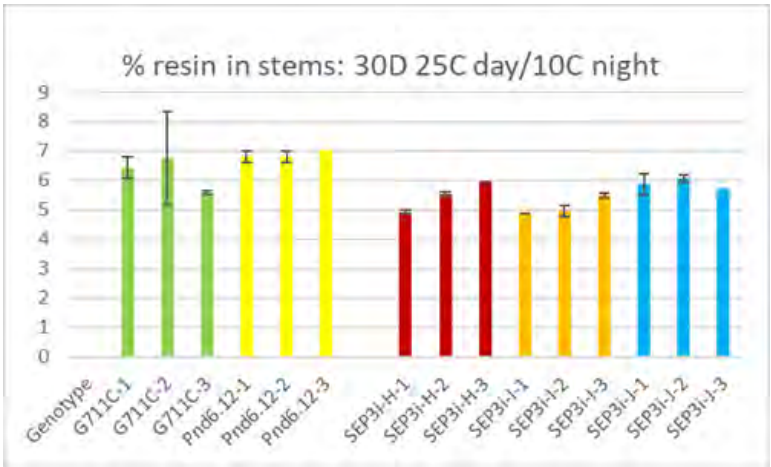


Figure 6. *Percent resin in stems.*

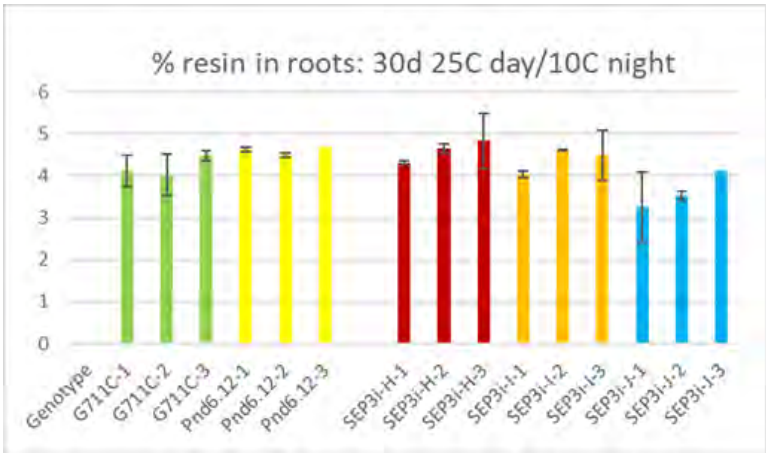


Figure 7. *Percent resin in roots.*

Transfer plants to greenhouse for flowering phenotype:

For the SEP3i genetic modification, ten lines in total have been recovered and moved to soil in the greenhouse. Due to space limitations, the phenotyping studies are being conducted in 3 sets. For each set, TC plants are moved to soil, then hardened in the greenhouse, then moved to the growth chamber for cold treatment/phenotyping.

Set 1: lines H, I, J: First round of growth chamber studies almost complete (see preliminary data below)
Set 2: lines A, B, C, E: Plants in growth chamber
Set 3: lines D, F, G: Plants hardening in greenhouse

Trends noted from the initial phenotyping include:

1. Lower flower number in some cases but not all.
2. Lower biomass for SEP3 lines I and J, but not for line H.

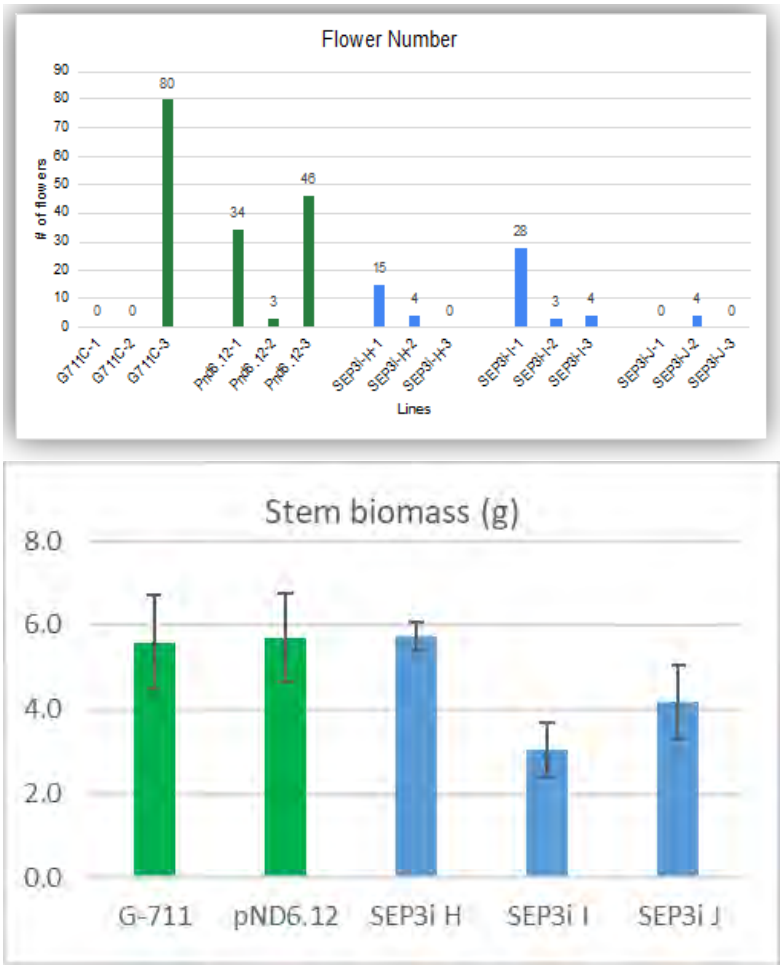


Figure 8. *Flower number and stem biomass for SEP3i genetic modification.*

An additional observation is that Line H has a distinct upright architecture. Rubber and resin content analysis are underway as of 4/17/21.

Figure 9. *Growth architecture of SEP3 lines under evaluation.*

===

In 2Q1, we continued phenotyping of SEP3i lines. Ten lines in total have been recovered and moved to soil in the greenhouse. Due to space limitations, the phenotyping studies are being conducted in 3 sets. For each set, TC plants were moved to soil, then hardened in the greenhouse, then moved to the growth chamber for cold treatment/phenotyping.
Set 1: lines H, I, J. First round of rubber and resin analysis almost complete (see below).
Set 2: lines A, B, C, E. Currently being processed for rubber and resin extraction via ASE.
Set 3: lines D, F, G. Plants in the growth chamber (partial set).

In the greenhouse conditions, we note the morphology of SEP3i-H-3 was different compared to the other transgenics where its flowering meristem grew out of an axillary meristem instead of its primary meristem. There are more flowering meristems on this transgenic compared to the controls near it.

Photo 1. *Flowering meristems for three samples: (L to R) Pnd6.12, G711C, and SEP3i-H.*

Growth and Rubber/Resin Content in Guayule Germplasm Lines:
Bridgestone transplanted seedlings at Campbell Ave farm on 10 February (four beds, five varieties).

Harvested the Campbell Avenue farm (Campus Ag Center) plants on 6 April. Recorded fresh weight of three plants then left to dry in the field. Chipped on 13 April, then dried further in lab.

Table 4. *Mean weights of guayule plants harvested from Campbell Ave. on 6 Aril. Values not connected by same letter are significantly different.*

Level	Number	Mean	Std Dev
AZ3	3	7.1	3.6 a
11635	4	6.1	3.6 ab
11693	4	6.0	3.2 abc
N575	4	5.8	5.3 abcd
N566	4	5.6	2.9 abcd
11701	4	5.4	2.3 abcd
AZ2	4	5.0	1.8 abcde
AZ5	4	4.9	2.2 abcde
AZ1	4	4.3	1.1 abcde
4265XF	3	4.2	0.8 abcde
R1108	3	4.0	1.4 abcde
R1100	4	4.0	1.8 abcde
11604	4	3.7	1.7 abcde
CAL7	3	3.5	1.2 abcde
593	4	3.0	1.7 bcde
R1093	4	2.8	0.9 bcde
CFS17-2005	3	2.7	1.0 bcde
4265X	4	2.7	1.4 cde
11619	3	2.6	3.0 bcde
R1101	4	2.5	0.9 de
11634	3	1.7	0.5 e

Root Growth/Architecture Compared to Water Use in Direct Seed and Transplant-Established:
This task is complete.

Objective 2. Develop high-throughput phenotyping to support crop expansion using remote-sensing methods to create interactive databases/tools.

Task #	Description of Task	Deliverable	Target Completion Date
1 Abdel-H.	Phenotypic characterization - Guayule	Collect and analyze available phenotypic data; plant stand and establishment, plant height and width, flowering time, rubber, resin	31 Dec 21
		Collect and analyze first set of available high-throughput	31 Dec 21

		phenotyping (HTP) parameters: vegetation indices and reflectance Summary report completed	 30 Jun 22
2 Abdel-H.	Phenotypic characterization – Guayule under stress conditions and stability	Field planting – plant and maintain USDA guayule collections Collect and analyze available phenotypic data: plant ht, plant width, flowering time, rubber, resin Collect and analyze available high-throughput phenotyping (HTP) parameters: vegetation indexes and reflectance Summary report completed	30 Jun 20 31 Dec 21 31 Dec 21 30 Jun 22
3 Angadi	Guar remote sensing	Seasonal multispectral data from deficit irrigation study	31 Mar 20

Phenotypic characterization – Guayule:
Evaluation of 48 USDA guayule accessions grown under normal Arizona conditions. A data set were collected from Maricopa site and are organized and shared with other sites toward summarizing and publishing in collaboration with Eloy and Tucson teams.

Phenotypic characterization – Guayule Under Stress Conditions:
An experiment to test stress responses in USDA guayule genotypes, including genotypes are first time to be tested, and 6 common checks is planted at Maricopa, AZ to study responses of guayule genotypes growing under stress and non-stress conditions, and the interactions of irrigation treatments by genotypes (G x E) interactions. Normal irrigation schedules were stated as non-stress while reduced irrigation is stated as stress treatments. At both trials, plots are maintained by hand weeding as needed. One-year plants were harvested in November 2020, and due to global COVID-19 pandemic situation and USDA policies of minimum essential operations at USDA-ALARC facility and maximum teleworking, dried plants were kept in the -18C.

The rubber and resin quantifications were analyzed and results are shown below. Data showed that resin and rubber content are affected by genotypes as well as irrigation levels (stress conditions). In general, drought stress condition reduced rubber %, still the reduction rates were varied among genotypes, indicating that there are different genetic bases for that variation and drought stress tolerance among guayule genotypes could follow different mechanisms. There was no clear correlation between stress condition and resin, where there is no clear trend among genotypes for resin induction under stress and non-stress conditions. Those data could indicate that the independence of inheritance of rubber and resin in guayule. When confirmed with 2-year old data (will be harvested in November 2021) several guayule genotypes could be good candidates for drought stress tolerance breeding and further studies.

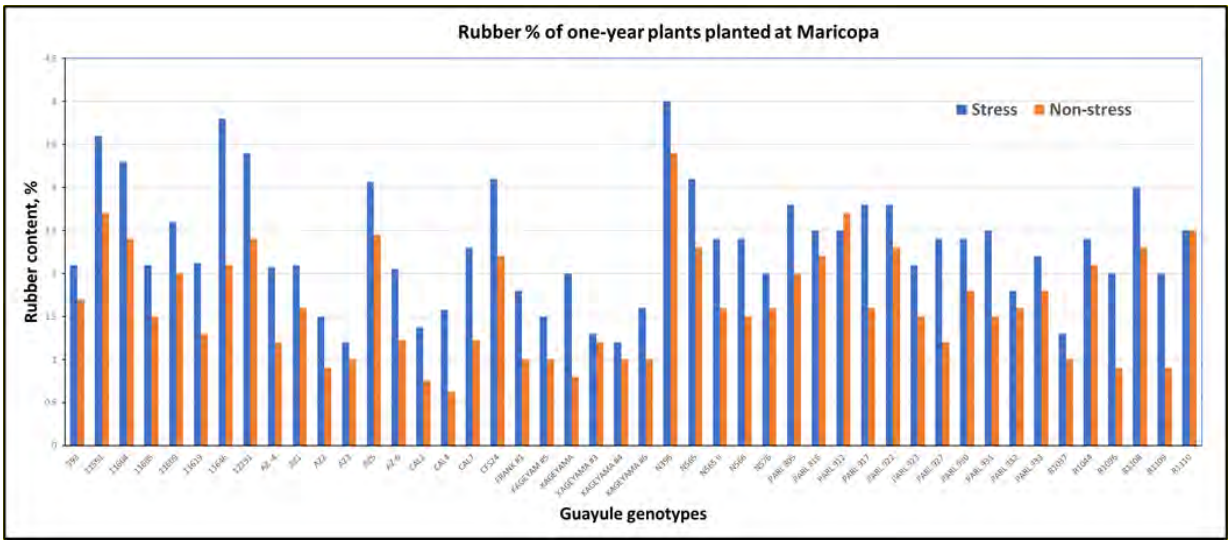


Figure 10. *Rubber percentage of one-year guayule plants at Maricopa Agriculture Center, Arizona.*

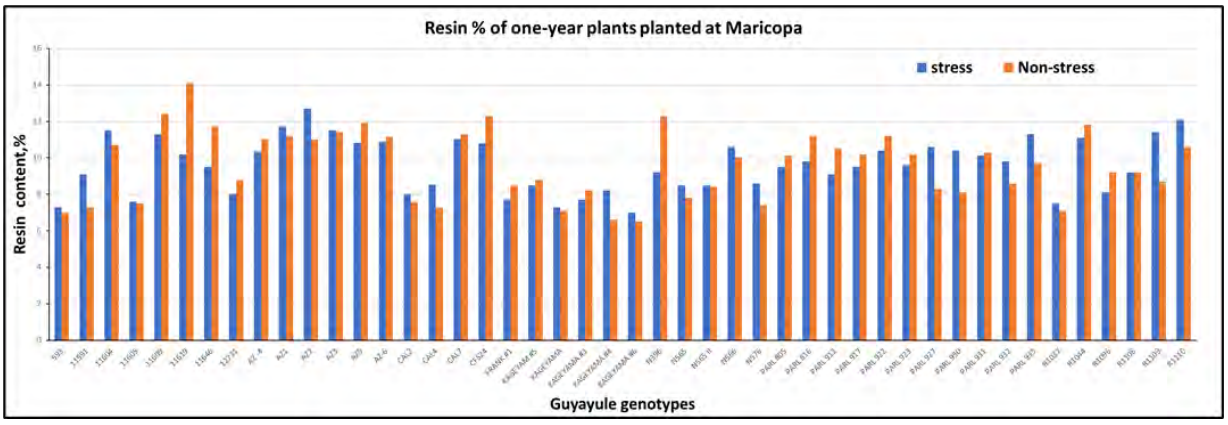


Figure 11. *Resin percentage of one-year guayule plants at Maricopa Agriculture Center, Arizona.*

The remote sensing data were collected 3 times and preliminary analyses were conducted. Estimation of the vegetation indexes and canopy temperatures were analyzed and results are shown in the figures below. Data showed that vegetation indexes and canopy temperatures are affected by genotypes as well irrigation levels (stress conditions). In general, drought stress condition reduced those traits still the reduction rates were varied among genotypes, indicating that there are different genetic bases for that variation and drought stress tolerance among guayule genotypes could follow different mechanisms.

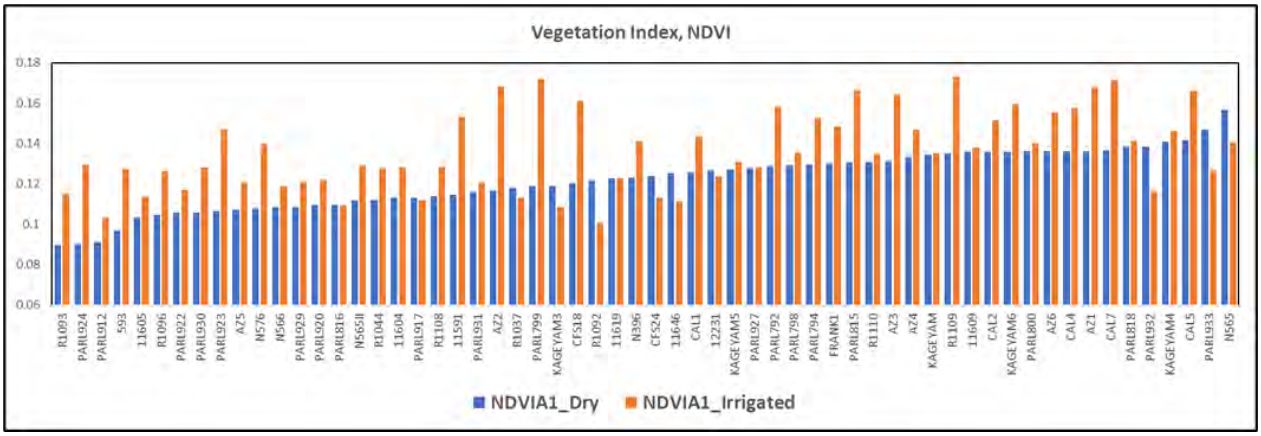


Figure 12. *Vegetation index for guayule plants sampled at MAC.*

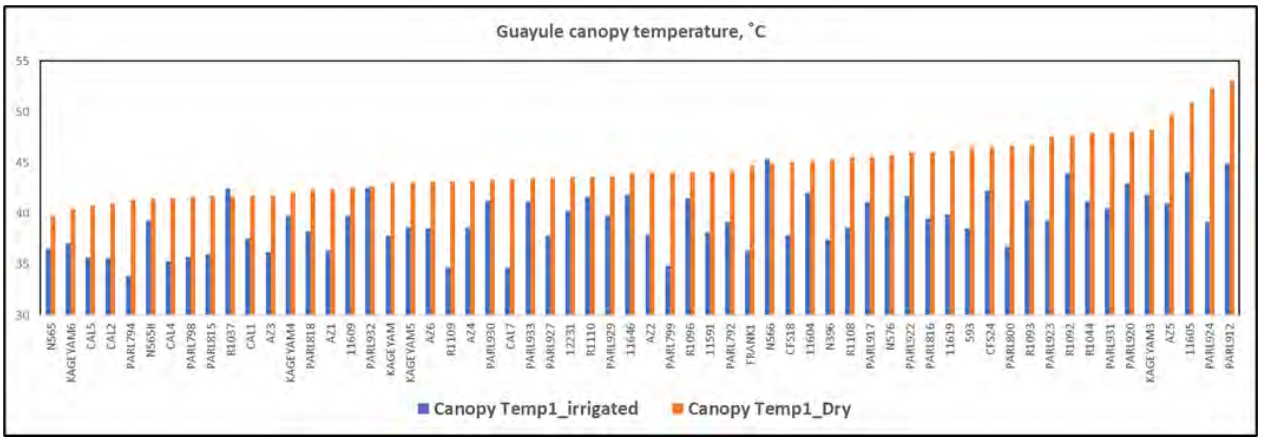


Figure 13. *Guayule canopy temperature sampled at MAC.*

Guar Remote Sensing:
This task is complete.

Objective 3. Deploy superior genotypes of guayule and guar to regional growers.

Task #	Description of Task	Deliverable	Target Completion Date
1 Angadi	Evaluate guar germplasm in New Mexico high plains environment	Screen guar germplasm for adoptability in High Plains Assess available guar cultivars at Clovis, NM	31 Mar 21 31 Jul 21
2 Grover	Evaluate guar germplasm lines for field performance	Thresh remaining Yr3 samples for seed collection	31 Oct 20
3 Ray	Evaluate seed from plants surviving root rot inoculation	New germplasm lines screened for the first time	31 Aug 21

4 Ray	Guayule salt tolerance trials	Screen new germplasm lines with most tolerance Surviving plants transplanted to field to increase seed Seed from surviving plants collected and planted for 2nd round of selection	31 Jul 21 30 Apr 21 31 Aug 21
5 Ray	Guar yield trials in Tucson, AZ; Las Cruces, NM; and Clovis, NM	Yield trials planted in 3 locations Yield trials harvested; yields compared	30 Jun 20 31 Dec 20

Guar Germplasm in New Mexico:
This task is complete.

Guar Germplasm Field Performance (threshing):
The study was harvested at Lyendecker Plant Science Center, Las Cruces, New Mexico, and plant samples collected for final seed yields. Threshing of the square meter harvested samples are completed and data were analyzed and shared with the Feedstock Development Lead. (see below for more detail)

Additionally, single plants threshing completed and data were collected – data analysis will be completed and shared on seed yield attributing characteristics.

In the year 2020, the highest plant dry biomass was produced by the genotype PI593058 (4,267 kg/ha) followed by PI180434 (3,967 kg/ha) and PI263406 (3,858 kg/ha). The highest seed yield of 1,350 kg/ha was recorded for the guar genotype PI593058 followed by seed yields of 1,317 kg/ha for PI263406 and 1,200 kg/ha for PI180434, respectively.

The highest harvest index of 0.47 was recorded for the genotype PI593049, followed by 0.42 for PI186477 and 0.39 for the genotype PI217923 at Lyendecker Plant Science Center in 2020.

Table 5. *Plant biomass, seed yield and harvest index of Guar germplasm lines, regional test study, 2020, at Lyendecker Plant Science Center, Las Cruces, NM.*

	Dry biomass (kg/ha)		Seed yield (kg/ha)		Harvest index	
Genotype	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
KINMAN	3100	313	1042	115	0.34	0.02
LEWIS	2283	357	817	208	0.35	0.03
MATADOR	3383	730	1108	194	0.33	0.03
PI158125	2692	548	858	142	0.32	0.03
PI158126	3225	438	975	246	0.30	0.04
PI164486	3067	298	900	87	0.30	0.04
PI176377	3008	877	892	330	0.29	0.03
PI179926	3050	1148	975	368	0.32	0.01
PI180434	3967	939	1200	425	0.30	0.04
PI186477	2258	496	958	218	0.42	0.01
PI217923	2617	227	1033	138	0.39	0.03
PI250360	3383	580	958	113	0.28	0.01
PI253182	2342	485	775	130	0.34	0.07
PI253186	2442	319	917	177	0.37	0.03
PI253187	3150	517	1167	318	0.37	0.05
PI262152	3433	645	895	48	0.27	0.06
PI263406	3858	354	1317	177	0.34	0.02
PI263698	3758	615	1042	29	0.28	0.04
PI268629	3183	681	900	205	0.28	0.01
PI338745	3442	1162	1033	325	0.30	0.03
PI338811	3817	274	1225	43	0.32	0.02
PI340261	3433	1014	1100	409	0.32	0.03
PI537281	3375	1054	1000	390	0.29	0.03
PI542608	3808	1092	1083	321	0.28	0.00
PI593048	2825	988	875	346	0.31	0.03
PI593049	2083	757	892	351	0.47	0.28
PI593058	4267	538	1350	363	0.31	0.05
PI671848	3250	246	1000	130	0.31	0.03

Seed Evaluation following Root Inoculation and Root Inoculation per Guayule Germplasm:
No new data to report. Work on new screenings has stopped until new sources of the root rot fungus are obtained. Fungal samples to inoculate guayule are currently unavailable and it's unlikely that our cooperator will be able to supply inoculant before the end of the grant. No further data is expected for this task.

Guayule Salt Tolerance Trials:
New lines have been transplanted and are ready for evaluation. Seed has been collected and is in storage.

Guar Yield Trials in Tucson, AZ; Las Cruces, NM; and Clovis, NM:
This task is complete.

Objective 4. Deploy agronomic production practices; identify agronomic information for salinity, herbicide, and nutrients to support production; provide irrigation apps using algorithms to growers.

Task #	Description of Task	Deliverable	Target Completion Date
1 Angadi	Conduct guar critical stage-based deficit irrigation trial	Report on growth stage-based irrigation management Present data at regional and national conferences	30 Nov 20 30 Nov 20
2 Dierig	Bi-monthly harvest from irrigation trials	Growth data over seasons from two locations	31 May 22
3 Dierig	Irrigation Timing Study	Plant replicated trial and begin treatments	31 Aug 21
4 Grover	Evaluate guar germplasm lines for field performance	Collect field data and harvest samples. Process lab data and complete data analysis. Generate report/publication from results obtained	30 Jun 21 30 Jun 21 31 Aug 21
5 Grover	Evaluate guar response for salinity tolerance	Screen 27 diverse guar lines under salinity stress Identify sources of salinity tolerance characterized by gene expression analysis. Summarize results	30 Jun 21 31 Aug 21 31 Dec 21
6 Grover	Evaluate guar response to moisture stress	Review, edit manuscript draft Revise, complete, submit manuscripts to journals	31 Dec 20 31 Mar 21
7 Grover	Evaluate guar response to planting density	Track and collect research data on guar density experiment Generate report/publication from results obtained	30 Jun 21 31 Aug 21
8 McClos	Conduct guayule herbicide tolerance study, at Eloy and Maricopa, AZ (Fall)	Collect data to support 24c SLN herbicide registrations – (a) post-directed herbicide; (b) herbicide application sequence for chemical weed control from seeding to 6mo old plants; (c) evaluate topical postemergence broadleaf herbicide	31 May 21
9 McClos	Conduct guayule herbicide tolerance studies, at Eloy and Maricopa, AZ (Spring)	Collect data to support 24c SLN herbicide registrations – (a) post-directed herbicide; (b)	31 Aug 21

		herbicide application sequence for chemical weed control from seeding to 6mo old plants; (c) evaluate topical, postemergence broadleaf herbicide	
10 McClos	Generate manuscripts and Extension bulletins	Research reports and manuscripts complete Extension bulletin and 24c SLN ADA application complete	31 Dec 20 31 Aug 21
11 Ogden	Development and testing of AquaCrop model	Growth model compared to field data	31 Dec 20
12 Ray	Guayule density trial	Yields for 2 lines, 5 densities, 2 locations, and 2 seasons compared	30 Nov 21
13 Ray	Range of N and P application	Compare N and P utilization and effects of nutrients on biomass, rubber and resin production	30 Nov 20
14 Ray	Direct-seeded vs. Transplant-established guayule	Compare root growth and top growth vs. water usage under varying conditions	31 Mar 21
15 Waller	Monitor TDR, infrared camera and flowmeter system	Provide data on guayule irrigation experiments Provide data set that can be used to refine the use of sensors for WINDS crop irrigation mgmt.	31 Aug 21 31 Aug 21
16 Waller	Integrate WINDS model with existing tools	Integrate new model with WINDS (winds.arizona.edu), and in-situ sensors	31 Aug 21
17 Waller	Irrigation experiments: Guayule and Guar	Collect data; image collection, neutron probe readings, in-situ sensors, crop coefficient development and destructive plant samples for chemical analysis Develop automated calibration system for WINDS	31 Aug 21 31 Aug 21

Guar Critical Stage-Based Deficit Irrigation Trial:

Data from all field trials have been compiled and data was sent to appropriate person to work on the report. Due to Covid19, conference presentation of guar deficit irrigation is delayed to this year and will be presented in 2021 meetings.

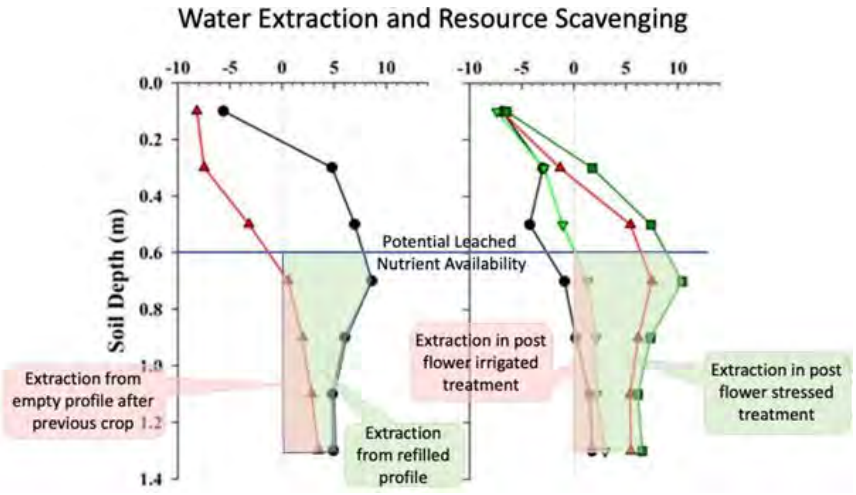


Figure 14. *Water extraction and resource scavenging in guar field, Clovis NM.*

My former graduate student, Jagdeep Singh, is working on the data from deficit irrigation and working on developing two manuscripts, which are expected to be ready by the end of July. Preliminary results were presented in the 2021 UCOWR Annual virtual meeting. An abstract has been submitted to ASA-CSSA-SSSA annual meeting to present final analysis and interpretation of the study. I have hired a new lab tech, Ms. M. Nielson. She will help with some research work. My effort to hire graduate student was delayed to fall. Therefore, I am trying to hire a Student Graduate Specialist to help with summer field research. He will help with deficit irrigation study.

Photo 2. *Aerial view of deficit irrigation field trial locations, Clovis NM.*

We are working on field research preparation and planning for 2021 field season. We hope to initiate second stage deficit irrigation study, which incoming graduate student will continue in 2022 field season. The student is expected to start in the fall. Dr. Dennis Ray's germplasm evaluation and a trial on agronomic management will be conducted at Clovis in the summer.

Next stage of assessing temperature requirement for germination and early growth will assess USDA germplasm as well as diverse breeding lines for cooler soil conditions will be initiated in the summer.

Field research trials were planted on June 7th and 8th and they are doing very well. A new trial combining deficit irrigation and fertility management effects on diverse guar cultivars was

initiated. We also planted Dr. J. Idowu's new plant population demonstration study. Germplasm evaluation trial of Dr. D.T. Ray is completed, and all data is submitted to Dr. Ray. Data from N & P trial was sent to Ms. D. Pruitt for analyzing and reporting in her thesis.

Bi-Monthly Harvest from Irrigation Trials:
Nothing new to report.

Irrigation Timing Study:
This is a deficit irrigation study for guayule.

Treatments:

1. Full Irrigation: Irrigate as determined by the model developed as part of this project.
2. Stress for Harvest: Full irrigation for the first 18 months, then stop irrigation. Sample plants every two months to study if stress helps rubber and resin content before final harvest.
3. Half Irrigation: Irrigate every other irrigation as determined by the model.
4. Minimum Irrigation: Irrigate three times per year, approximately every growth stage (May/June, September, and February).
5. Minimum Year2: Year 1 irrigate as determined by the model, and Year 2 irrigate three times (February, May/June, September).
6. One Irrigation: One irrigation after establishment in the first year (Sept), one irrigation in year 2 (Apr).

Photo 3. *Guayule plants from the stress irrigation trial, 2020.*

Data and Results:

Data on plant growth, rubber and resin content and yield have been collected during quarter 1 on both varieties from all treatments. These plant samples represent the first 9 months of growth. In the first year, treatments 1, 4 and 6 received the same amount of irrigation since stress is applied at year 2 in treatments 4 and 6. Treatments 3 and 5 are also the same in the first year for the same reason. Three different treatment amounts are applied in year 1. The legend is colored to show the ranking of treatments that in the first year are equal in amount of water applied.

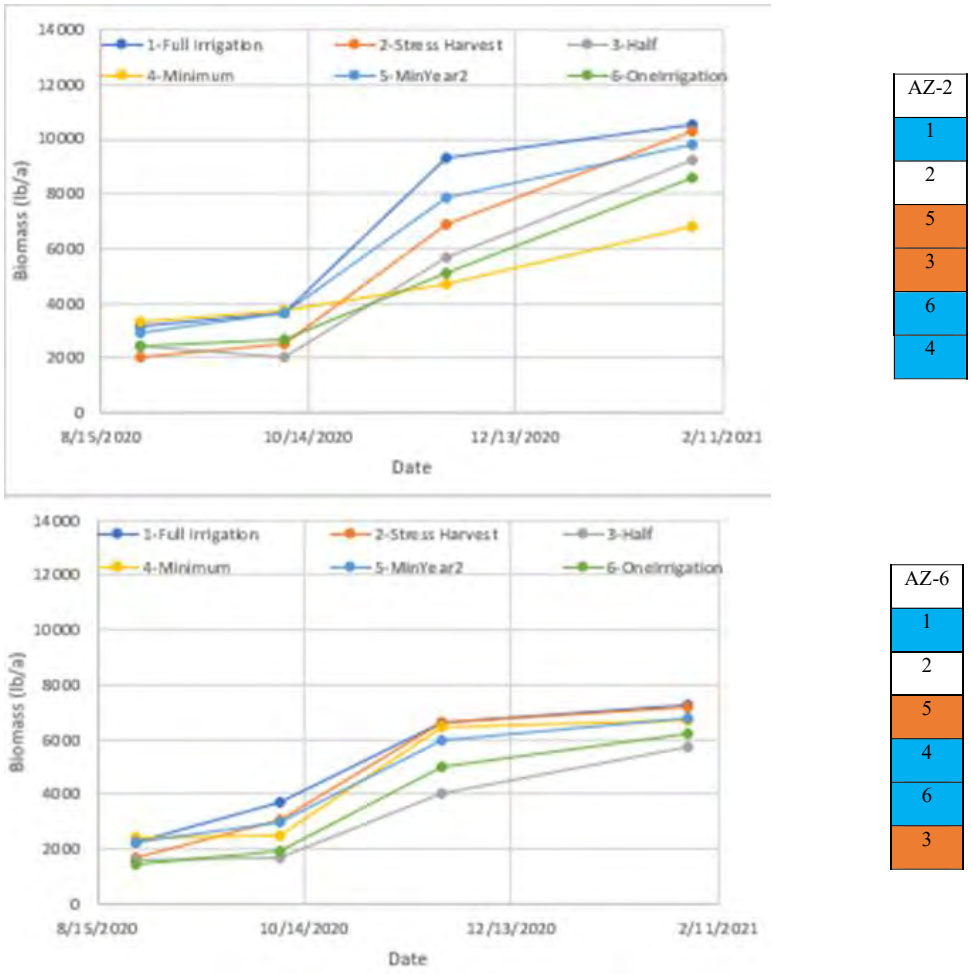


Figure 15. *Biomass yield over time for AZ-2 and AZ-6. Treatments with the same color in the right-hand legend had equal amounts of water applied in the first year since some treatments are not stressed until year 2.*

In the first year, full irrigation, stress before harvest, and minimum irrigation in year 2 received the same amount of irrigation. Generally, although plants in deficit irrigation treatment survived the summer, the plants are smaller. AZ-6 seemed to tolerate drought stress better compared to AZ-2 but are smaller than AZ-2 plants.

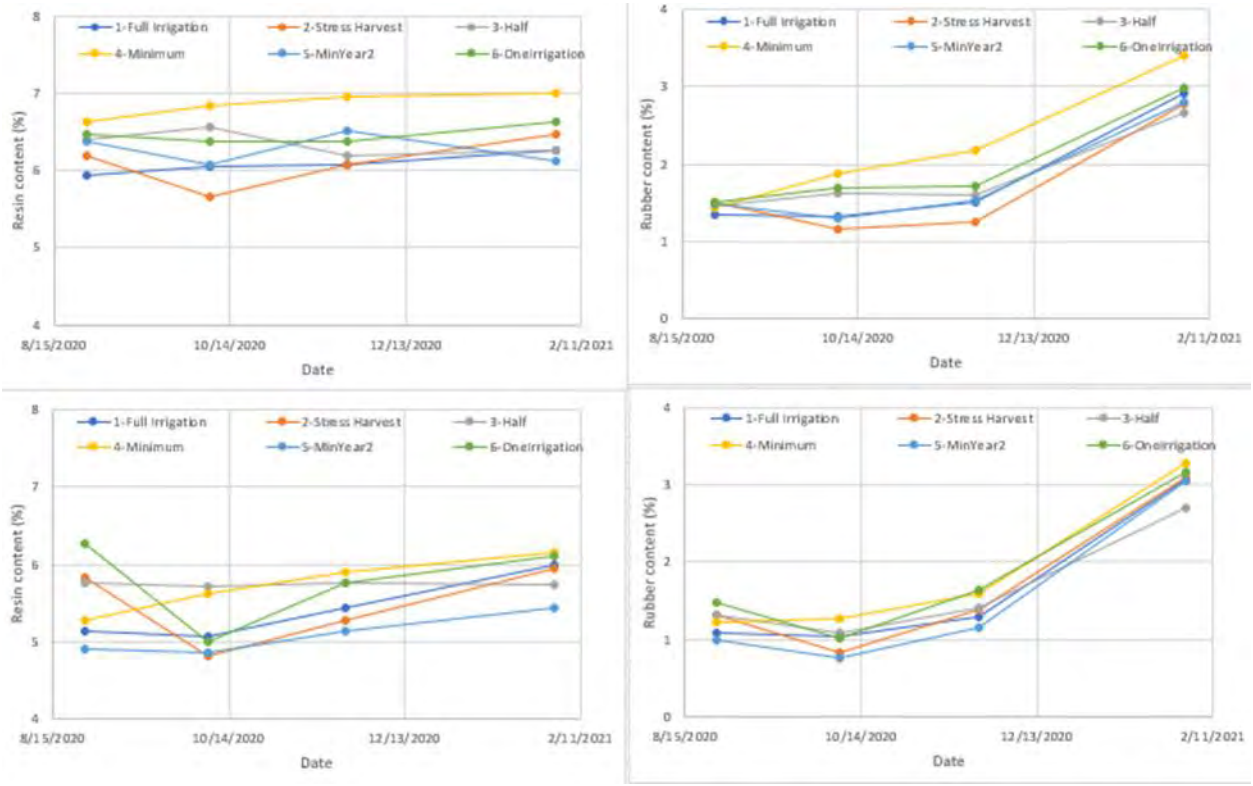


Figure 16. *Resin and rubber content under different irrigation treatments for AZ-2 (above) and AZ-6 (below).*

Resin content was high at an early stage for both AZ-2 and AZ-6, while rubber content increased significantly during the winter as expected. The differences among irrigation treatments on rubber content is small at this stage and will be measured going forward. As a result, trends for rubber and resin yield are similar to biomass.

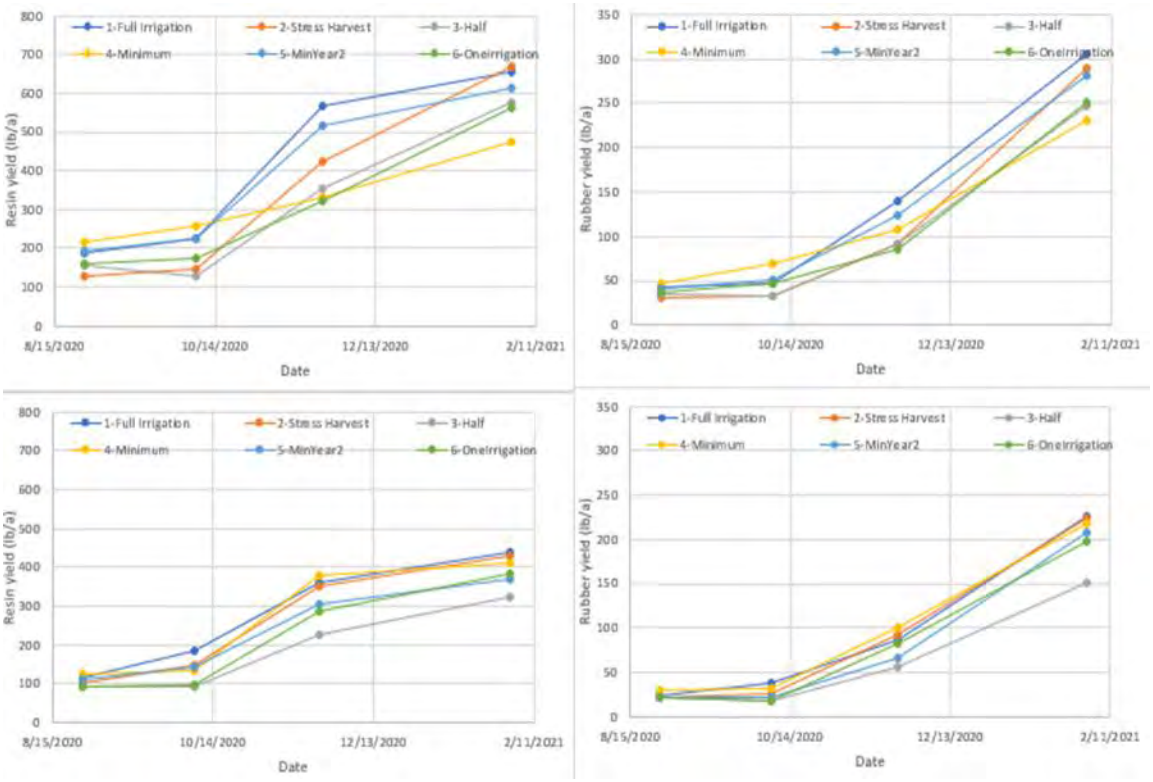


Figure 17. *Resin and rubber yield under different irrigation treatments for AZ-2 (above) and AZ-6 (below).*

Canopy width and height showed similar trend as NDVI. However, there were no significant differences in canopy temperature among the treatments. This was surprising as one expects irrigated plots would have cooler canopy temperatures. We will compare this measurement with data collected by USDA and U of A scientists.

=====

Additional data on plant growth, rubber, and resin content/yield were collected in quarter 2 on both varieties from all treatments. These plant samples represent the first 14 months of growth. In the first year, treatment from 1, 4, and 6 received the same amount of irrigation since stress in applied at year 2 in treatments 4 and 6. Treatments 3 and 5 are also the same in the first year. Three different treatment amounts are applied in year 1.

Photo 4. *Stress irrigation trial in 2020 [AZ-6 (left); AZ-2 (right)], Eloy, Arizona.*

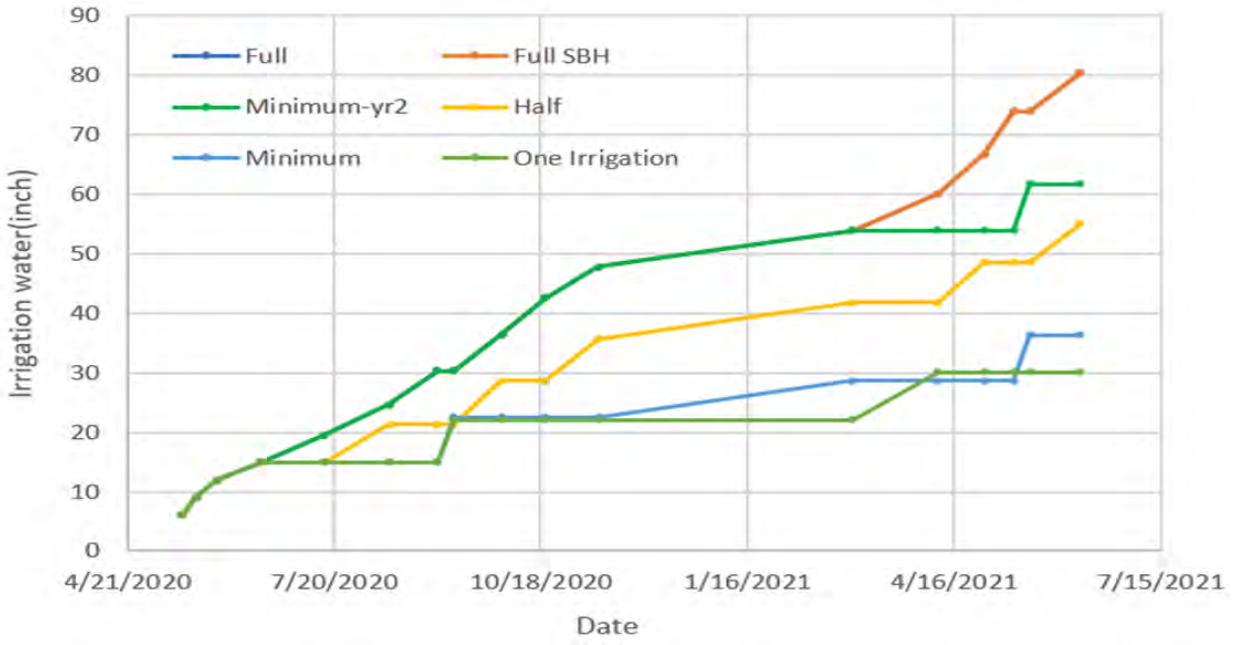


Figure 18. *Applied irrigation water to the 6 different treatments at Eloy including establishment.*

Differential treatments started after the scheduled June 15, 2020 irrigation. By June 2021, Treatment #1, the Full irrigation treatments received 80 inches of water, while Treatment #6 (One Irrigation) treatment received 30 inches of water.

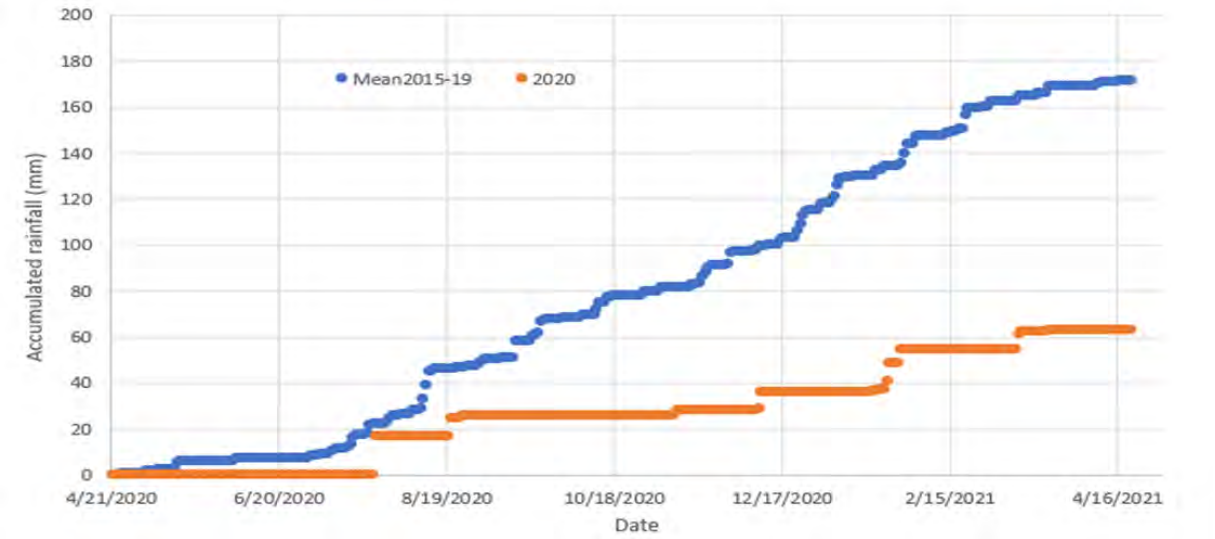


Figure 19. *Rainfall in Eloy, Arizona, in 2020 vs. 2015-2019 mean.*

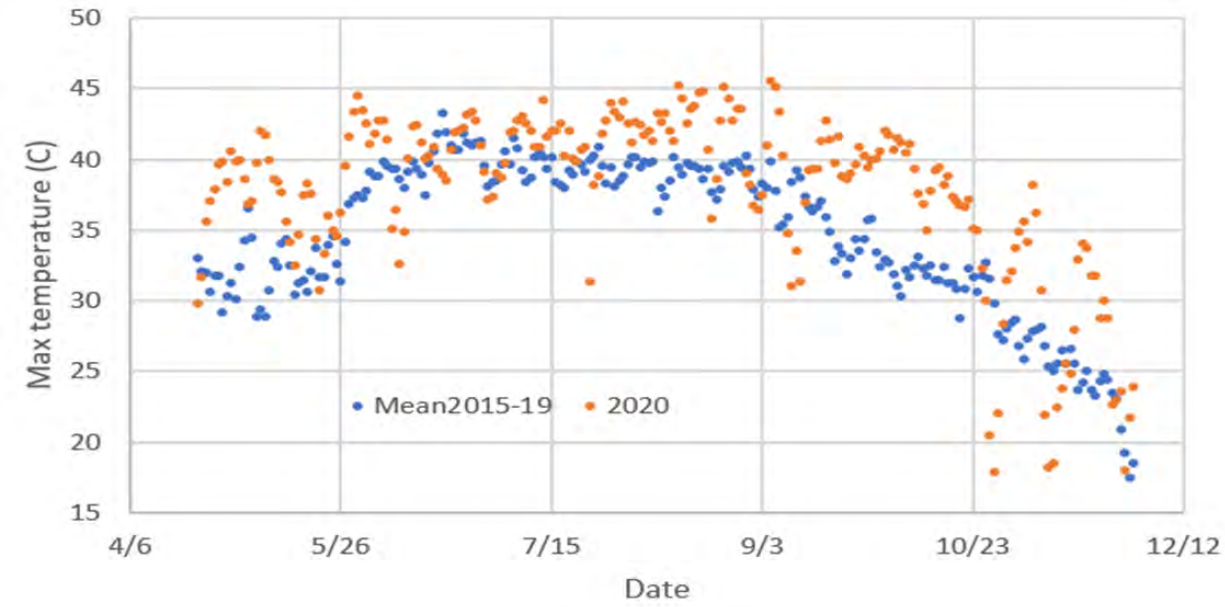


Figure 20. *Temperature in Eloy, Arizona, in 2020 vs. 2015-1019 mean.*

The summer of 2020 was the driest and hottest summers in Arizona history. The Minimum irrigation and One Irrigation treatments did not receive water from June 15 to September 15 in 2020. Guayule was able to survive.

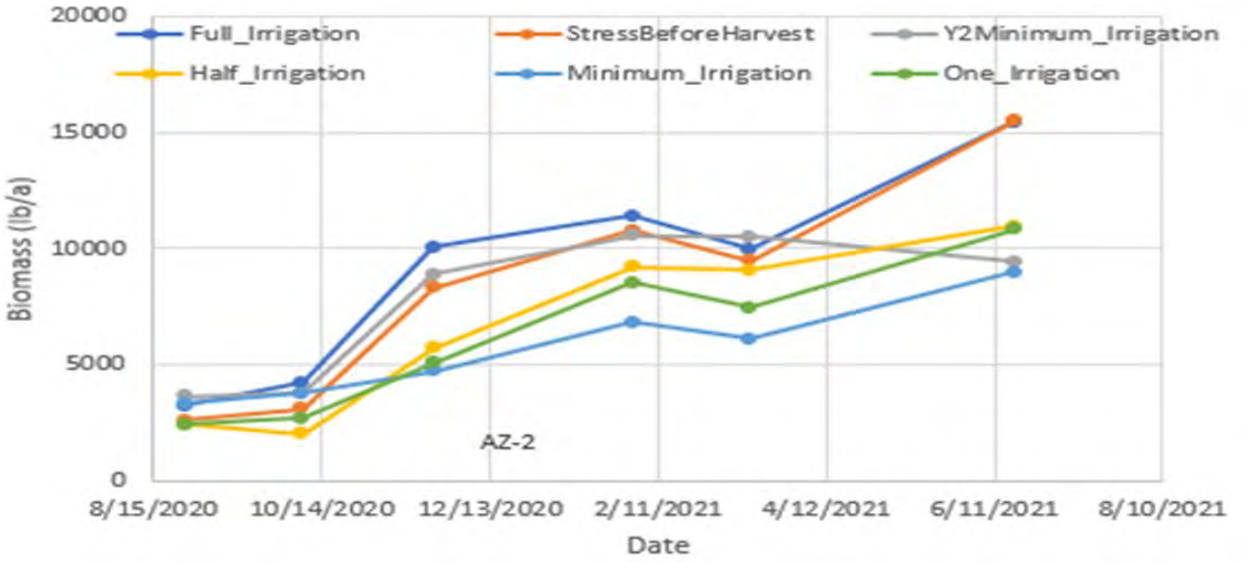


Figure 21. *Biomass yield over time under different irrigation treatments for AZ-2.*

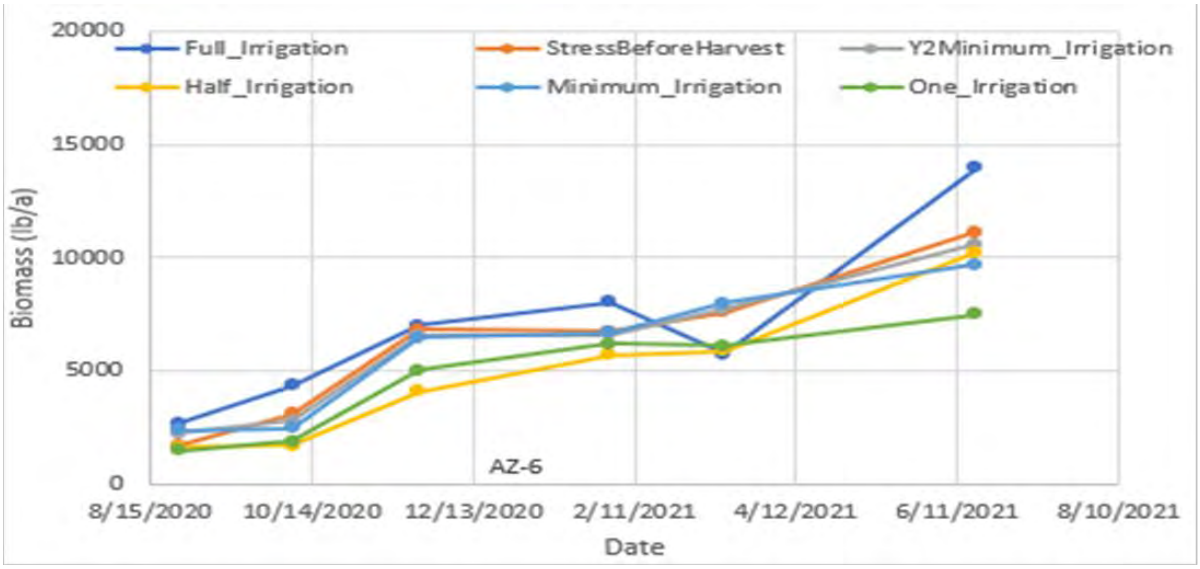


Figure 22. *Biomass yield over time under different irrigation treatments for AZ-6.*

Although drought stress reduced biomass as expected, guayule biomass under stress still increased, but at a lower rate. Short-statured AZ-6 was affected less by drought treatment. This indicates that guayule can survive with 1-3 irrigations per year after establishment, providing a good option for Arizona farms with low water availability.

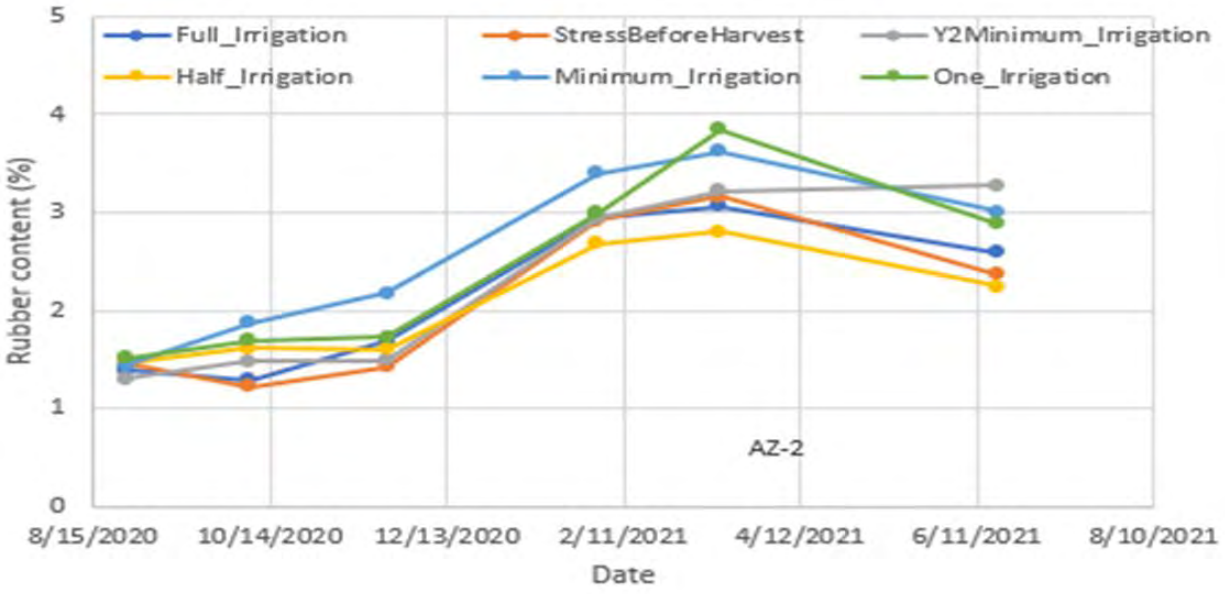


Figure 23. *Rubber content over time under different irrigation treatments for AZ-2.*

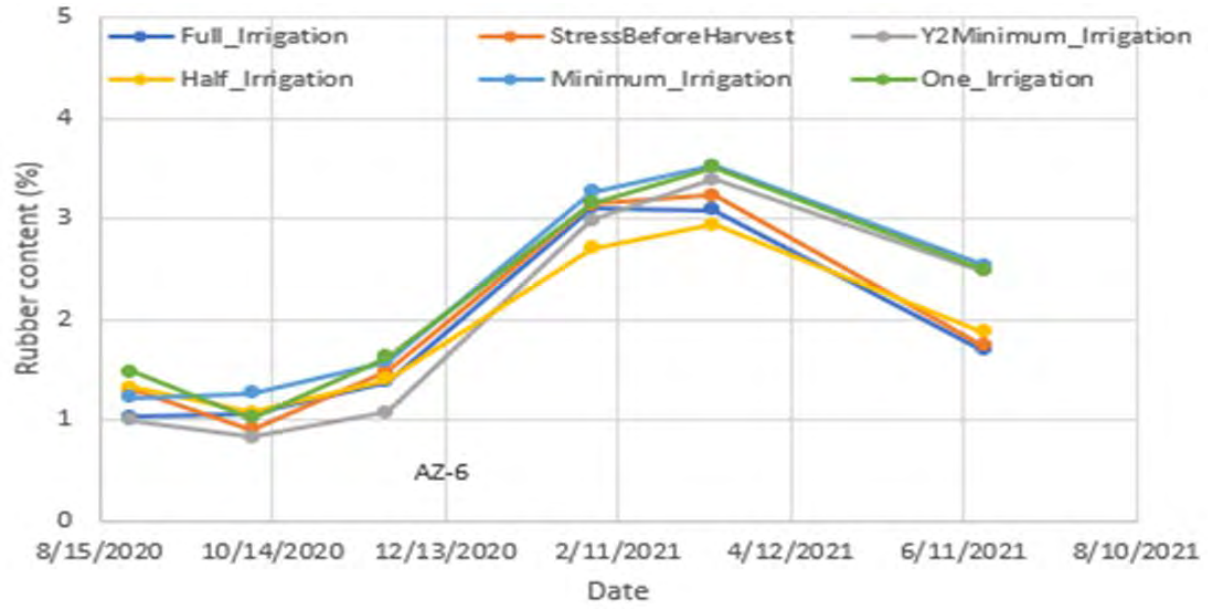


Figure 24. *Rubber content over time under different irrigation treatments for AZ-6.*

Rubber content increased significantly in the first winter. Then rubber content decreased due to dilution from fast biomass growth during spring. Drought stress did not affect rubber content significantly. AZ-2 had slightly higher rubber than AZ-6 at 14 months.

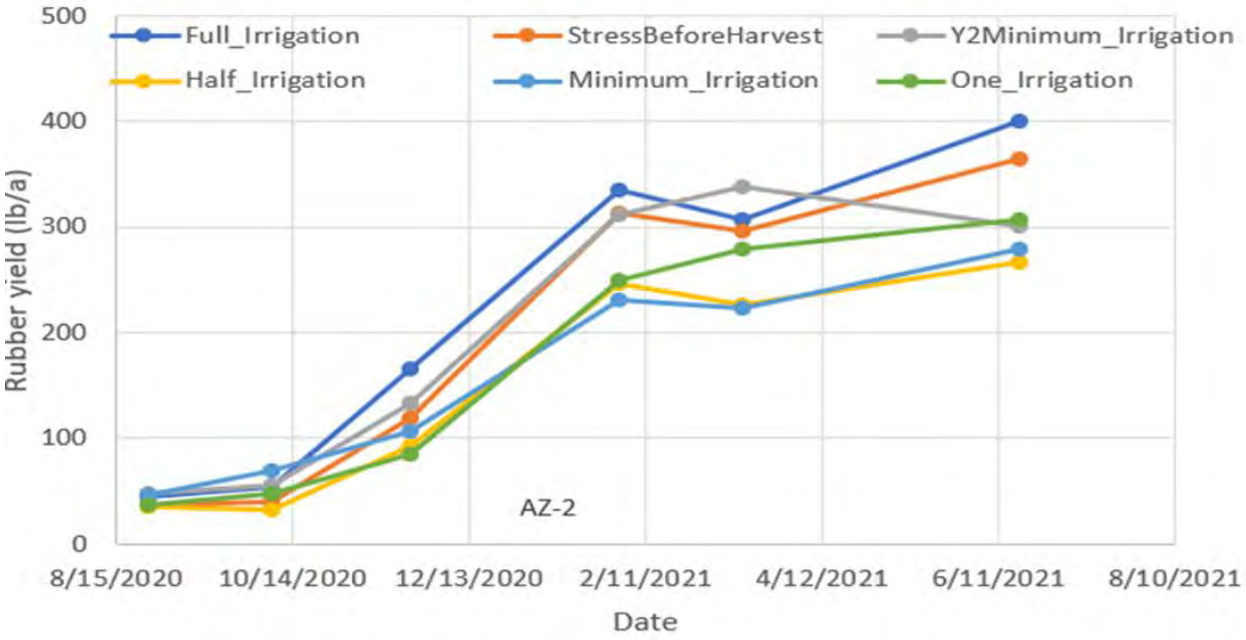


Figure 25. *Rubber yield over time under different irrigation treatments for AZ-2.*

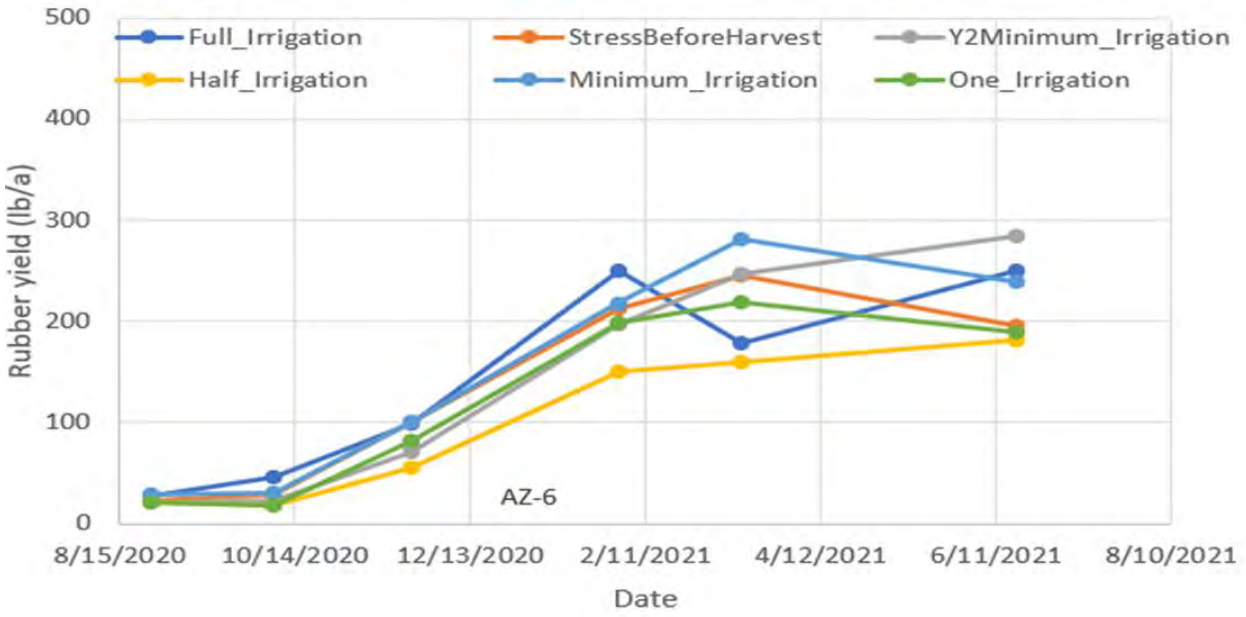


Figure 26. *Rubber yield over time under different irrigation treatments for AZ-6.*

A few general observations:

- AZ-2 had a higher rubber yield than AZ-6 due to higher biomass.
- In 14 months, the One Irrigation and Minimum Irrigation treatments (30-37 inches of water) had respectable rubber yield compared to the Full Irrigation treatment (80 inches of water), showing guayule can be grown with low water input.
- 30 inches of irrigation water per year would be too low for all other major crops in Arizona.

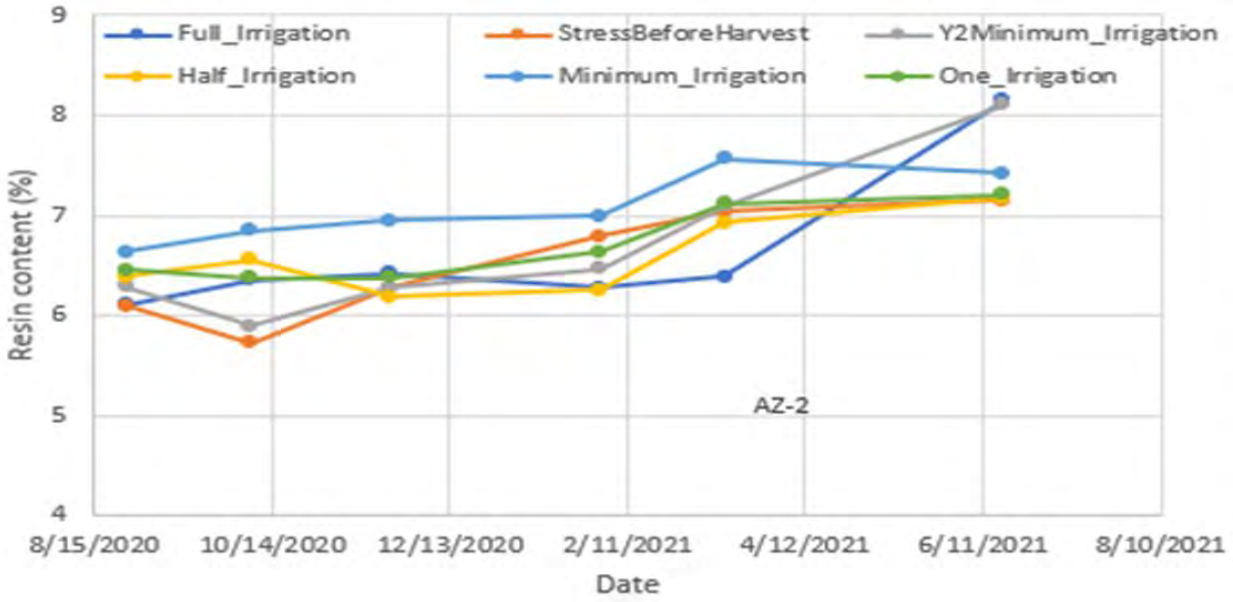


Figure 27. *Resin content over time under different irrigation treatments for AZ-2.*

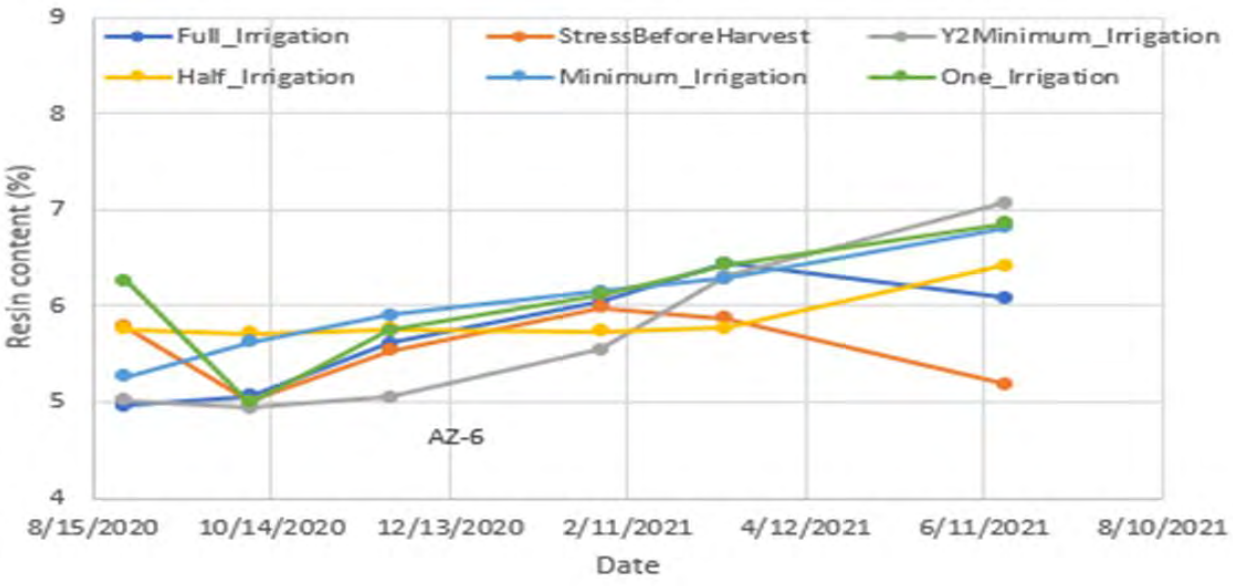


Figure 28. *Resin content over time under different irrigation treatments for AZ-6.*

Resin content was already at a high level at early stage and increased slowly over time. AZ-2 had higher resin content than AZ-6. Drought stress did not affect resin content significantly.

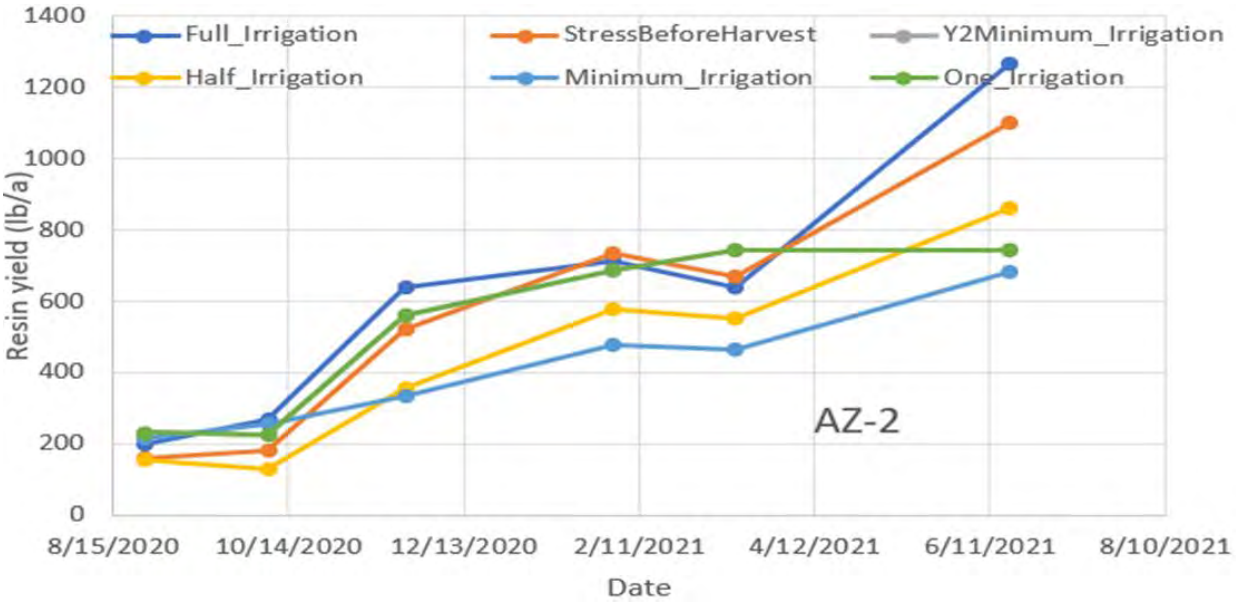


Figure 29. *Resin yield over time under different irrigation treatments for AZ-2.*

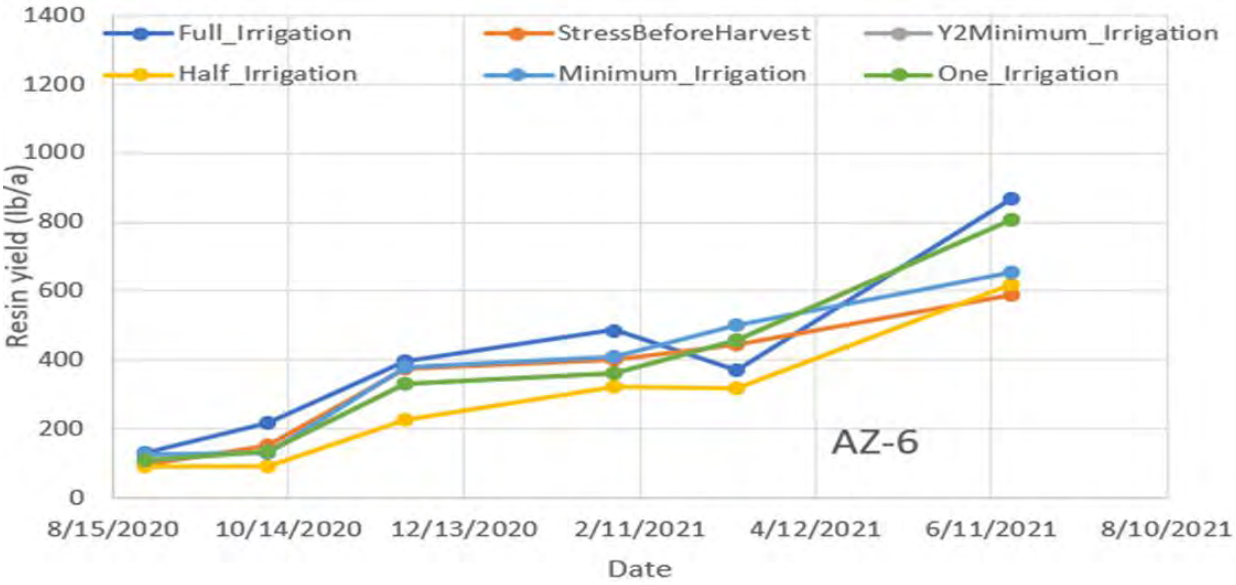


Figure 30. *Resin yield over time under different irrigation treatments for AZ-6.*

AZ-2 had a higher resin yield than AZ-6 due to higher biomass and resin content, making it a better option when resin price is high. In the first year, full irrigation, stress before harvest, and minimum irrigation in year 2 received the same amount of irrigation. Generally, although plants in deficit irrigation treatment survived the summer, the plants are smaller. AZ-6 seemed to tolerate drought stress better compared to AZ-2 but are smaller than AZ-2.

Guar Response for Field Performance:
Nothing to report.

Guar Response to Salinity Tolerance:
The study continued in 2020 to screen diverse guar lines under salinity stress to identify different sources of salinity tolerance and characterize those based on gene expression analysis.

Preliminary results show significant variation in salinity tolerance among selected genotypes. Results were shared with the SBAR Team. Additional ion analysis has also recently been completed. A manuscript is currently in preparation on salinity tolerance mechanism titled, “Contrasting responses of guar genotypes shed light on multiple component traits of salinity tolerance mechanisms” and will be submitted in the coming weeks.

RNA-sequence study also is in progress to help identify salinity tolerance mechanisms specific to guar.

This study conducted a detailed analysis of four genotypes (Matador, PI 268229, PI340261, and PI 537281) to understand morphological responses and ionic relationships during salinity stress in guar and linked those with underlying genetic determinants. Greenhouse evaluations of four genotypes under saline irrigation water (13.65 dS m^{-1}), Matador and PI 268229 performed significantly better than PI 340261 and PI 537281. However, shoot biomass STI for Matador, PI 268229, PI340261, and PI 537281 were 1.35, 1.58, 0.21, and 0.20, respectively. Similarly, root biomass STI for Matador, PI 268229, PI340261, and PI 537281 were 1.42, 1.77, 0.20, and 0.27, respectively. Likewise, for height STI, Matador and PI 268229 performed significantly better than PI 340261 and PI 537281. Based on this analysis, Matador and PI 268229 were classified as salt-tolerant, and PI 340261 and PI 537281 were classified as salt-sensitive.

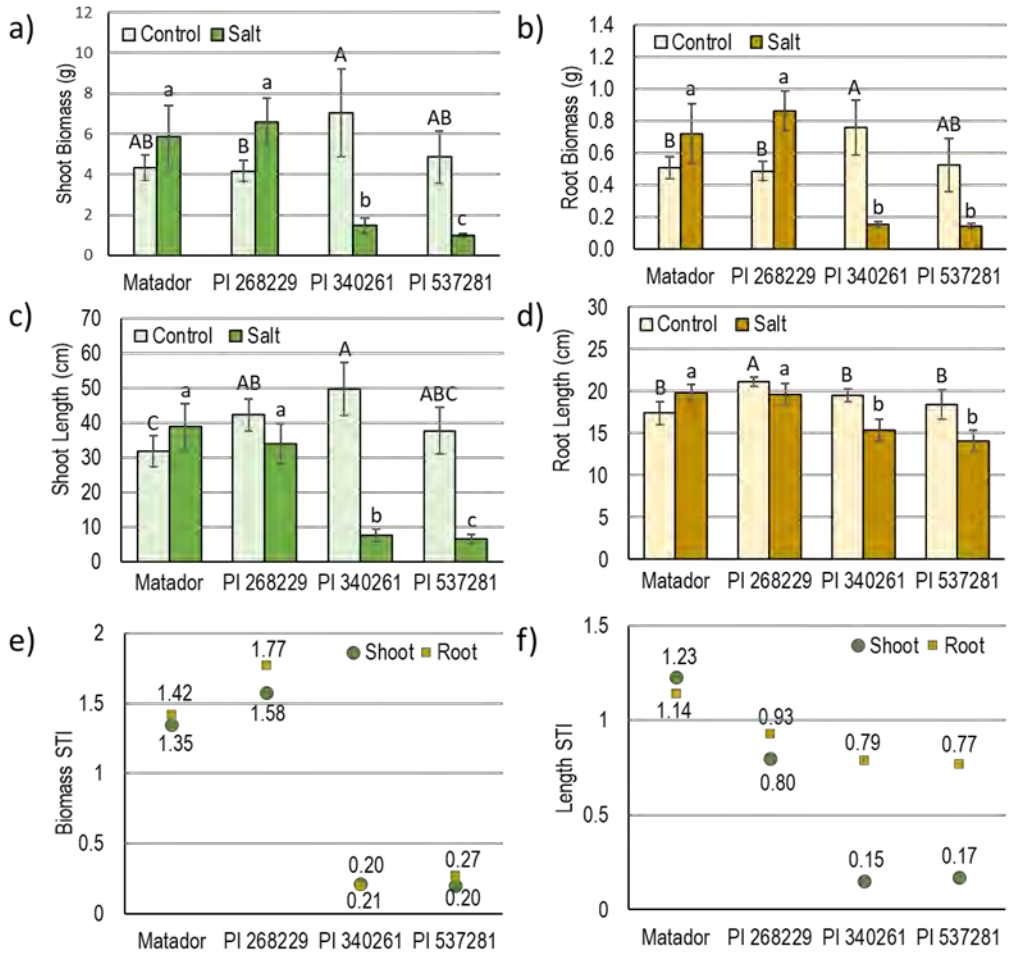


Figure 31. *Performance of four guar genotypes under control and salinity conditions. a) Shoot biomass. b) Root biomass. c) Shoot length. d) Root length. e) Salt tolerance index (STI) for the shoot and root biomass. f) STI for the shoot and root length. Capital letters signify significant differences in yield under control conditions, while lower case letters signify significant yield differences under saline conditions ($p \leq 0.05$). Error bars represent standard errors.*

Na and Cl concentrations increased in all four genotypes under salinity; however, K concentration decreased. Leaf Na concentrations were 4.0 to 5.5-fold higher in salt-sensitive lines compared to salt-tolerant lines under salinity. Leaf Cl concentrations were 1.6 to 1.9-fold higher in salt-sensitive lines compared to salt-tolerant lines under salinity. PI 268229 (a salt-tolerant line) and PI 340261 (a salt-sensitive line) accumulated comparable concentrations of Cl in roots; however, PI 340261 accumulated 1.8-fold higher Cl in leaves as compared to PI 268229, indicating different regulation of Cl^- movement from root to shoot in these genotypes.

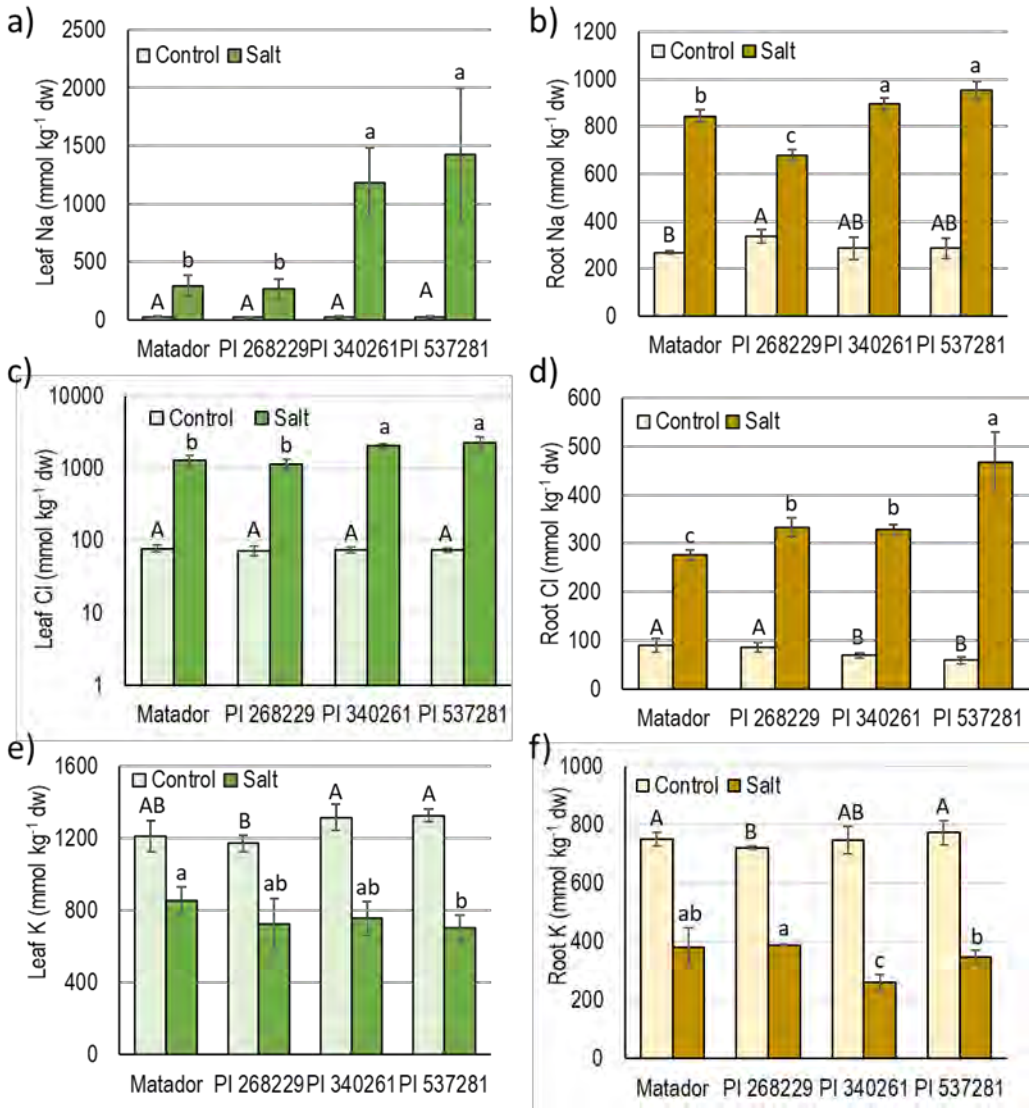


Figure 32. *Tissue ion concentrations of four guar genotypes irrigated with control and saline irrigation waters. a) Leaf NA concentrations. b) Root Na concentrations. c) Leaf Cl concentrations. d) Root Cl concentrations. e) Leaf K concentrations. f) Root K concentrations. Capital letters denote differences between varieties under saline treatment, lower-case letters signify significant differences in yield under saline conditions ($p<0.05$). Error bars represent standard errors.*

The relative leaf K concentrations under salinity compared to control (K-salinity/K-control) was significantly different between salt-tolerant (Matador = 0.71 and PI 268229 = 0.62) and salt-sensitive (PI 340261 = 0.57 and PI 537281 = 0.53) genotypes. The R^2 values between leaf K-salinity/K-control and STI shoot length and leaf K-salinity/K-control and STI root length were 0.9113 and 0.963, respectively. Similarly, the R^2 values between K-salinity/K-control and STI shoot biomass and STI root biomass were 0.6153 and 0.5526, respectively. These observations suggest a strong association between the leaf K-salinity/K-control ratio with STI for the stem and root lengths and STI for the shoot and root biomasses. Hence, our data advocate that leaf K-salinity/K-control is more critical during salinity stress than total leaf K concentrations.

To characterize different players involved in salinity tolerance, we conducted the expression analyses of 10 genes involved in Na^+ and Cl^- transport in the roots of four guar genotypes. The expression analyses of genes involved in Na^+ and Cl^- transport revealed the importance of different component traits of salinity tolerance mechanisms such as the exclusion of Na^+/Cl^- from the root, sequestration of Cl^- in root vacuoles, retrieval of Na^+/Cl^- from xylem during salinity stress, root to shoot Na^+/Cl^- translocation, and K^+-Na^+ homeostasis.

RNA-Sequencing (RNA-Seq) has been completed for one salt-tolerant (Matador) and salt-sensitive (PI 340261) genotypes. We are currently in the process of data analysis. Manuscript will be submitted for publication in coming months.

Guar Response to Moisture Stress:
This task is complete. A manuscript is in process.

Guar Response to Planting Densities:
The seed density trial was harvested at Lyendecker Plant Science Center, Las Cruces, New Mexico. Square meter harvest samples were collected for final seed yields. Threshing of the square meter harvest samples was completed and data collected. Single plants were also manually threshed and observations on seed yield attributing characteristics recorded.

The results showed that plant biomass at maturity differed significantly genotypes (p=0.0465) and seed rates (p=0.0051). Highest biomass was recorded for genotype NMS-15-G1 and was significantly higher than Lewis. Higher seeding rates of eight and twelve seeds/ft produced higher biomass than lowest seeding rate of two seeds/ft. Seed yield didn't differ among genotypes (p=0.182) while was slightly different among seeding rates (p=0.05). The seeding rates of eight and twelve seeds/ft produced highest seed yields while the seeding rate of two seeds/ft had the lowest seed yields. Harvest index (HI) differed significantly among genotypes (p=0.0003) and seed rates (p=0.0317) while the genotype*seed rate interaction Lewis genotype had highest HI) and Matador the lowest HI) (0.38).

Table 6. *Biomass, seed yield and harvest index of guar genotypes under various seeding rates planted in July 2020.*

	Plant Dry Biomass (Kg/ha)		Seed yield (Kg/ha)		Harvest Index	
Genotype	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Kinman	3054	568	1221	231	0.40	0.012
Lewis	2550	775	1067	315	0.42	0.022
Matador	2933	379	1110	154	0.38	0.020
NMS-15-G1	3117	865	1231	318	0.40	0.028
Seed rate (seeds/ft)						
Eight	3210	584	1252	232	0.39	0.019
Four	2750	625	1098	238	0.40	0.016
Twelve	3179	638	1242	253	0.39	0.035
Two	2515	715	1038	294	0.41	0.022

Guayule Herbicide Tolerance Study, Fall 2020:

These field experiments were initiated in September 2020 at Bridgestone-Eloy (mid-September plantings) and at MAC (9/28/2020 planting. Subtask 1a is being conducted at the Bridgestone Eloy farm in field 6B with the last data being collected on May 25, 2021. The experiment at MAC could not be conducted because the plant density was too low and the variation in plant size was too great (field was abandoned). The sequential application studies (primarily with Aim) were completed at MAC and Eloy. At Eloy the plants were repurposed to conduct experiments to accomplish both subtasks. This experiment could not be conducted at MAC as indicated above.

The problem at MAC and Eloy in obtaining good stands did not allow for completion of the research tasks as planned. There was almost a complete loss of guayule seedlings at MAC in field 5E, borders 19 to 20 and in two field plantings at Eloy. This objective is being partially accomplish as part of the experiment initiated to address task 1a at Eloy.

Table 7. *Details of the 2021 preemergence herbicide experiments.*

Spray Date	Chemicals Applied	Location/ Field	Method of Incorporation	ARM File Name / Data Tables?	Data Collected to Date
4-12-2021	Prowl H2O Dual Magnum Warrant Spartan Prefar Aim Activator 90	MAC / F2 B 63, 64, 65	PPI-flat, field cultivator, lister, bed-top, incorporvator, irrigation	Field 2 MAC Spring 2021 Herbicide Systems F2	3/24/2021 – Farm applied application code A – PPI flat 4/12/2021 – applied application code B – PPI flat 4/14/2021 – Planted at 1 lb/A 5/1/2021 –Farm applied Pyrethroid at 4 oz/A 5/5/2021 –Farm applied Pyrethroid at 1.8 oz/A 5/25/2021 – Stand Counts 5/28/2021 – Nadir Pictures

Spray Date	Chemicals Applied	Location/ Field	Method of Incorporation	ARM File Name / Data Tables?	Data Collected to Date
					6/5/2021 – Prespray Leaf Counts 6/9/2021 – applied bulk Aim @ 2 oz/A 6/10/2021 – Farm applied bulk Prowl H2O @ 4 pt/A 6/15/2021 – Stand Counts 6/18/2021 – Nadir Pictures
4-12-2021	Prowl H2O Dual Magnum Warrant Spartan Prefar Aim Activator 90	MAC / F3 B 66, 67, 68	PPI-flat, field cultivator, lister, bed-top, incorporvator, irrigation	MAC Spring 2021 Herbicide Systems Field 3	3/24/2021 – Farm applied application code A – PPI flat 4/12/2021 – applied application code B – PPI flat 4/14/2021 – Planted at 1 lb/A 5/1/2021 –Farm applied Pyrethroid at 4 oz/A 5/5/2021 –Farm applied Pyrethroid at 1.8 oz/A 5/25/2021 – Stand Counts 5/28/2021 – Nadir Pictures 6/5/2021 – Prespray Leaf Counts 6/9/2021 – applied bulk Aim @ 2 oz/A 6/10/2021 – Farm applied bulk Prowl H2O @ 4 pt/A 6/15/2021 – Stand Counts 6/10/2021 – Farm applied bulk Fusilade @ 24 oz/A 6/18/2021 – Nadir Pictures

Guayule Herbicide Tolerance Study, Spring 2021:

At MAC, the field locations were chosen, farm service agreements were completed, experimental protocols were completed and field preparation began at the end of March 2021. At Eloy, the fields will be planted in early- and mid-April with all fields begin treated with Prowl H2O preplant incorporated. Study sites will be chosen after emergence and experiments will begin with early season herbicide applications and will mirror the work conducted at MAC. We are hoping for a good stand at both locations this spring.

Table 8. *Details of the 2021 postemergence herbicide experiments.*

Spray Date	Chemicals Applied	Location/ Field	Method of Incorporation	ARM File Name / Data Tables?	Data Collected to Date
4-5-2021	Chateau Goal Tender Liberty Caparol Aim Karmex Matrix Sandea Spartan Aim	Bridgestone B6	Furrow	Guayule Bridgestone Eloy Field B6 Spring 2021 Post Direct	4/14/2021 – Planted 4/2/2021 – Plant Height (cm) 4/19/2021 – Plant Height (cm) 4/19/2021 – Necrosis/Chlorosis rating 4/19/2021 – Injury Above Spray Zone rating 4/19/2021 – Malva injury rating 5/13/2021 – applied application code B 5/26/2021 – Height Rating 5/26/2021 – Canopy Injury
5-20-2021	Prowl H2O, Aim Activator 90 MSO	MAC / F2 B61/62	PPI-flat, field cultivator, lister, bed-top,	F2 Aim Sequential Spring 2021 MAC F2	3/24/2021 – Farm applied application code A – PPI flat 4/12/2021 – applied application code B – PPI flat

Spray Date	Chemicals Applied	Location/ Field	Method of Incorporation	ARM File Name / Data Tables?	Data Collected to Date
4-5-2021	Chateau Goal Tender Liberty Caparol Aim Karmex Matrix Sandea Spartan Aim	Bridgestone B6	Furrow	Guayule Bridgestone Eloy Field B6 Spring 2021 Post Direct	4/14/2021 – Planted 4/2/2021 – Plant Height (cm) 4/19/2021 – Plant Height (cm) 4/19/2021 – Necrosis/Chlorosis rating 4/19/2021 – Injury Above Spray Zone rating 4/19/2021 – Malva injury rating 5/13/2021 – applied application code B 5/26/2021 – Height Rating 5/26/2021 – Canopy Injury
			incorporvator, irrigation		4/14/2021 – Planted at 1 lb/A 5/1/2021 –Farm applied Pyrethroid at 4 oz/A 5/5/2021 –Farm applied Pyrethroid at 1.8 oz/A 5/25/2021 – Stand Counts 5/28/2021 – Nadir Pictures 6/5/2021 – Prespray Leaf Counts 6/9/2021 – applied bulk Aim @ 2 oz/A 6/10/2021 – Farm applied bulk Prowl H2O @ 4 pt/A 6/15/2021 – Stand Counts 6/18/2021 – Nadir Pictures
5-20-2021	Prowl H2O, Aim Activator 90 MSO	MAC / F3 / B65/66	PPI-flat, field cultivator, lister, bed-top, incorporvator, irrigation	F3 Aim Sequential Spring 2021 MAC F3	3/24/2021 – Farm applied application code A – PPI flat 4/12/2021 – applied application code B – PPI flat 4/14/2021 – Planted at 1 lb/A 5/1/2021 –Farm applied Pyrethroid at 4 oz/A 5/5/2021 –Farm applied Pyrethroid at 1.8 oz/A 5/25/2021 – Stand Counts 5/28/2021 – Nadir Pictures 6/5/2021 – Prespray Leaf Counts 6/9/2021 – applied bulk Aim @ 2 oz/A 6/10/2021 – Farm applied bulk Prowl H2O @ 4 pt/A 6/15/2021 – Stand Counts 6/10/2021 – Farm applied bulk Fusilade @ 24 oz/A 6/18/2021 – Nadir Pictures

Herbicide Trials – Publication, Extension Bulletin and 24c SLN Applications

This work is ongoing. Data and summaries will be prepared and submitted to herbicide manufacturers in order to develop submissions for 24c SLN registrations starting in 2021 Q4 and continuing until completed. These data summaries will be used to prepare publications.

Development and Testing of AquaCrop Model:

W. Huang worked on the AquaCrop model with Dr. Waller's group. G. Wolkon has joined this team. According to the weather and soil data from 01/01/2018, the guayule yield was predicted to be 0.504832 tonne/ha on July 27th, 2018. The predicted canopy cover and the biomass of guayule are shown below.

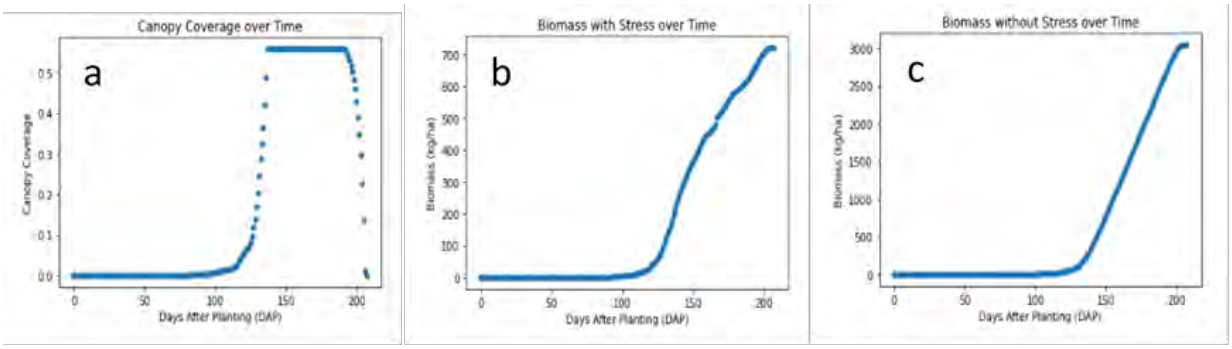


Figure 33. *Guayule canopy coverage (a), biomass with water stress (b), and biomass without water stress (c).*

===

Huang used a program called HeidiSQL to save Aquacrop data and directly ran the data using Python. New scrips were created using Python. However, there was no canopy coverage and biomass with water stress for 2018 data Therefore, she switched back to the old script for 2019 data. The 2019 predicted canopy and biomass (see Figure 2a, 2b, and 2c) were compared to the data in 2018 (see Figure 1a, 1b, and 1c). The increase in canopy coverage and biomass with water stress were observed in 2019 compared to 2018 ones. Additionally, according to Fig. 1a and 2a, the harvest dates decreased from 206 days in 2018 to 135 days in 2019.

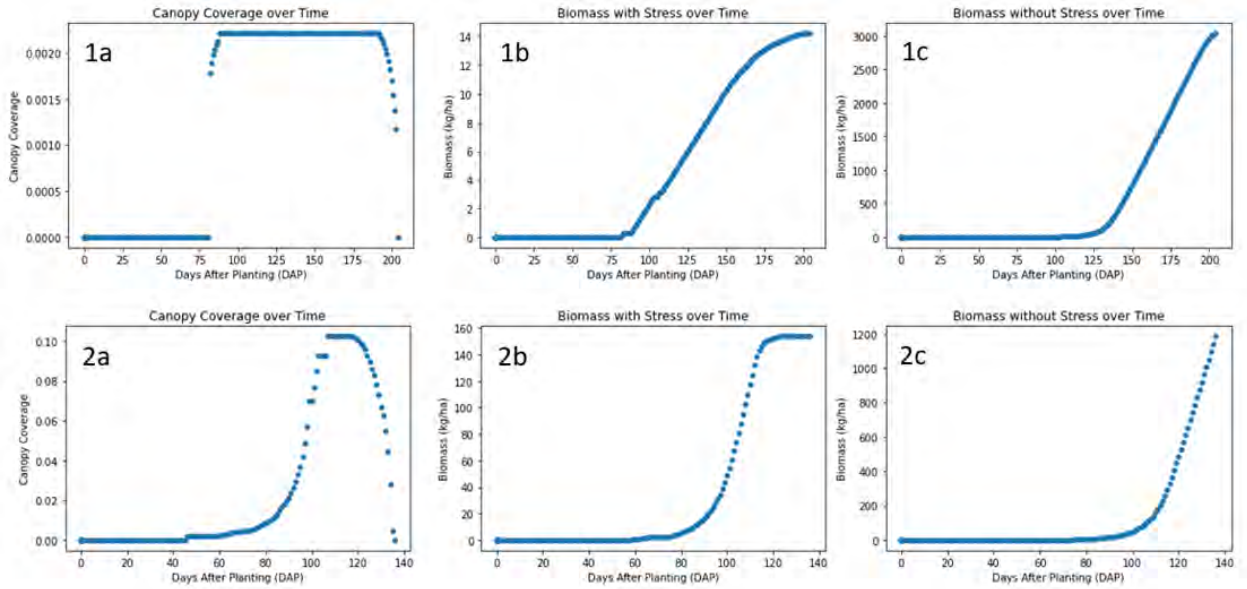


Figure 34. *Guayule canopy coverage (1a), biomass with water stress (1b), and biomass without water stress (1c) in 2018, and guayule canopy coverage (2a), biomass with water stress (2b), and biomass without water stress (2c) in 2019.*

Guayule Density Trials (Direct-Seeded and Transplant-Established):
Research continues as planned; nothing new to report.

Range of N and P Utilization:
LI-COR readings for photosynthesis taken on 12 February. Samples were harvested and dried on 19 February.

Plant heights were measured and plants were harvested.

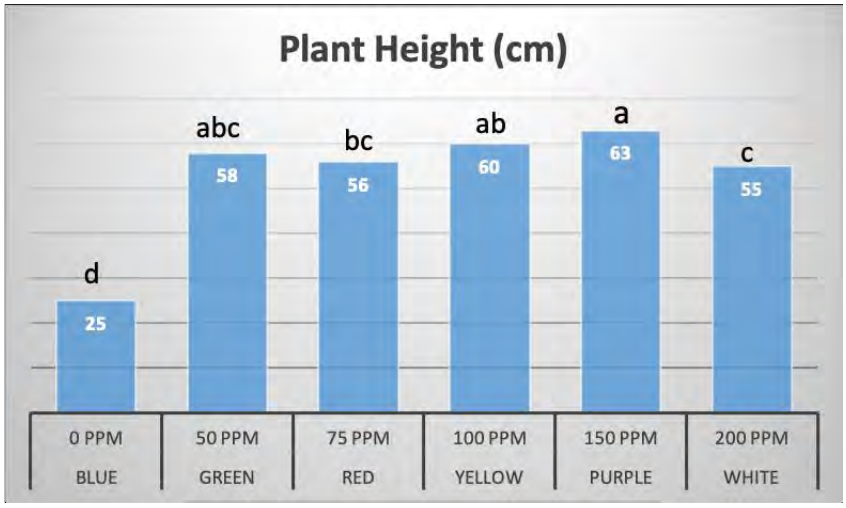


Figure 35. *Mean heights of guayule plants by nitrogen treatment. Data points with different letters indicate a significant difference using a LSD test at a significance level of 0.05.*

Plants were also dried and weighed. Leaf samples were analyzed for total nitrogen content. Stem samples to be analyzed for resin and rubber. New experiment planted on 30 April to validate findings and clarify minimum Nitrogen threshold. Treatments are 0, 20, 30, 40, and 50 ppm Nitrogen.

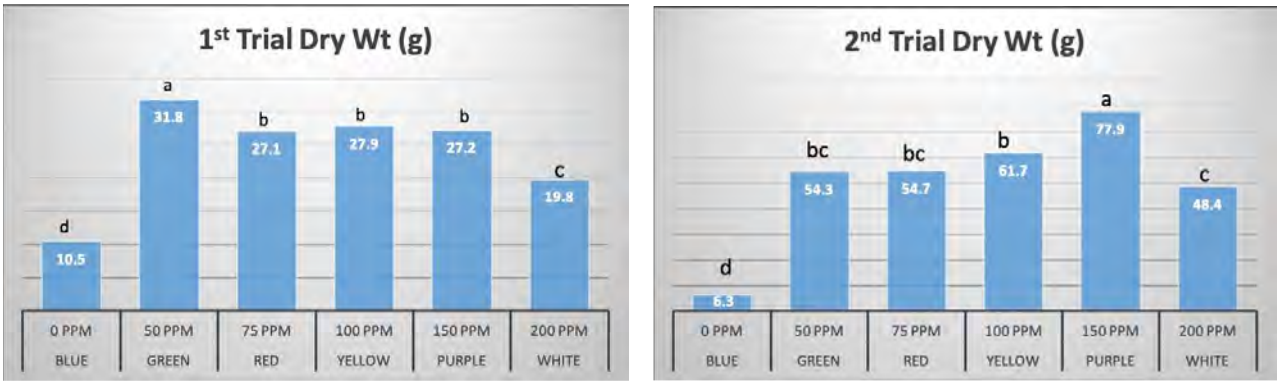


Figure 36. *Mean dry weights by nitrogen treatment for first harvest (L) and second harvest (R). Data points with different letters indicate a significant difference using a LSD test at a significance level of 0.05.*

Direct-seeded vs. Transplant-established Guayule:
Nothing new to report.

Monitor TDR, Infrared Cameras, and Flowmeter System:
We have been maintaining the TDR and camera sensors. The Bowen ratio station was installed and is under repair.

D. Hoare installed the Bowen ratio station and continues to work on its maintenance. Half of the TDR probes are providing good data. We continue to work on improving the placement. Have of the cameras are working. We covered the cameras with polyethylene, which helped with the reliability. There was a problem with a battery in the Bowen ratio station so it is being replaced. Weekly neutron probe readings and drone flights are also continuing in the irrigation experiments at Eloy and Maricopa.

A manuscript on temperature and camera sensors is underway.

WINDS Model Integration with Existing Tools:
We are focusing on tying into the database and user interaction with the website.

We are continuing to work on three papers related to the WINDS model. One is a calibration paper on a cotton field. The second shows how the WINDS model improves the water balance data in the Clovis (NM) field. The third describes the use of the Excel WINDS model, and how it parameterizes the online Python WINDS model. We reconfigured the Excel WINDS model to match the format of the database at Amazon web services. We connected the AquaCrop model to a database at Amazon web services. We also coordinated the team efforts through Github.

Irrigation Experiments – Guayule and Guar:
Irrigation experiments are going well. Irrigations for the 2021 season began in March in Eloy and Maricopa. Plants in all treatments have been growing rapidly. Measurements are continuing. El-Shikha manuscript was published on the first two-year irrigation experiment, and he presented two posters on the guayule experiments at the summer ASABE meeting. Another manuscript is underway on crop coefficients and remote sensing.

During the second quarter, irrigation frequency increased in the two guayule experiments (deficit irrigation experiment/irrigation rate and method experiment [regrowth]). Soil moisture and plant data was collected weekly-biweekly and monthly, respectively. Also, multispectral and RGB images were collected via drones every 1-4 weeks for the two experiments. Nitrogen was applied in the form of UAN-32 to the guayule field in April-May 2021. Except for some maintenance that we did to the drip irrigation system in June and July 2021, everything looks okay. Weekly moisture data was analyzed and used for irrigation scheduling. Growth and yield data for the first year was analyzed for presentation at the ASABE 2021 International Annual Meeting.

Objective 5. Develop soil quality and health knowledge critical to environmental sustainability.

Task #	Description of Task	Deliverable	Target Completion Date
1 Maier/ Neilson	Physical analysis of Yr1 soil samples (n=108)	Soil texture characterization complete	31 Dec 20
2 Maier/ Neilson	DNA extraction of soil samples for microbiome analysis (Yr1 and Yr2)	MAC Yr1 complete MAC & Eloy Yr2 complete	28 Feb 21 28 Feb 21
3 Maier/ Neilson	Amplicon sequencing: bacteria, archaea, and fungi	MAC Yr1 and Yr2 complete Eloy Yr2 complete MAC and Eloy Yr3 samples complete	30 Apr 20 30 Apr 21 31 Oct 21
4 Maier/ Neilson	Winter dormancy rubber production studies	Manuscript submitted for review and publication	31 Aug 21
5 Maier/ Neilson	Temporal microbiome network analysis of community interactions	DNA extraction for 240 samples Bioinformatics of soil samples collected monthly	30 Jun 21 1 Mar 21
6 Maier/ Neilson	Annual soil quality analysis of guayule irrigation field (MAC and Eloy)	Assess relative abundance of putative guayule pathogens Assess soil microbe diversity Manuscript preparation for guayule pathogen analysis	31 Dec 20 31 Dec 20 1 Jun 21
7 Maier/ Neilson	Harvest analysis of irrigation field trial	DNA extraction of guayule field soil samples (MAC and Eloy) Amplicon sequencing of soil samples collected (MAC and Eloy) Statistical analysis of associations between microbial community and plant metrics	31 Dec 20 1 Feb 21 1 Aug 21

Chemical and Physical Analysis:

Soil texture analysis is complete. Some analyses were done on Year 2 soils when replication was needed. Data has been shared with SBAR group members working on the guayule irrigation field trials.

DNA Extraction for Microbiome Analysis:

Progress has been made on the DNA extractions, but the work is still in progress. All 2018 MAC and Eloy samples have been completed, and the 2019 Eloy samples are complete. 40:54 2019 MAC samples are still in progress. Regular law work is still impeded due to COVID restrictions.

Vaccination and the relaxation of COVID restrictions will enable more potential for lab work in Q2.

Another 7 samples were completed in Q2. A revised target date (to completion) has been set for 1 August 2021.

Amplicon Sequencing: Bacteria, Archaea, Fungi:
Amplicon sequencing is complete for the 2018 Eloy samples. Remaining amplicon sequencing must wait until all 2018 and 2019 samples are extracted to avoid sequencing bias. A revised target completion date is 1 September 2021.

Winter Dormancy Rubber Production Study:
Manuscript preparation is underway; nothing new to report.

Temporal soil microbiome associated with guayule growth cycle:
DNA extractions from the 240 soil samples collected for this project are now complete.

Annual Soil Quality Analysis of Guayule Irrigation Field (MAC and Eloy):
Temporal and spatial relative abundance profiles of putative fungal pathogens from amplicon sequence data sets will begin when Year 3 tasks are complete. A manuscript draft has been initiated, with the introduction and literature review sections complete.

Progress on this task is delayed due to COVID restrictions that prevent lab work. K. Brown continues to work on the literature reviews on the putative guayule fungal pathogens identified by UA Plant Pathologist, Dr. A. Hu, and the impact of bacterial, archael, and fungal diversity on the relative abundance of plant pathogens in agricultural soils. Brown presented information from these literature reviews at the 2021 ENViSion UA Annual EArthweek Symposium in a presentation entitled, *Fungal Pathogens and Guayule (Parthenium argentatum): Optimizing Crop Production in an Arid Environment*.

Temporal Soil Microbiome Network Analysis Associated with Guayule Growth Cycles:
Major progress was made by Y. Chen on this task. All DNA extractions were completed for the 240 samples collected from Eloy Flood 50 (F50) and 100 (F100) irrigation treatments during 2019 and 2020. Amplicon sequencing on bacterial, archael, and fungal communities was also completed. This quarter, we report on the bioinformatics analysis of the microbial communities that has been conducted thus far.

Chen's overall objective is to define the core microbiome associated with the guayule plant across multiple growth stages and environmental conditions to identity a 'most-wanted' list of critical players that can be defined as essential components of a productive guayule microbiome. Bacterial, archaeal and fungal species are being evaluated as potential members of this core microbial community. Chen's study focuses on the F50 irrigation treatment to closely replicate the natural environment of native guayule and identify the microbial community that facilitates guayule productivity under harsh arid conditions. Samples were collected monthly from August 2019 through May 2020 from the F50 and F100 treatments (5 samples per field) to document temporal microbial community patterns throughout the growth cycle, with more intense sampling (30 samples) conducted on the F50 field in October, November. January,

February, March, and May. Intensive sampling facilitates a more complex analysis of microbial community interactions. The initial data analysis revealed that bacterial/archaeal and fungal communities were more diverse in October and May and less diverse from November through February (see figures below). This period of lower diversity coincides with the time of highest rubber production.

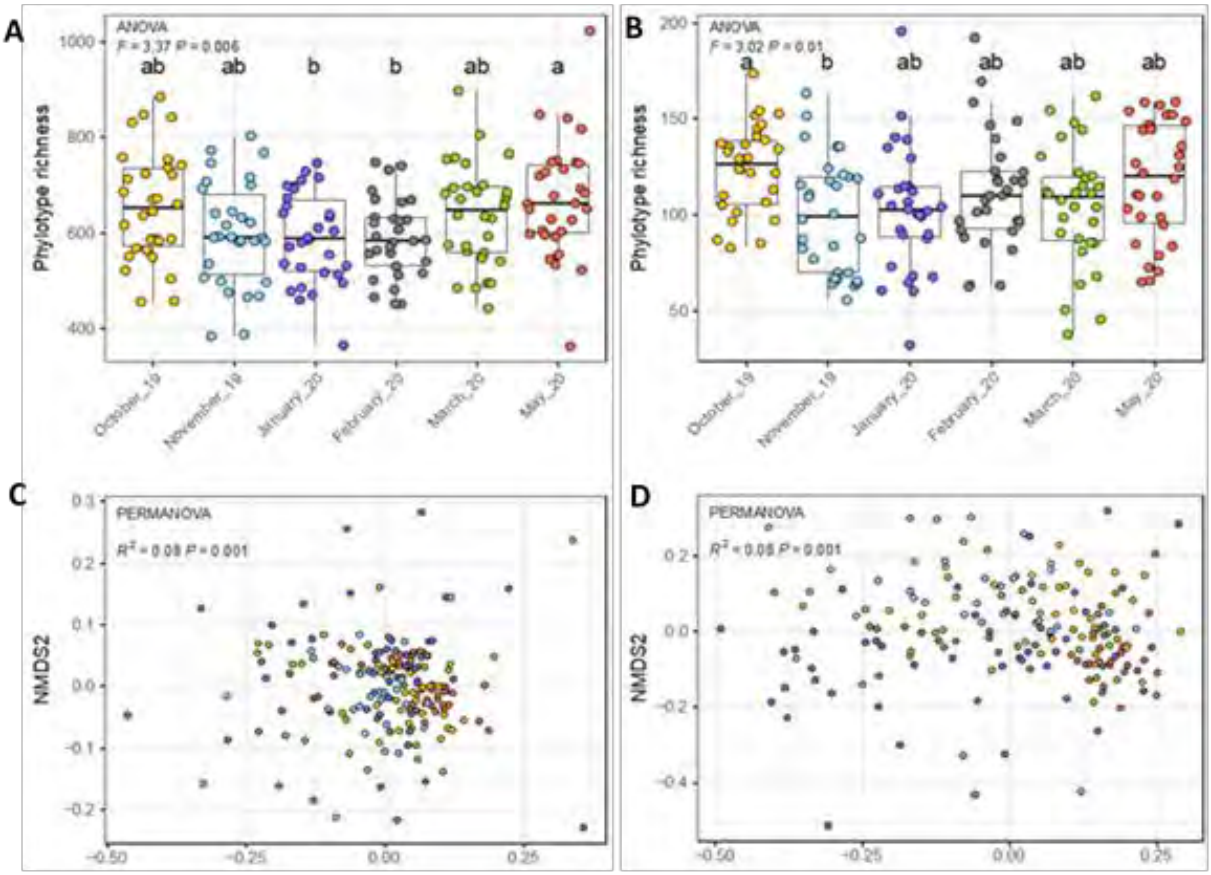


Figure 37. *Alpha- and beta-diversity analysis of bacterial/archaea (A and C) and fungal (B and D) communities associated with the guayule root zone of the F50 irrigation treatment from October 2019 through May 2020.*

Thus, the microbial community alpha-diversity varied significantly across the different guayule growth stages. Interestingly, no temporal changes in community composition were observed for bacteria/archaea or fungi.

Plant-microbe interactions contribute significantly to plant productivity due to services such as nutrient cycling that are provided by the microbial community. However, these functional contributions are not accomplished by individual microbes acting in isolation, but rather consortia of microbes that interact in complex and dynamic associations. Thus, Chen chose to use network analysis to screen the complex microbial community at each time point to identify the critical players associated with the guayule microbiome. Network analysis is a novel approach that quantifies microbial co-occurrence patterns. The analysis identifies “hub species” that co-occur with a greater number of species in the community than do less connected

individuals. Each microbial phylotype is assigned a betweenness value that quantifies how much a given species is connected to other species. Hub species are those members of the community with the highest betweenness values. They function as connectors that facilitate the interaction of other species that do not have the same co-occurrence pattern. Hub species are thought to have greater impact on the productivity of ecosystems. The root-zone bacterial/archaeal networks for October, February, March and May are shown in the figures below.

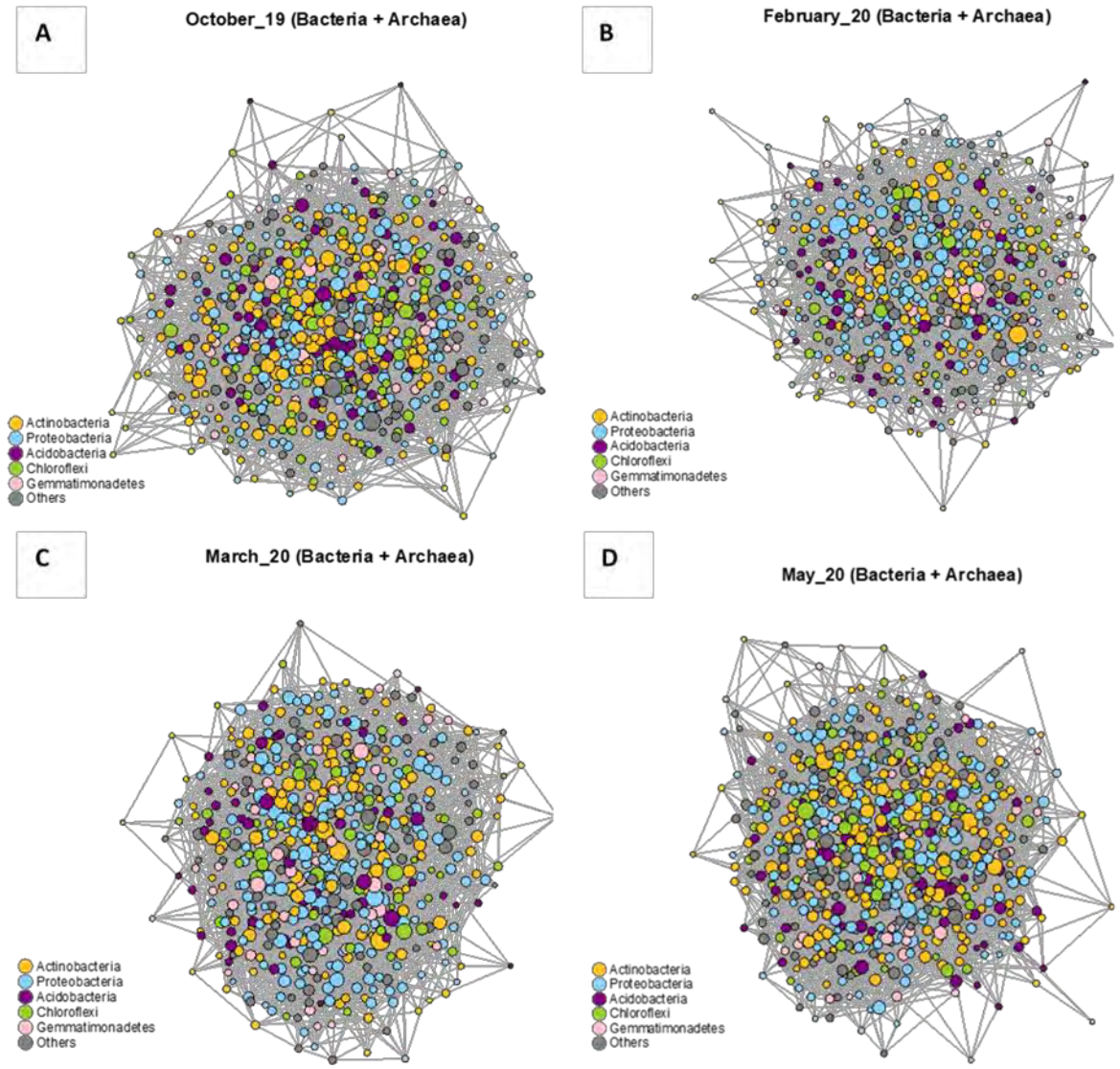


Figure 38. *Four of the six networks for the sampling period of October to May are represented. The networks reveal microbial interactions between bacteria and archaea present in the guayule root zone samples collected at each sample time.*

Each circle or node represents a different microbial phylotype or amplicon sequence variant (ASV). The size of the node indicates its degree of connectedness to the rest of the community and the color represents the taxonomic classification at the phylum level as indicated by the figure legend. The largest nodes are the hub species.

The networks in the figure above reveal several key patterns. First, the January network is less densely connected than the October and May networks. In addition, the interactions among root-associated microbes change dynamically across the growth stages of guayule. The key hub species are associated with different phyla during the active growth (October), dormancy (February, March) and spring flowering (May) growth stages. ASVs belonging to Planctomycetes and the ammonium-oxidizing archaea, Thaumarcheota, were the highest ranked hub species in October, yet these phyla are not represented among the top ten hub species for the remaining months. Proteobacteria represented the dominant hub species in November and January, but this phylum was secondary to Actinobacteria in March and May. Whereas, the community composition did not change significantly with growth stage (Fig, 12C and 12d), the network analysis reveals that the interactions between species was dynamic over this time period and the most significant hub species varied with growth stage. Thus, results from one sampling time would give an incomplete picture of the microbial co-occurrence network and an incomplete list of hub species. The monthly networks will be combined into a single network to identify hub species that are important across all growth stages. Work will continue to develop similar networks for the fungal communities. Finally, Chen plans to integrate the bacterial/archaeal and fungal networks to evaluate co-occurrence patterns between the different domains. This last goal is novel and will require developmental bioinformatics by Chen. The results thus far clearly indicate that the root-zone microbiome during active rubber production is quite distinct from that associated with the plant during flowering and active biomass production. The predicted functional capacity of the bacterial/archaeal and fungal communities at each growth stage is also being characterized.

===

The overall objective of this study is to define the core microbiome associated with the guayule root zone across multiple growth stages. A ‘most-wanted’ list of critical players will be identified that can be defined as essential components of a productive guayule soil microbiome. Characterization of the soil microbiome is important because it contributes significantly to plant nutrient availability and plant pathogen control. Less well characterized contributions of the soil microbiome to plant health include plant hormone and signaling compound production. Bacterial, archaeal, and fungal community composition are being evaluated as a function of time from October 2019 through May 2020. The study focuses on the Eloy F50 irrigation treatment to mimic the natural environment of the guayule plant. Y. Chen continues to analyze the microbial communities of samples collected in October, November, January, February, March and May. Thirty samples were collected at each time point to facilitate a complex analysis of microbial community interactions. The initial microbial community alpha- and beta-diversity results were presented above.

During Q2, Y.Chen performed a predictive functional analysis of potential contributions by the bacterial and archaeal communities to soil ecosystem services using Faprotax. Fifteen functional activities associated with bacterial/archaeal taxa were identified whose relative abundance in the soil root zone changed significantly with guayule growth stage from October through May. The results are shown in the figures below. Of interest in the first figure are taxa associated with nitrate and nitrite denitrification whose relative abundance was significantly lower in February than in the period from October – January. This trend is supported by similar

trends in the relative abundance of taxa associated with total denitrification and nitrous oxide denitrification. Denitrification is the process in the nitrogen-cycle when plant available nitrogen is reduced and lost to the atmosphere as N_2 gas. The potential decrease in this activity observed in February suggests that nitrogen is more bioavailable to guayule in February when rubber production is highest. A second pattern of interest is the concurrent increase in taxa associated with celluolysis in November through March, relative to October. Celluolysis is an early step in the mineralization of organic matter and results in nutrient release into the soil root zone, also leading to a potential increase in nutrient availability during the time of maximum rubber production.

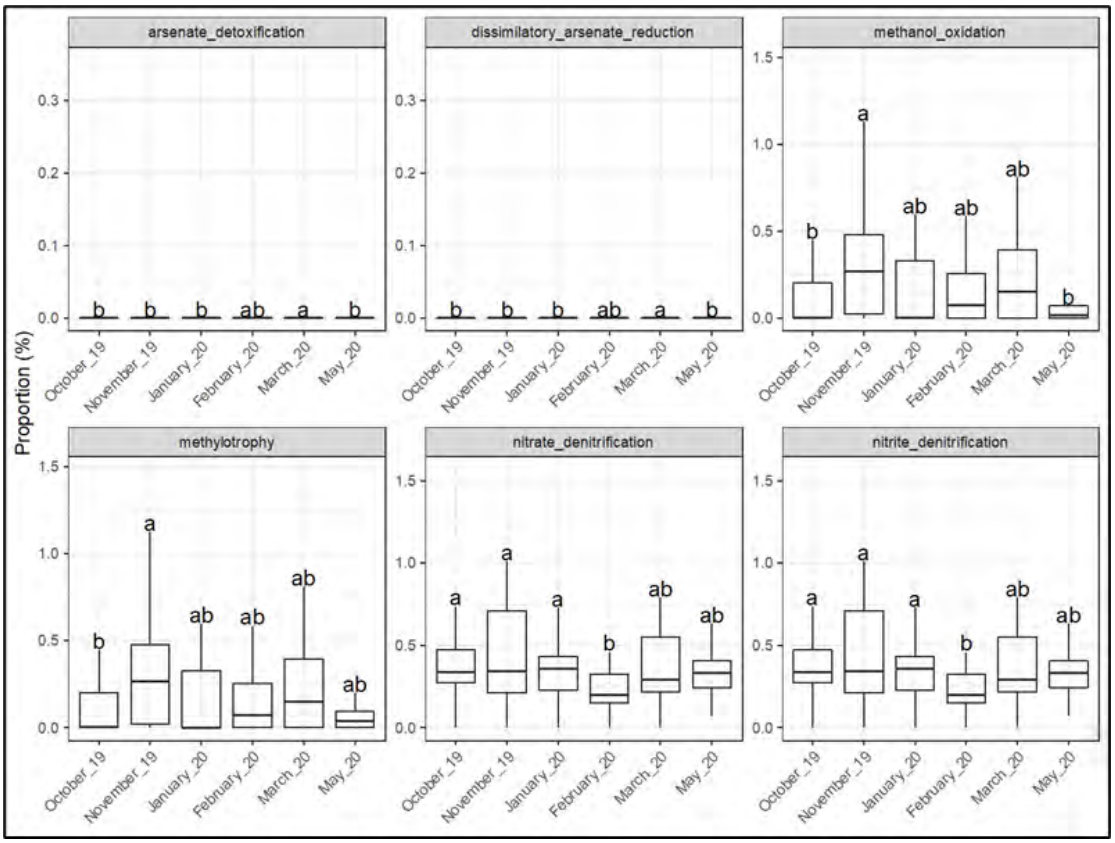


Figure 39. *Six soil functional activities whose associated bacterial and archaeal groups demonstrated significant changes in relative abundance with guayule growth stage.*

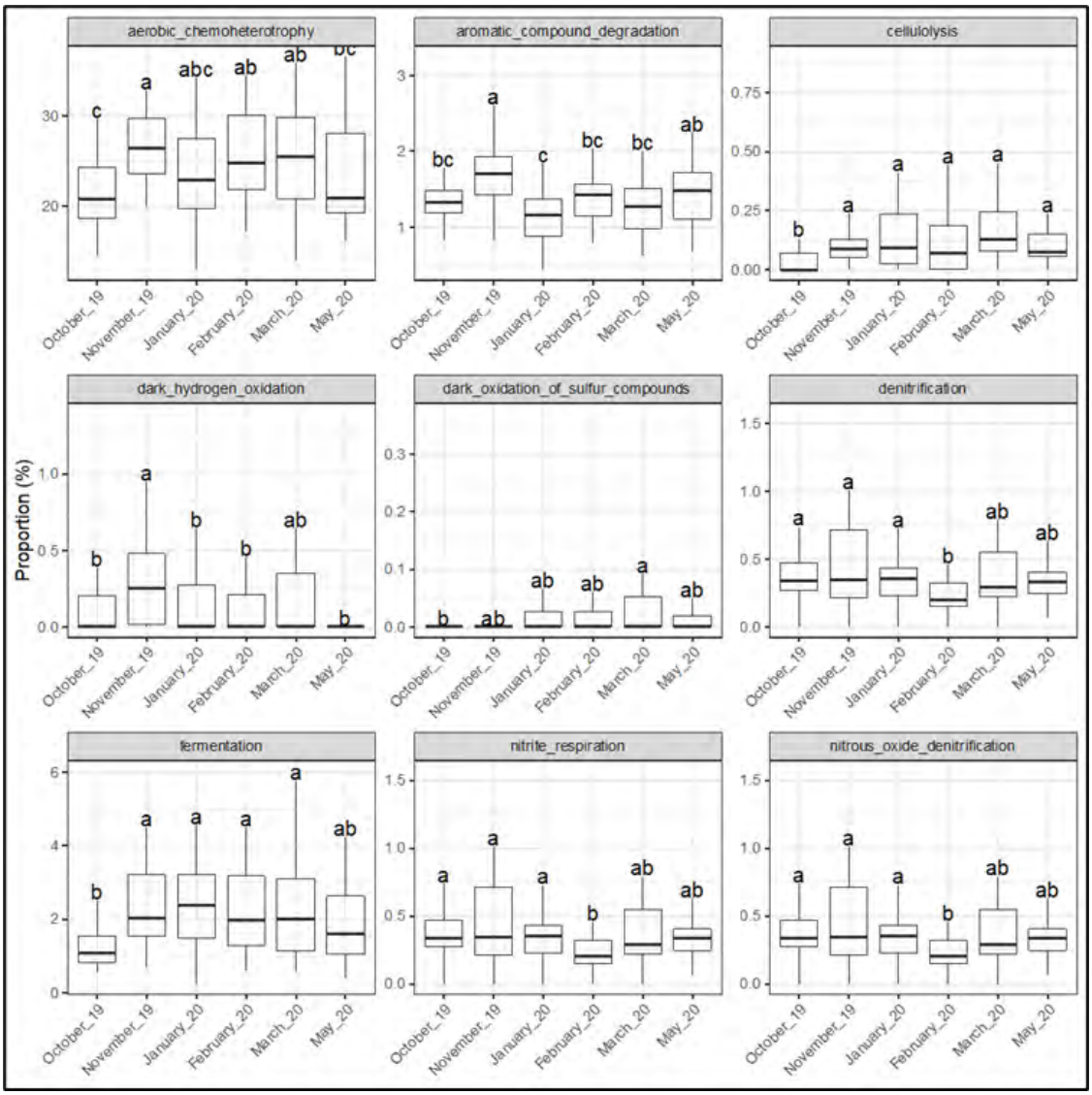


Figure 40. *Nine additional soil functional activities whose assocated bacterial and archaeal groups demonstrated significant changes in relative abundance with guayule growth stage.*

A similar analysis was done for fungi using Funguild; however, the results were less clear. For example, arbuscular mycorrhizal fungi (AMF) were least abundant in January and most abundant in October and May. AMF form symbiotic relationships with plants and facilitate increased plant nutrient acquisition from soils. However, AMF rely on plants as a carbon-source, thus the decrease in abundance during guayule dormancy may reflect a reduction in the food supply provided to the AMF by the dormant plant.

In addition to the microbial functional analysis, Y. Chen is evaluating multiple network analysis tools that are used to quantify microbe-microbe co-occurrence patterns in soil communities. Critical ecosystem services such as nutrient cycling are provided by microbial taxa through coordinated metabolic activity with other members of the community. Thus, the quantification of the connectivity of different members of the community is considered an index of their relative importance in the function of the community as a whole and is a cutting-edge tool being

developed to identify the core microbiota of a plant-associated community. Network analysis defines “hub species’ as those taxa that demonstrate high levels of connectivity with other members of the microbiome and thus are considered critical players in the community. Despite their importance, there is debate in the literature concerning the best metrics for identifying the hub species, especially among fungi. Therefore, Y. Chen is using the guayule data set to work on method development by comparing the network modeling strategies shown in the table below. Each method uses a distinct algorithm. The figure below shows the results from three of these methods for the month of October. The results clearly demonstrate that the different methods produce distinct network patterns. SPIEC-EASI and SparCC produce more robust networks for bacteria and archaea, whereas SparCC and MENA produce better results for fungi. Y. Chen is currently evaluating the differences in hub species identified by each of the methods. Interestingly, the temporal variation in network density through the guayule growth season is conserved across these different methods. Ultimately, the distinct network analysis methods will be compared across temporal data sets to identify the most robust method for identification of the core members of a productive guayule microbiome.

Table 9. *Network construction methods.*

Methods	Implementation
SPIEC-EASI	https://github.com/zdk123/SpiecEasi
SparCC	https://github.com/zdk123/SpiecEasi https://github.com/scwatts/FastSpar
CoNet	http://apps.cytoscape.org/apps/conet
REBACCA	https://faculty.wcas.northwestern.edu/~hji403/REBACCA.htm
CCLasso	https://github.com/huayingfang/CCLasso
MENA	http://ieg4.rccc.ou.edu/MENA/
MInt	https://cran.r-project.org/web/packages/MInt/vignettes/MInt.html

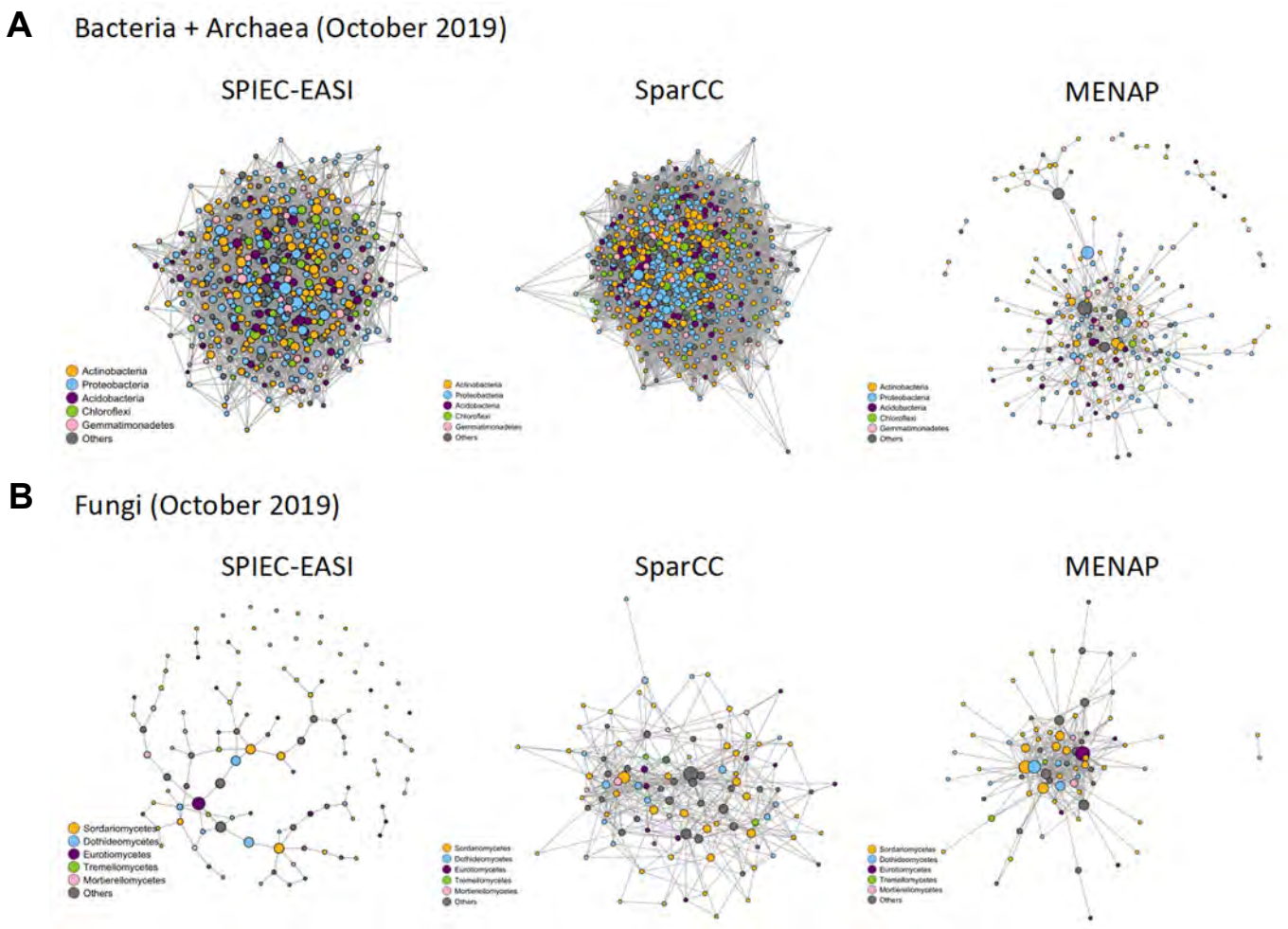


Figure 41. *Three network analysis methods were used to characterize co-occurence patterns of taxa in the (A) bacterial and archaeal and (B) fungal communities assocated with the guayule root zone in October 2019.*

Harvest Analysis of Irrigation Field Trial:
DNA extraction of the Year 3 field trial samples collected in March 2020 (Task 3a) has not begun due to COVID delays. This project will be initiated when the Task 1 pathogen analysis project is complete. Chemical analysis of these March 2020 field soils has not been done.

OTHER ASSOCIATED (GUAR) RESEARCH

Rhizobia Strain Compatibility with Guar for Successful Nodulation:
The soil health group collaborated with the Ray research team in a project not included in the soil health SOW. The project objective is to identify rhizobia strains capable of infecting guar to produce nitrogen-fixing root nodules. USDA strains 3089, 3385, and 3386 were provided by Patrick Elia of the USDA and were cultured and tested for purity by the soil health team.

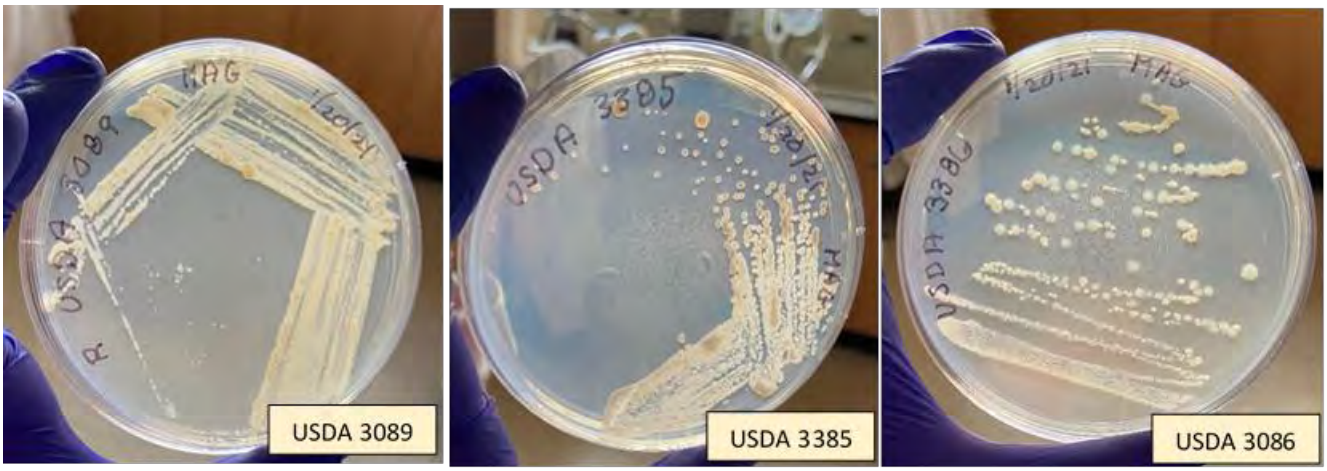


Figure 42. *Evidence that USDA rhizobia cultures included multiple bacterial strains.*

The three cultures were grown on a medium selective for rhizobia species; however, all cultures were found to contain a mixture of two or more strains (see figures above). Collaboration continues with Patrick Elia to obtain pure rhizobia strains to be cultured for the guar greenhouse studies.

CHARACTERIZATIONS & CO-PRODUCTS

Project Coordination: The Characterizations working group meetings are hosted by NMSU once monthly, and led by Dr. Catherine Brewer. During these meetings, progress reports for all component tasks are provided by team members, issues and challenges are discussed for resolution, and specific tasks are integrated where possible. Data exchange is accommodated via a shared access folder online, and meeting minutes are maintained as a reference.

Issues/Risks:
Brewer: Installation of the blast shields for the supercritical fluid extractor (SFE) was delayed by a backorder at the manufacturer; the new expected ship date is April 20. Shakedown testing and operation are not permitted by our college safety officer until installation is complete. Operation of the system should be cleared by early May. Submission of a manuscript is likely to be later in the fall rather than in August depending on how quickly the characterization processes go.

Carried over from the 2020 Q4 report: No additional work was done this quarter on the third of the three biomass conversion review manuscripts, on low-cost waste/residue feedstocks for biofuels, as Bayat's time was occupied by her work on the NSF education grant providing her research assistantship. (Bayat did not receive any support from SBAR during the spring semester.) Work on that manuscript will be picked up again in 2021 Q2 after Bayat completes her PhD comprehensive exam.

Dehghanizadeh and the undergraduate students completed the HAZOP review and procedure development process for the supercritical fluid extraction system. The blast panels, CO_2 sensor system, and auxiliary component purchases were received. On June 1, staff from NMSU Facilities & Services evaluated the lab space and provided a quote for the installation work for all of the components. On June 15, Brewer forwarded that quote to Rogstad and Ogden to determine which of those expenses could be charged to the SBAR project. Once funding sources (between the SBAR grant and the CHME department) are decided, the work can be scheduled, after which shakedown trials at pressure to test system function can be conducted. The goal is still to make the go/no-go equipment funding decisions by the end of Year 4 for parts/repairs to the pressure system components. Submission of a manuscript will be delayed until the fall/winter 2021 depending on how quickly the post-extraction characterization processes go.

Holguin: Dr. Jarvis has offered to continue to assist with analysis o fthe FT-ICR MS data. However, this has significantly slowed our progress on the interpretation.

S. Shalygin and K. Laje were recruited to new positions in the middle of this quarter. These employment status changes led to a reduction in graduate student staff. We will be rehiring additional help in May 2021 to assist with the projects.

Our primary instrument for metabolomics work is still nonfunctional. Another lab on campus with a GC/MS will aid us to hep complete the work. This laboratory will begin the analysis of our samples in April (>6-month delay).

The CHNOS analyzer issue is currently not resolved. We hope to have this resolved to support Dr. Brewer's group again. (<6-month delay).
We are still working through our backlog of chemical analysis we hope to have this resolved by July 2021 (>6-month delay). We will be recruiting 3 undergraduate students soon.

As of Q2, NMSU is still under phase 3 of COVID restrictions, limiting on-site research activity to an estimated 35-50% of normal.

Dr. L. Rodriguez Uribe is temporarily employed by another NMSU department and facilitates a workshop in May/June. This has added some delay to the guayule field experiment data collection and analysis. Texas Tech recruited U. Sehar in May for a research position, which further reduced our scientist support.

Molnár: Due to work permit processing, Dr. M. Cascaes-Inacio joined the project and started experimental work on 21 October 2020, delaying the start of the biotransformation, compound isolation, and characterization work.

Both of our two LC-MS equipment were out of order for approximately 1.5 months, with one of the machines still only working in the LC mode (no MS). This caused significant problems with our compound isolation work. Several commercial gene synthesis companies were contacted to obtain the best price, but doe to pandemic supply chain disruptions, ordering of the genes had to be delayed for about 2 months. The order for this large-scale gene synthesis was placed in Q2.

Ogden: It has been a year where we are consistently adapting ourselves to working under the changing pandemic situation. It was very challenging to work effectively while minimizing the risk to be infected by the COVID-19. Therefore, there are some delays in the work progress. Vaccinations help. The work efficiency should be better with a safer environment.

Objective 1. Evaluate how seasonality, processing, and storage affect product quality, conversion efficiency, and economics.

Task #	Description of Task	Deliverable	Target Completion Date
1 Holg	Biochemical composition analysis of guayule and respective products	Identify metabolic pools and gene targets for cold adaptation, rubber production, and survivability Identify minor resin components for resin byproducts	31 Dec 20 31 Aug 21
2 Holg	Biochemical composition analysis of guar and respective products	Develop methods to characterize polysaccharide composition of select varieties of guar	31 May 21
3 Holg	Commissioning and testing of supercritical fluid extraction equipment and analyses	Chemical analysis of SFE extracts and contribute to manuscript development	31 Aug 21

Guayule Biochemical Composition Analysis: Dr. Jarvis provided an updated analysis using the FT-ICR MS located at the national magnet lab. The data was discussed with Dr. McMahan's group detailing the results from the submitted leaf, root, and stem samples. The analysis provided included the spectral calibration to sub-ppm mass accuracy followed by chemical formula assignments. The resulting data generated with chemical formula and relative abundance was used to produce a comparison of chemical features found in the different tissue types. The data was discussed, and a sequential analysis on resin and solvents was being discussed to be performed by the staff and the FT-ICR Mag lab.

Photo 5. *Guayule plants that survived the winter in New Mexico.*

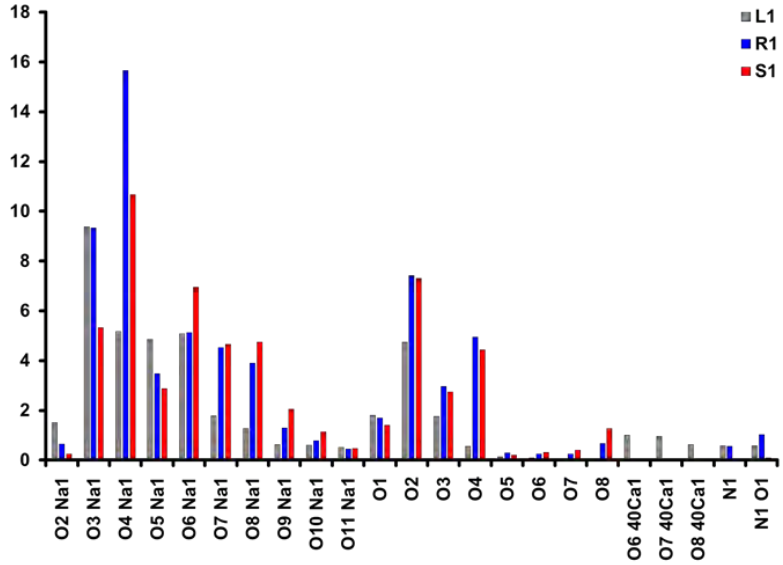


Figure 43. *FT-ICR MS heteroatom class distribution in guayule leaf, root, and shoot samples.*

The figure above illustrates which heteroatom classes amongst tissue types are conserved and those that are unique to a tissue type. For example, the O6 40Ca1 to O8 40Ca1 and the N1-N1O1 classes are unique to leaf and leaf/root tissue types, respectively.

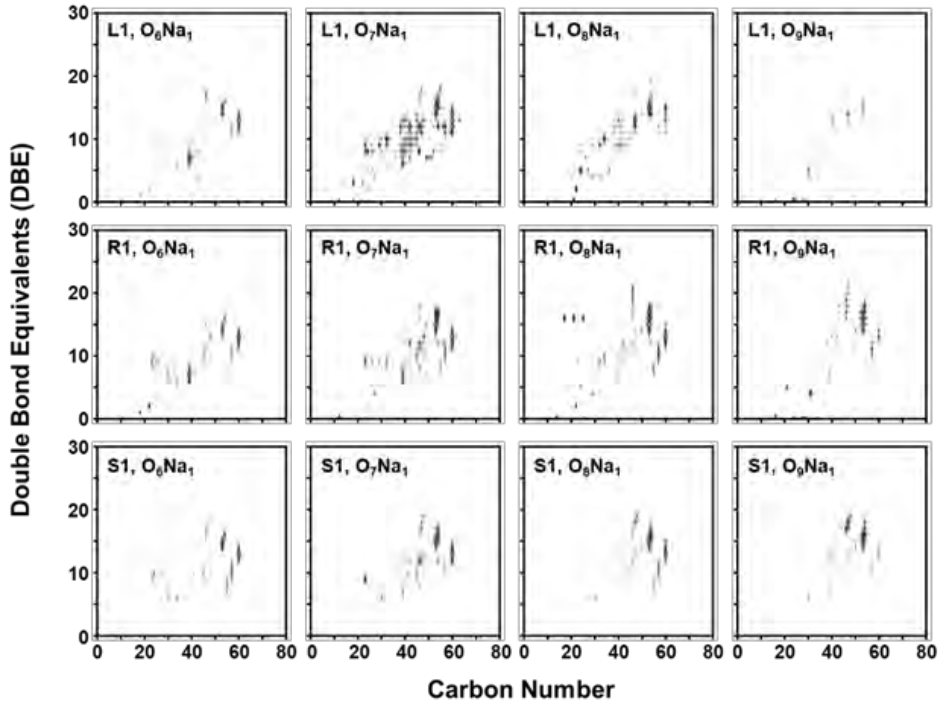


Figure 44. *Carbon number and DBE distribution of the O6Na1-O9Na1 heteroatom classes in guayule leaf, root, and shoot samples.*

The figure above illustrates how some compound classes are conserved amongst the different tissue types, as seen in the O6Na1 class. While the other compound class distributions indicate that there is a shift in chemical structure and nature between the tissue types.

===

During Q2, guayule resin mixture was fractionated with chloroform, acetone, and methanol on silica gel Sepak. LC-MS and LC-MS/MS techniques were applied in order to confirm the presence of already identified compounds and novel metabolites based on structural information coming from MS^2. LC methods are being performed to detect isobaric isomers. Most of the gradients described in the literature were utilized. LC gradients were modified (isopropanol used instead of water). Both positive and negative ion modes were used in MS analysis. Ammonium acetate was used for improved ionization. Metabolynx software (Waters) was used for the identification of known compounds and analogs.

LC-MS revealed the presence of free fatty acids (FFA), and lipids (TAG and DAG). More detailed identification of TAG and DAG are the subject of future investigation. Following FFA was detected: Palmitic, Stearic, Linoleic, and Myristic (see figure below). Palmitic acid was found in the chloroform fraction. Stearic acid was found in all fractions and also in the crude extract. Linoleic acid was in the acetone fraction. Myristic acid was determined in the crude extract as ammonium adduct. None of the Guayulins were detected on LC methods. The absence of guayulins in the LC scans is a subject of further investigation (more efficient fractionation, larger volumes of injection perhaps needed). A similar trend was observed with argentatins. However, Argentatin A was detected on LC-MS run. LC-MS/MS showed that 219

m/z was missing in the analysis compared with direct infusion (Fig. 2). This phenomenon is interpreted as a direct infusion artifact.

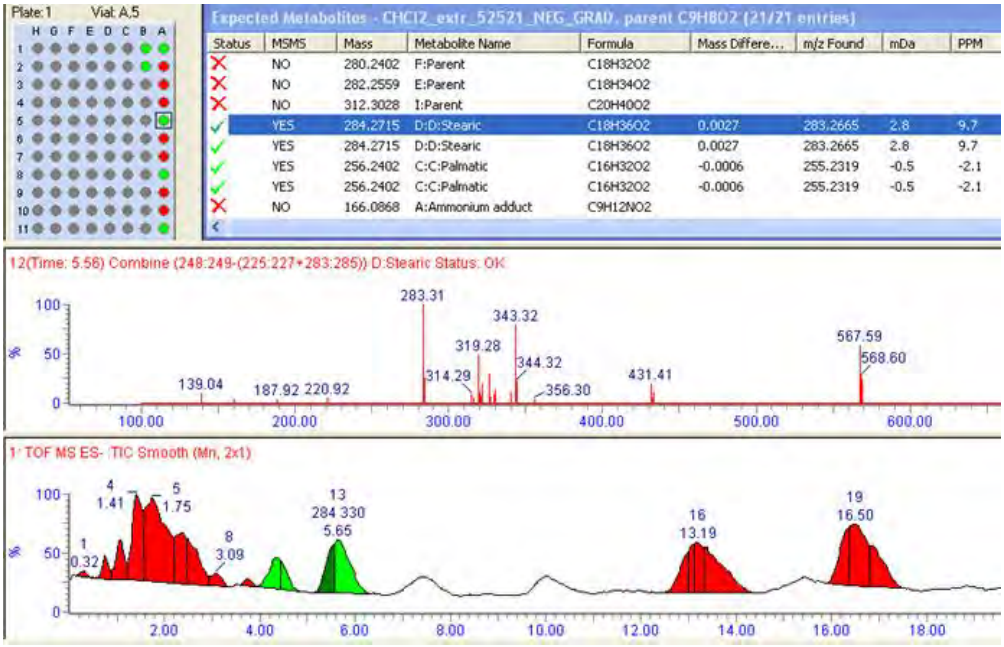


Figure 45. *Screenshot of the Metabolynx software showing peaks of the free fatty acids.*

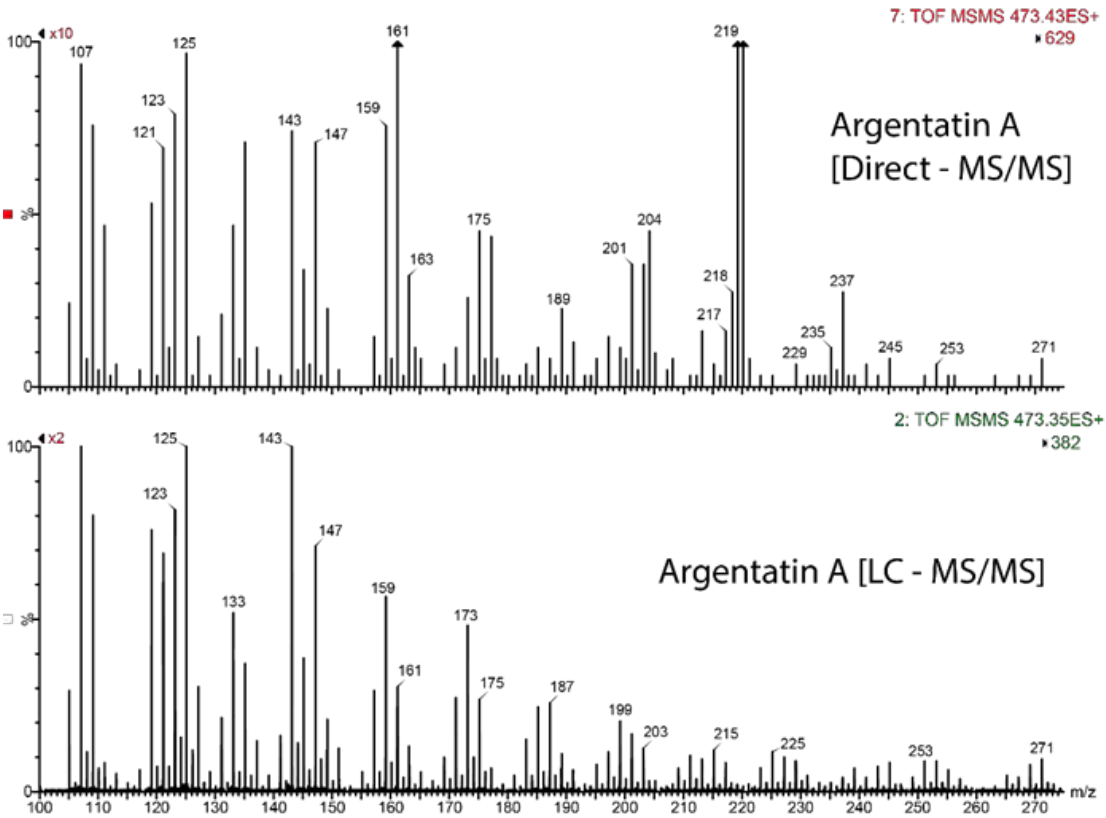


Figure 46. *LC-MS/MS spectra of Argentatin A compared with direct infusion MS/MS. Note: 219 m/z is missing in LC-MS/MS.*

We plan to continue MS/MS investigation of the resin mixture. Comparison with ICR data will be more deeply performed. Comparison of "old" resin mixture with newly prepared fresh material to identify the naturally occurring compounds (not compounds which are a result of the processing/extraction) will be performed. Fresh resin will be analyzed on the high resolution/sensitivity Orbitrap mass spectrometer. Purified argentatines (from Gunatilaka group) will be fragmented and use as reference compounds. For unknown argentatine, LC-MS^E analysis will be developed and tested utilizing the most abundant fragments (125 m/z, 143 m/z, 161 m/z).

Guar Biochemical Composition Analysis:
We plan to initiate the guar gum analysis of the Fall 2020 samples in May. The analysis will include gum quantification and characterization.

We are working with the manufacture Megazyme to address inconsistencies in the galactomann assay kit. If we cannot resolve these, then we will use a gravimetric analysis of the guar samples for quantification.

Commissioning and Testing Supercritical Fluid Extraction Equipment and Analyses:
In collaboration between Dr. Brewer's group and Dr. Holguin's group, we will be performing chemical analysis on extractions from the SFE CO2 extractor. These analyses have been delayed due to rigorous lab safety implementation before commissioning of the instrument.

Objective 2. Demonstrate feasibility of farm to fuel conversion of bagasse.

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Prepare 2 manuscripts on guayule/guar bagasse composition, biomass-to-conversion method matching (HTL product yields)	Manuscripts prepared Manuscripts submitted for peer-review process	31 Aug 20 31 Aug 20

Manuscript Preparation:
This task is complete; nothing new to report.

Objective 3. Identify economic co-products in guayule and guar, e.g., biologically active components.

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Perform liquid-liquid, accelerated, and filtration separations; characterize fractions from guayule resin	Manuscript of guayule resin separation/characterization	31 Aug 21
2 Brewer	Conduct tests of guayule resin-derived materials for insect repellency applications	Manuscript on potential insect repellency	31 Aug 21

3 Brewer	Characterize biomass and fraction samples	Characterizations data provided to SBAR team to support sustainability models	31 Aug 21
4 Gunat	Evaluate major metabolites of guayule	Evaluate transformation products of argentatins A, B, C for potential anticancer/ antimicrobial activities	30 Nov 20
5 Gunat	Isolate and characterize major metabolites of guayule terpene solution	Identify metabolites within solution that can be converted to value-added products Submit manuscript to *J. of Agricultural & Food Chemistry*	31 Jul 20 28 Feb 21
6 Gunat	Complete work on semi-synthesis, characterization of products, and biological evaluation of nine pyrimidine analogues of guayule resin	Draft manuscript complete; submitted to *Bioorganic and Medicinal Chemistry*	28 Feb 21
7 Molnár	Comprehensive literature/bioinformatic review to identify major classes of guayule secondary metabolites	Retrobiosynthetic analysis of major products of guayule resin/terpenes Bioinformatic identification in guayule genome/transcriptome databases	31 Dec 20 31 Jul 21
8 Molnár	Evaluation of microbial transformations in guayule resin or terpene solution	Develop methods for use of recombinant yeast strains, filamentous fungi, and chemical semisynthesis for conversion to value-added co-products	31 Aug 21
9 Molnár	Characterize novel compounds originating from biotransformation or semisynthesis as potential value-added co-products	Isolation, structure elucidation, and evaluation of antimicrobial and anticancer bioactivities	31 Aug 21
10 Ogden	Characterization of pure resin and blended adhesives	IP disclosures 2 papers submitted for review	31 Oct 20 31 May 21
11 Ogden	Development of guayule-based adhesives	Results with possibility of patents and/or publications	31 Dec 21
12 Ogden	Distillation of resin into multiple fractions	Distilled fractions analyzed MS Thesis complete; separation strategy hypothesized	31 Dec 20 31 May 21

Liquid-liquid, Accelerated, and Filtration Separations and Characterizations from Guayule Resin: The guayule resin review article co-authored with the Quinn group was published in *Industrial Crops & Products*. Cheng and Brewer revised and resubmitted a review article manuscript on biochemical conversion of high-protein, high-lignin feedstocks to *Renewable & Sustainable Energy Reviews*, which has been accepted for publication. Bayat, Dehghanizadeh, and Brewer completed and submitted a review article on low-cost waste/residue feedstocks for biofuels to *Energy & Fuels*. Bayat, Dehghanizadeh, and the undergraduate students continued characterization of the bio-crude oils and chars from the co-HTL of guayule bagasse and wastewater for a manuscript to be submitted to a special issue on Bioenergy Conversion Methods in *Energies* by the end of July.

Insect Repellency of Guayule Resin:
Dehghanizadeh and the undergraduate students continued work with the Romero group on the cockroach repellency tests for the guayule resin fractions. One more set of tests, from fractions obtained from the Ogden group produced using vacuum distillation, will be run in the next quarter to target submission of a manuscript to an entomology journal in the summer. Brewer, Dehghanizadeh, Romero, Ogden and McMahan met with agricultural chemistry researchers from the Universidad de Castilla-La Mancha regarding collaboration on insect repellency and characterization of guayule resins; industry R&D relationships for both groups led to a decision to focus on the repellency and characterization method components so as to avoid process/composition IP issues.

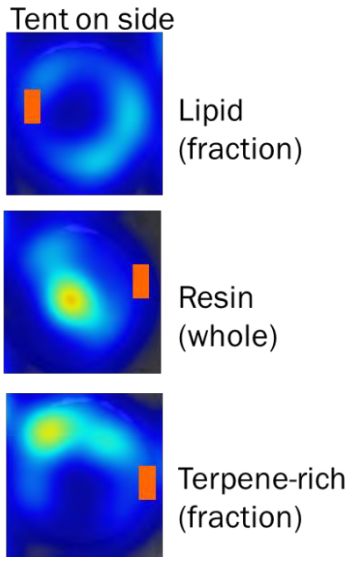


Figure 47. *Heat maps showing movement of a cockroach over a 25-min period.*

In Q2, Dehghanizadeh and the undergraduate students continued work with the Romero group on the cockroach repellency tests for the guayule resin fractions and drafted a partial manuscript on the insect repellency efficacy for an entomology journal. One more set of tests, from fractions obtained from the Ogden group using vacuum distillation, remains to be run once the Romero group has completed the move into their temporary lab space while the new building is constructed. Resin samples were received from the Universidad de Castilla-La Mancha and will be included in the next set of insect repellency tests, this time with bed bug species. Dehghanizadeh, Romero, and Brewer drafted an invention disclosure for guayule resin-based repellents that will be submitted to NMSU's Arrowhead Center for IP evaluation in the next quarter.

Characterization of Biomass and Fraction Samples:
Dehghanizadeh and the undergraduate students continued the HAZOP review and procedure development process for the supercritical fluid extraction system. Additional safety and auxiliary equipment purchases were completed.

In Q2, Dehghanizadeh began collaboration with Shalygin from the Holguin group on the characterization/quantification of resin components using a combination of techniques, in

particular the combination of mass spectroscopy techniques to quantify argentatins in guayule biomass and in derived resin fractions.

Evaluate Major Metabolites of Guayule:
This task is complete; nothing new to report.

Isolate and Characterize Major Metabolites of Guayule Terpene Solution:
This task is complete; nothing new to report.

Semi-synthesis, Characterization of Products, and Biological Evaluation of Guayule Resin:
This task is complete; nothing new to report.

Literature/Bioinformatics Searches:
Two putative cycloartenol synthases (catalyzing the first committed step towards argentatins) had previously been identified by bioinformatic analysis, using the guayule genome database (CAS073979 and CAS484873). Both were found to be expressed (i.e., present in the transcriptome databases) and to show a roughly 3-fold reduction in expression under drought conditions. These two CASs are the prime candidates for the biosynthesis of the argentatin skeleton.

- We are waiting for the McMahan group to PCR-amplify these transcripts from guayule cDNA, when they are allowed to return to their labs. The amplified genes will then be used for expression in yeast to verify their predicted function.

Sesquiterpene synthases (STS) producing bicyclogermacrene are catalyzing the first committed step of guayulin biosynthesis. Experimentally validated bicyclogermacrene synthases (BCGSs) from several plants were used as baits to search for similar STSs in the guatyule genome sequence.

- 35 STS candidates were identified in the genome sequence, and were cross-referenced against 3 guayule transcriptome databases. All sequence data (genomic assemblies, unassembled genomic reads, and the various transcriptomes) were used to derive the best models for the STS genes. Some of these gene models remained incomplete, likely due to missing sequence data. Some STS models correspond to likely pseudogenes, as shown by internal stop codons and other, uncorrectable sequence mistakes, and the lack of transcriptomic evidence.

- Phylogenetic analyses were conducted with the guayule STS models; their nearest database homologs from flowering plants; and the experimentally validated bicyclogermacrene synthases that we had used as baits. Evolutionary histories were inferred with the Maximum Likelihood method and JTT matrix-based model. The resulting tree with the highest log likelihood reveals clades that mostly correspond to the experimentally determined sesquiterpene product structures of the comparator enzymes.

- BCGSs from model plants do not form a coherent clade. Reasonable clades with guayule STSs as members were detected for α-copaene, germacrene A, β-farnesene, β-caryophyllene, α-isocomene, and germacrene D synthesis, and for two vaguely classified product groups. Phylogenetic prediction of products for STSs is notoriously difficult, per literature.

- Taking into account the phylogenetic analysis, the completeness and quality of the gene models, and proof for expression, a “short” list of 9 STSs were selected. Members of this short list may be responsible for bicyclogermacrene biosynthesis in guayule. These genes may be cloned from cDNA, or synthesized through commercial suppliers, for expression in yeast for function verification.

===

Cycloartenol synthases (CAS) were predicted to catalyze the first committed step towards argentatin biosynthesis. Three putative CAS-encoding genes were identified in Q1 from the guayule genome database by bioinformatic analysis. Two of these were found to be expressed (i.e., present in the transcriptome databases) while one was identified as a pseudogene.

Sesquiterpene synthases (STS) producing bicyclogermacrene were predicted to catalyze the first committed step towards guayulin biosynthesis. 35 STS candidate genes were identified in the genome sequence, and analyzed for the completeness of the gene model; for the expression of the gene (presence in various transcriptome libraries); and for their evolutionary histories (Maximum Likelihood method and JTT matrix-based model). A “short” list of 9 STSs were prioritized for functional studies as the result of these analyses.

Collaboration with the McMahan group to PCR-amplify CAS and STS transcripts from guayule cDNA was postponed due to pandemic lab closures and restrictions. Instead, the 9 STS and the 2 CAS genes will be obtained as synthetic DNA from commercial suppliers. The genes were optimized with the codon usage of the intended host, *Saccharomyces cerevisiae*; and splicing sites, repeat sequences, potential mRNA secondary structure and instability elements, and undesired restriction sites were eliminated.

Evaluate Microbial Transformations and Continue Chemical Transformations of Major Metabolites in Guayule Resin:

Small-scale biotransformations were attempted with actively growing cultures (“feeding assay”), and in some cases with resting cells, using 4 different filamentous fungi: *Chaetomium* sp, *Cunninghamella echinulata*, *Beauveria bassiana*, and *Fusarium graminearum*. Argentatin B, argentatin C, and a mixture of argentatin A + *iso*-argentatin A were used as the substrates.

Photo 6. *High-definition image of Chaetomium sp.*

- No biotransformation products were detected with *Beauveria* and *Fusarium*, irrespective of the substrates used.
- *Chaetomium* successfully biotransformed argentatin C and the mixture of *iso*-argentatin A + argentatin A in the feeding assay, but not in the resting cell assay. Argentatin B was not biotransformed.
- Feeding assays were successful with *Cunninghamella* for the mixture of *iso*-argentatin A + argentatin A, and for argentatin B as the substrates, although the yield with argentatin

B biotransformations is low. Resting cell assays were not successful. Argentatin C was not used as a substrate due to the relatively low amount of compounds we have.

Small-scale feeding assay biotransformations were attempted with *Chaetomium* sp. and *Cunninghamella echinulata,* using guayulin A and guayulin B as the substrates. Both substrates were biotransformed by *Chaetomium*, but not by *Cunninghamella*.

===

Small-scale biotransformations were attempted with actively growing cultures ("feeding assay") using 7 different filamentous fungi. Argentatin C (**argC**), argentatin B (**argB**), and a mixture of argentatin A and *iso*-argentatin A (**argA**) were used as substrates. The products were characterized by LC-MS-ELS, determining their putative molecular weights, and the conversion rates were quantitated at 3 different time points each to determine optimal biotransformation conditions. In some cases, feeding assays were also repeated using different media.

- *Beauveria bassiana*, *Fusarium graminearum*, *Aspergillus niger*, and *Corynespora cassiicola* did not biotransform any of the tested substrates.
- *Chaetomium* sp. provided 4 products each with **argC** and **argA**, and no products with **argB**. The feeding assays were scaled up under the optimized conditions to isolate products (see **Task 3** below).
- *Cunninghamella echinulata* provided two products with **argB**. The same fungus yielded up to 10 products with **argA**, with the yields of 3-4 products appearing to be sufficient for isolation. Scaling up the **argA** and **argB** reactions is currently under way for product isolation. Biotransformation was not attempted with **argC** as the substrate, due to the limited amount of the compound available.
- *Chaetomium globosum* afforded 2 products with **argA**, but these products appear to be identical to those already seen with *Chaetomium* sp. Three products were detected with **argB** as the substrate. While these are different from the biotransformation products of *Cu. echinulata*, only 1 of these products is present in isolable amounts. Scaling up the feeding assay with the *C. globosum* – **argB** pair is ongoing for the isolation of this product. Argentatin C was not used as a substrate due to the relatively low amount of compounds we have.

Resting cell assays (small scale biotransformations with cells suspended in buffer) were also conducted with the same fungi and the same substrates, but no products (or only very small amounts of products) were observed even in those fungus – substrate pairs where the feeding assays were successful. Consequently, we decided to de-prioritize this assay format for the rest of the project.

Small-scale feeding assays were conducted with guayulin A (**guyA**) and guayulin B (**guyB**) as the substrates, using only those fungi that were productive with the argentatin substrates. Testing of guayulins in a larger range of fungi could not be attempted due to the limited amount of guayulins available to us.

- *Chaetomium* sp. afforded 4 products with **guyA**, but the yields of these products are too low for isolation. With **guyB**, a single product was obtained, and the biotransformation will be scaled up to isolate this product.

- *Cunninghamella echinulata* yielded 1 product each with **guyA** and **guyB**, but the yields are too low for isolation.
- *Chaetomium globosum* did not biotransform **guyB**. However, two products were obtained with **guyA** in reasonable yields, and this feeding assay will be scaled up for isolation.

Characterize Novel Compounds from Biotransformations/Semisynthesis as Value-Added Products:

Scaled-up biotransformations in the feeding assay format were conducted with *Chaetomium* sp., using argentatin C, and a mixture of argentatin A + *iso*-argentatin A as the substrates. Four products each were detected in these biotransformations by LC-MS analysis.

- *iso*-Argentatin A-P2, argentatin A-P3, and argentatin C-P3 were purified by various chromatography procedures, and their structures were solved by NMR as shown below.
- Argentatin C-P4 and (iso)argentatin A-P4 have also been isolated by various chromatographic procedures, and their structures are currently being solved by NMR.
- Isolation of argentatin C-P1, argentatin C-P2, and (iso)argentatin A-P1 is currently in process.

All these products likely derive from a Baeyer-Villiger type oxidation of ring A of the argentatin scaffold, catalyzed by an unknown oxidase enzyme of the *Chaetomium* fungus.

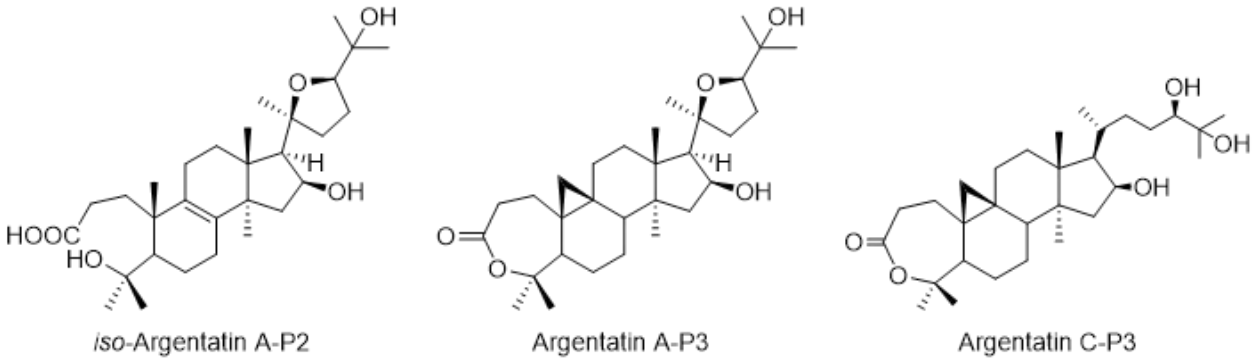


Figure 48. *Chemical structures identified for iso-Argentatin A-P2, Argentatin A-P3, and Argentatin C-P3 using various chromatography procedures.*

Several rounds of scaled-up biotransformations in the feeding assay format were conducted with *Chaetomium* sp., using **argC** and **argA** as the substrates. The same 4 products each were detected in these scaled-up assays as in the small scale feedings, showing the robustness of the biotransformation.

- The structures of 3 products, namely *iso*-argentatin A-P2, argentatin A-P3, and argentatin C-P3, were solved by one- and two-dimensional NMR, and reported in Q1.
- *iso*-Argentatin A-P4 and argentatin C-P4 have now been isolated by various chromatographic procedures, and their structures have been solved by one- and two-dimensional NMR (see figure below).
- Attempts to isolate argentatin C-P1, argentatin C-P2, and (iso)argentatin A-P1 are still ongoing, but the yields of these products are only borderline for isolation.

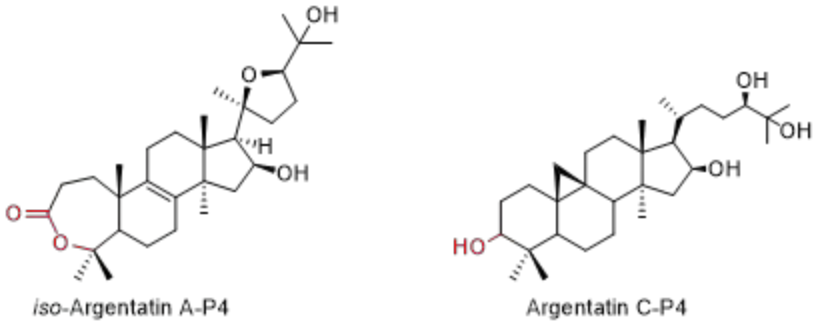


Figure 49. *Chemical structures of iso-argentatin A P4 and argentatin C-P4.*

iso-Argentatin A-P2, argentatin A-P3, and argentatin C-P3, and *iso*-argentatin A-P4 likely derive from a Baeyer-Villiger type oxidation of ring A of the argentatin scaffold, catalyzed by an unknown oxidase enzyme of the *Chaetomium* fungus. Argentatin C-P4 derives from the reduction of the keto group at C3 in ring A of the argentatin scaffold.
Bioassays with the isolated compounds will be conducted during the next reporting period.

Characterization of Pure Resin and Blended Adhesives:
We have been doing experiments with caution under COVID restriction policies. We had more access to other facilities and have continued looking for the facilities/consultants to analyze the resin/resin-adhesives samples.

S. Pradyawong focused on resin-protein characterization and extended the study to identifying the modified resin compositions and structure with collaborators. However, the global pandemic situation had a significant impact on her working progress. She contacted more facilities to run additional characterization tests of resin and resin-soy protein adhesives for the manuscript. We should have more results in the next quarter.

In Q2, the soy protein extraction from soymeal were done with the help of Dr. Molnar's group. Dr. Ogden and S. Pradyawong were still seeking help from collaborators to identify the modified resin compositions and structure.

Development of Guayule Resin-based Adhesives:
S. Pradyawong worked on resin adhesive experiments at Advanced Ceramics Company. With help of the company's staff, she finished building an environmental control chamber and the hot-press system for wood boding experiments. At the end of the quarter, she prepared the experimental materials and equipment to start the experiment on comparing the resin adhesives with commercial adhesives in the next quarter.

In Q2, Pradyawong still worked with the company staff to set up the facility for adhesion test at Advanced Ceramics Company and started doing the experiment. She mainly focused on enhancing the adhesion property of guayule resin by acid and base modifications. The modified/unmodified guayule resin and guayule resin blends with commercial urea formaldehyde were tested for the adhesion performance with the help of A. Hinojosa, a student worker. However, there was delays about tensile strength test due to the Instron grips issues. Therefore, adhesion test of guayule resin fractions from A. Smith was not finished yet.

The unmodified resin in solvents has no adhesion property. The acid/base modification methods provided an adhesion property to guayule resin. The preliminary test of acid/base modified-guayule resin in different solvents indicated that the acid modification provided a better adhesion strength to both types of the resin compared to the base modification method (see Table below). This preliminary information will be used to design the experiments in the next quarter for further development of guayule resin in different aspects such as pure resin, UF-resin, and protein-resin adhesives. However, improving a wet adhesion performance has been a challenge for bio-based adhesives including our guayule resin-based adhesive.

Table 10. *The adhesion strength of acid/base modified-guayule resin in different solvents.*

Solvent	Acid/Base	Resin	Wet Strength (MPa)	Dry Strength (MPa)
Isopropanol	Base	325	0 ± 0	**0.58 ± 0.23**
	Base	225	0 ± 0	**0.79 ± 0.17**
	Acid	325	0 ± 0	**2.46 ± 0.37**
	Acid	225	0 ± 0	**3.11 ± 0.36**
Acetone	Base	325	0 ± 0	**1.19 ± 0.22**
	Base	225	0 ± 0	**1.16 ± 0.1**
	Acid	325	**1.64 ± 0.11**	**2.73 ± 0.2**
	Acid	225	**0.56 ± 0.28**	**2.74 ± 0.11**
Hexane & Acetone	Base	325	0 ± 0	**1.86 ± 0.07**
	Base	225	0 ± 0	**1.36 ± 0.06**
	Acid	325	0 ± 0	**2.11 ± 0.09**
	Acid	225	0 ± 0	**2.66 ± 0.11**

Distillation of Resin into Multiple Fractions:

A. Smith, who mentors K. Burke, fractionated the resin at a constant temperature of 150 ºC while varying pressure from atmospheric to 0.20 PSI. Incremental improvements in pressure, temperature control and apparatus setup reduced pressure step size by half to 0.15 PSI and temperature variation from ±5 C to ±2 ºC. The distillation profile is shown below.

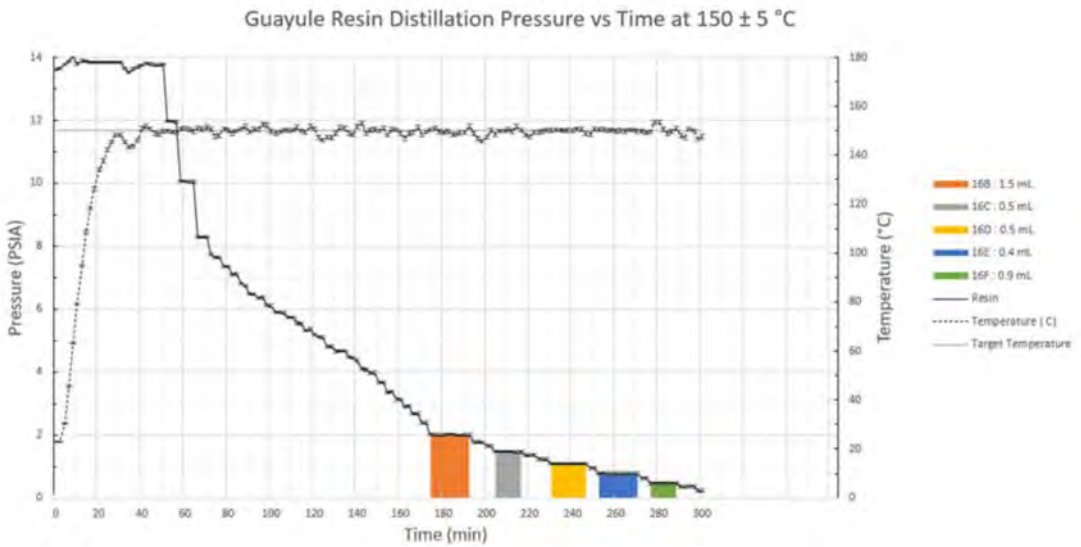


Figure 50. *Guayule resin distillation profile.*

Chemically removing low molecular weight (LMW) rubber from resin prior to distillation is a promising method to prevent rubber composition changes and either use it by itself or supplement it to a bio-adhesive. The adhesion performance of the fraction will be tested in the next quarter. Distillation using LMW rubber removed resin is currently underway but has faced setbacks due to difficulty in completely removing the acetone solvent from the LMW rubber removed resin.

During Q2, A. Smith worked on distillation with T. Lane, a student worker. Low molecular weight (LMW) rubber-removed resin was distilled three times at 0.15, 0.20 and 0.25 PSI. Distillation using atmosphere rather than nitrogen to control pressure was also done to see the extent of oxidation. Distillation fractions were sent to S. Pradyawong and M. Dehghanizadeh for testing as an adhesive and insect repellent, respectively.

Fats in raw resin and residuals were trans-esterified to fatty acid methyl esters (FAMEs) and analyzed via GC-MS for total fat content and composition. Detected fats include linolenic, linoleic, stearic, palmitic and oleic fatty acids, which is consistent with literature (see figure below). Fats remained in residuals for both 150 C and 260 C final temperature distillations. However, there is a difficulty of fully removing acetone solvent from LMW rubber-removed resin which has setback distillation experiments.

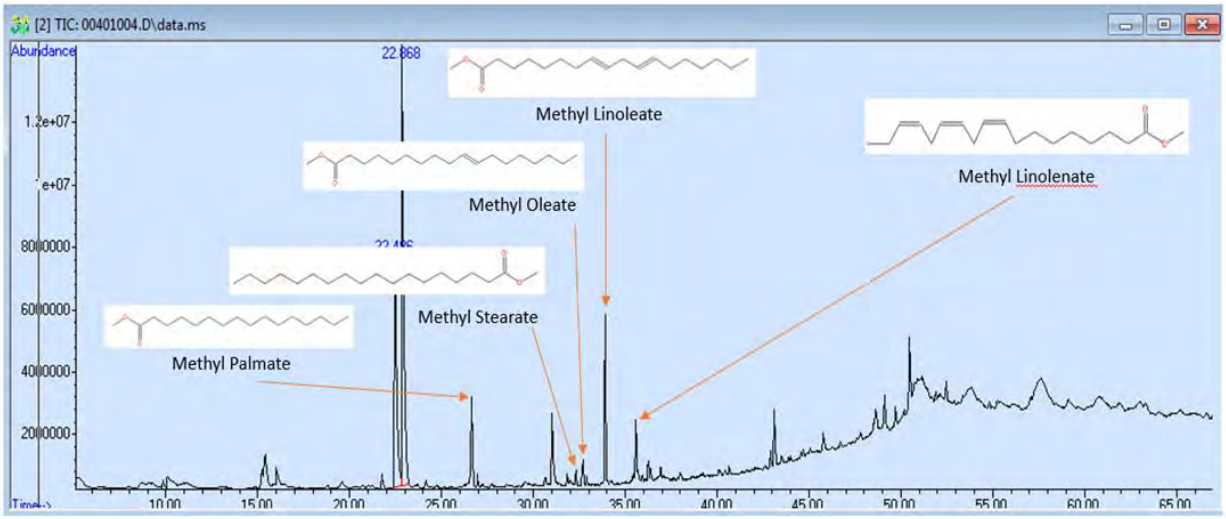


Figure 51. *Methylate fatty acid profile of guayule resin.*

SYSTEM PERFORMANCE & SUSTAINABILITY

Project Coordination: Colorado State University (Dr. Jason Quinn) leads the fortnightly working group webinar/phone calls. The meetings are leveraged to ensure all team members are on schedule and work can seamlessly integrate across institutions. The structure for the team meetings has been alternating between team updates and individual deep-dive presentations.

The team meetings have been on team updates and individual deep dive presentations. The team has two meetings each month with presentations being done every other meeting this quarter and slide updates on the other meeting times. COVID-19 has had minimal impact on the CSU and SUS team in general in terms of research productivity.

The focus this quarter has been:

- Development of a manuscript draft of downstream bagasse to fuel process results
- Refinement of the integrated models
- Model integration across the sustainability team focused on validation and improved fidelity
- Developing water LCA manuscript
- Development and moderation of sustainability team meetings on a bi-monthly basis in support of research goals
- Supporting CSM data integration and modeling
- Acceptance of abstracts to the ISSST conference

All notes and presentation materials are maintained in a community workspace available to all partners for future reference.

Issues/Risks:
Fan: One issue is related to the input of parameters and verification of our models for guayule supply chain. To reduce cost, alternative to reduce to harvesting cost of guayule were being analyzed. One of the efforts included an analysis performed by Bridgestone with different machinery. This analysis could take a considerable amount of time. Members of the Sustainability Team have been in contact with Bridgestone to provide support for addressing this issue.

Miller: Contacted H. Summers about obtaining data from one of the recent Seminars that was presented on irrigation levels and yield levels to complete some tasks, but normal response times and time inputting data may delay this into May (one month past target).

Quinn: P. Mendoza Moreno will be transitioning off the project this summer as she will be doing an internship at Argonne National Laboratory doing LCA work. Following this internship, she will be going to Cambridge on a Gates Scholarship to pursue her PhD. This is low risk to the project as she has been working closely with E. Sproul.

H. Summers has graduated and originally planned to work at CSU as a research scientist. Another opportunity presented that she has decided to pursue. While her loss will impact the project, CSU has put together a plan to be successful. Specifically, a new graduate students will

be recruited and mentored by Jason Quinn and Evan Sproul. This graduate student has not yet been identified Recruitment activities have been initiated.

Seavert: COVID-19 pandemic has stalled all in-person meetings, however planning for online programs continues.

Objective 1. Develop a scalable engineering process model for crop production and processing that is coupled with Techno-Economic Analysis (TEA) and Life Cycle Analysis (LCA) to understand the economic impact to rural communities through input-output methods.

Task #	Description of Task	Deliverable	Target Completion Date
1 Gutierr	Functional integration of economic analysis into system model	Conduct input/output analysis of system model results (IMPLAN) Validate preliminary analysis for farm production and profitability Develop market/transportation study to optimize industry location	31 Aug 21 31 Aug 21 31 Aug 21
2 Gutierr	Develop/test online producer systems model	Create online tool for evaluating guar/guayule alternative crops	31 Mar 21
3 Landis	Field data transfer	Field trial database updated with data quality codes for guar and guayule	31 Oct 20
4 Landis	Integrate guayule field data into LCA/TEA model	Updated LCA/TEA results and capability to choose likelihood for guayule	1 Dec 20
5 Landis	Support incorporation of guar data into LCA/TEA model	Collect data that enables LCA/TEA results for guar	15 Dec 20
6 Landis	Define guayule Monte Carlo parameters within model; run Monte Carlo analysis	Updated guayule field data Monte Carlo analysis report for guayule (integrated model)	15 Jan 21
7 Landis	Guayule: Statistical analysis on field data; compare to baseline model	Statistics report and comparative graphs generated/complete	15 Feb 21
8 Landis	Guar: Support best-fit probability distributions	Field data updated; methods documented	28 Feb 21
9 Landis	Sensitivity analysis (integrated model)	Tornado plots and report on model parameters causing most impact	15 Mar 21
10 Landis	Support guar manuscript development	Data support provided to sustainability team	15 May 21
11 Landis	Guayule scenario analysis	LCA/TEA results and report comparing scenarios to baseline	30 Apr 21

12 Landis	Guayule manuscript development	Draft manuscript circulated within sustainability team for review Manuscript generated and submitted to peer review journal	15 Mar 21 15 May 21
13 Miller	Transition NM SBAR Sustainability work to new personnel	Attend meetings; identify and articulate specific contributions	31 Mar 21
14 Miller	Validate farm level scenarios within system model	List of assumptions compiled; parameters for acreage, production values, and relevant technology	30 Apr 21
15 Miller	Evaluate economic impacts in rural areas using whole farm budgets and input models	IMPLAN model analysis for crop adoption; report generated for Extension dissemination	31 Aug 21
16 Quinn	Techno-economic and Life Cycle Assessment results	Update/finalize economic and environmental impact results Manuscript on water use for guar submitted to peer review	1 Aug 21 1 Sep 21
17 Quinn	Data integration	Integrate experimental data into foundational processing model	1 Sep 21
18 Seav	Validated integrated model, including alternative crops	Updated integrated model to evaluate farm-level economics	31 Aug 21
19 Teeg	Facilitate working agreement between Tribal Farms and Bridgestone to establish experimental plots	At least one experimental plot established on Tribal lands	31 Aug 21
20 Teeg	Validated integrated model	Update and incorporate new information under various scenarios	31 Aug 21

Functional Integration of Economic Analysis into System Model:
This task has transitioned to new personnel and is reported below.

Online Producer Systems Model:
This task has transitioned to new personnel and is reported below.

Field Data Transfer:
Field trial database was updated with data quality codes (guayule and guar).

Integrate Current Guayule Field Data into LCA/TEA Model:
Incorporate guayule field data (Irrigation, N & P, Herbicide, Tillage, Seed Rate, Harvest, Yield) into integrated model & ensure that results propagate properly through LCA, TEA

All guayule field trials have been integrated into the model as well. The full accurate propagation of the new field trial data through the LCA is complete and TEA propagation is in progress. All new processes from field trials have been added including specific irrigation processes (sprinkler, flood, drip) and herbicide processes that were not included originally.

All field trial data through the TEA was completed in Q2. All new process costs from field trials have been added to economics model including specific herbicide processes that were not included originally.

Support Incorporation of Guar Data into LCA/TEA Model:
Nothing new to report.

Define Guayule Monte Carlo Parameters Within Model and Analyze:
Best fit probability distributions have been set for all variables and preliminary uncertainty and variability analysis results have been produced for all the types of averaged data (e.g., all, likely, unlikely, optimistic) for all the inputs available. The VBA and @Risk error is resolved.

In Q2, we best fit probability distributions to guayule field data and defined Monte Carlo. Uncertainty and variability analysis results have been produced for all the types of averaged data for all the inputs available and are now incorporated into the manuscript.

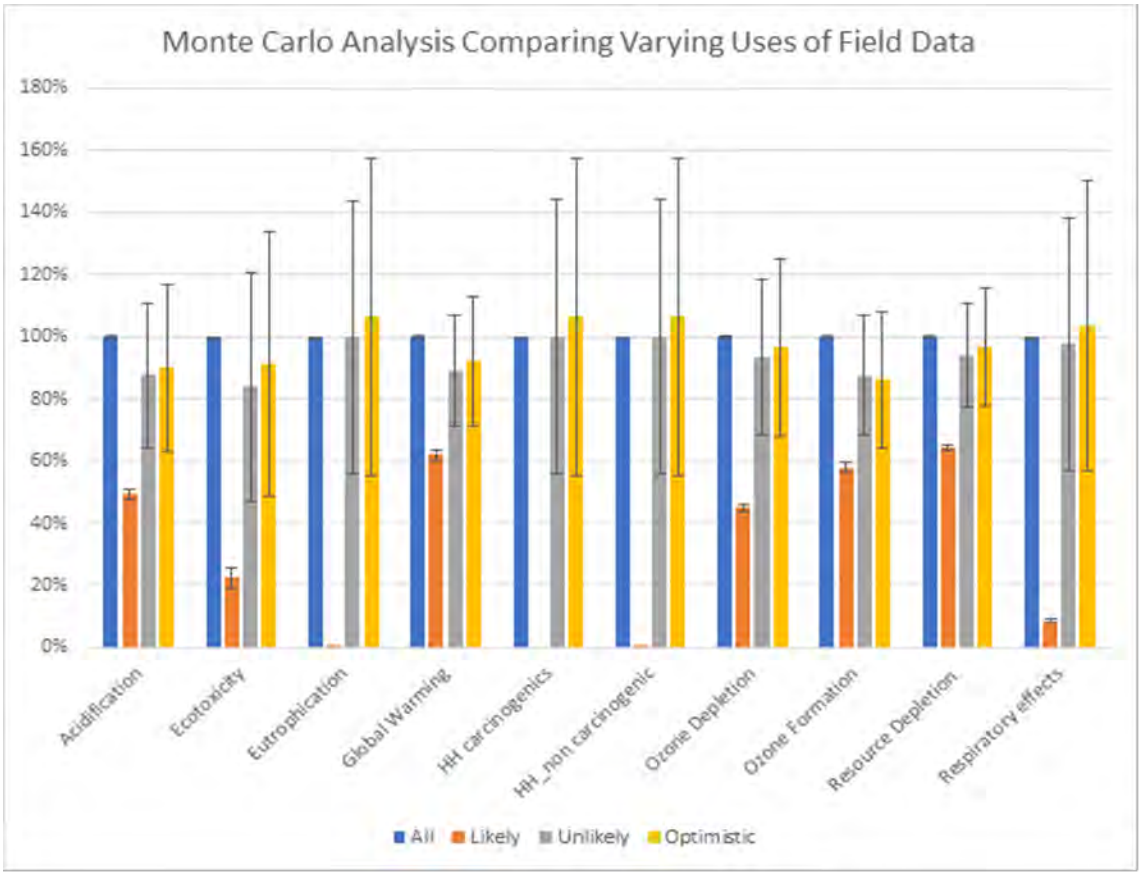


Figure 52. *Monte Carlo analysis for field data that shows uncertainty and variability within the data points.*

Guayule: Statistical Analysis on Field Data Compared to Baseline:
To help capture the uncertainty and variability of our newly added field data V. Mealing ran the Monte Carlo analysis for the Guayule model. The outputs distributions have been defined and 10,000 iterations have been run for each type of averaged data. Results from this were presented to the sustainability team on 4/14.

Guar: Support Best-Fit Probability Distribution:
Nothing new to report.

Sensitivity Analysis (Integrated Model):
Initial sensitivity analysis has been started in the integrated model; tornado plots will be the next step for assessing comparing the sensitivity analysis results.

Support Guar Manuscript Development:
Nothing new to report.

Guayule Scenario Analysis:
Nothing new to report.

Guayule Manuscript Development:
Manuscript for guayule field data and Monte Carlo is in progress.

In Q2, the manuscript draft for guayule field data and Monte Carlo was completed and is in the review process with co-authors. Once authors have reviewed and made edits, this manuscript will be submitted for publication. The outline for LCA and TEA manuscript is in progress.

Transition NM SBAR Sustainability Work to New Personnel:
Miller and Omotayo began working with Gutierrez, Teegerstrom, and Seavert to learn how to use the BENCO model they developed. We worked on identifying any errors or inconsistencies in the model. We now have a New Mexico copy of the model and are working to help validate farm level scenarios within the system model using different average farm sizes, irrigation technologies, and crop acreages for New Mexico. The New Mexico model will allow the inclusion of some of the specialty crops common in New Mexico.

Validate Farm Level Scenarios within System Model:
O. Omotayo is preparing an abstract for a lightning round presentation looking at changes in irrigation rates and yield, utilizing Dr. Seavert's BENCO model. He is submitting this to the International Arid Lands Consortium Virtual Conference.

Miller and Omotayo obtained information from New Mexico farmer and custom harvester to incorporate New Mexico prices and farm operations into the New Mexico BENCO developed by Dr. Seavert. Inclusion of crops more common in New Mexico allows analysis of how guar and guayule adoption might occur on New Mexican farms.

Evaluate Economic Impacts in Rural Areas Using Whole Farm Budgets and Input Models:
Contacted H. Summers about obtaining data from one of the recent Seminars that she presented on irrigation levels and yield levels to complete this task.

Many of the projects use the BENCO model as the basis for analysis. This model is almost fully updated. Meanwhile, a significant amount of background work and data collection is being completed towards the scheduled publications.

Techno-economic and Life Cycle Assessment Results:
Improved Data: CSU and CSM have collaborated on incorporating revised life cycle inventory data that was previously unavailable. This new data has led to improved LCA results, specifically for irrigation inputs.

Water LCA: During Q1, CSU started to investigate how to incorporate water within the LCA framework. Standard water scarcity footprint methods, Available Water Remaining (AWARE), were determined insufficient for the project needs of SBAR primarily due to the lack of resolution in arid regions. Therefore, a new method was developed and has been drafted into a manuscript. In summary, while an effective method for determining WSF, the AWARE methods have limitations that constrain capabilities for determining freshwater environmental impact in arid regions. The work developed is a novel method for determining WSF in arid regions where AWARE methodology falls short. The primary limitation with the AWARE methods is the inability to compare regions when more water demand exists than what is available, which typically occurs in arid regions (AZ and NM). The AWARE method truncates these situations and considers them all equally scarce. While effective, this does not allow decisions to be made in these areas considering WSF. The proposed method captures and quantifies scarcity when water demand is greater than availability and therefore increased resolution within arid regions. This approach, called the demand to availability (DTA) method has been developed universally, allowing for application and implementation in arid regions where other assessment techniques fail to give resolved results.

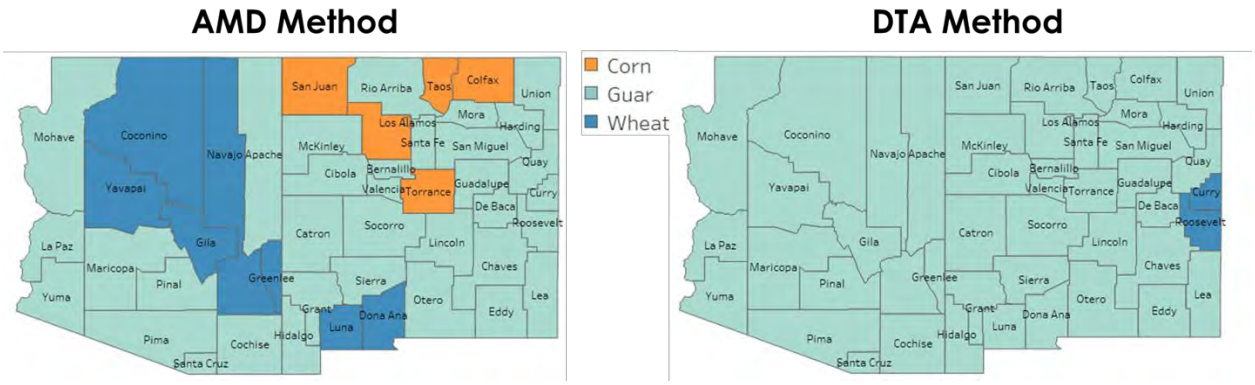


Figure 53. *County level lowest water scarcity footprint per hectare.*

During Q2, CSU has revised and resubmitted the water LCA methods paper. The reviewer comments in general were positive and we were invited to submit a revised manuscript. In addition, the methods were presented at the ISSST conference.

Data Integration:
Research continues as planned; nothing new to report.

Validated Integrated Model, Including Alternative Crops:
Continue to work in concert with the SUS Team, modifying the integrated models as needed. Machinery calculations may change to coincide with modifications to the BENCO Model.

Facilitate and Foster Relationship between Tribal Farms and Bridgestone:
Continuing to assist in securing experimental plots on at least two tribal farms. 1) Connect Bridgestone and CRIT farms for experimental acreage agreement, establish introduction meeting and started contract negotiations 2) Connecting Bridgestone and Fort McDowell Farm or Ak Chin Farms for experimental acreage agreement. Started the conversation, but still trying to establish an agreement that will work for both parties. This continues to be a difficult task, but will keep trying.

Validated Integrated Model:
Continue enhancement to the farm level scenarios using different average farm sizes, irrigation technologies, and add in different crops into the mix for both New Mexico and Arizona.

Objective 2. Integrate regionally appropriate metrics and combine results from SBAR-developed data into sustainability models to provide a path to commercialization of biofuels and bioproducts.

Task #	Description of Task	Deliverable	Target Completion Date
1 Quinn	Scenario analysis	Generate results of scenario analysis Present results of scenario analysis at conferences for feedback Submission of manuscript based on field trial data	1 Apr 21 1 Apr 21 1 Jul 21

Scenario Analysis:
The CSU team continues to work on the integrated models, leading the guar modeling effort and supporting CSM as they lead the guayule modeling efforts. Data integration work has been focused on incorporating Monte Carlo analysis within the existing model code and structure. CSU/CSM collaboration on Monte Carlo analysis has included reviewing input data, debugging @Risk software runs, and analyzing initial LCA results.

Bagasse to Fuels:
A manuscript related to bagasse to fuels modeling is being developed. The modeling includes pyrolysis and pelletization pathways. Results include economic and environmental assessments of both pathways. The team has presented this work at the ISSST conference and will submit this manuscript in August.

Objective 3. Interface with regional growers to de-risk US production of guayule and guar while evaluating social impacts.

Task #	Description of Task	Deliverable	Target Completion Date
1 Landis	Qualitative social sustainability manuscript	Complete manuscript: modify existing manuscript to focus on "hot spot assessment" of guar and guayule	31 May 21

Qualitative Social Sustainability Manuscript:
Nothing new to report.

Objective 4. Develop and optimize system-level logistics models for demand-driven harvesting.

Task #	Description of Task	Deliverable	Target Completion Date
1 Fan	Comprehensive sustainability and economics analysis	Conference presentation Manuscript submitted to peer review journal	30 Apr 21 30 Apr 21
2 Fan	Apply integer optimization approaches to design smart farm production plan/ scheduling	Computer codes and programs with embedded optimization models and algorithms	31 Aug 21
3 Fan	System-level model/algorithm generation for decision support for guar and guayule	Data/model/algorithm shared for Yr4 research (integration of 3 decision modules)	31 Aug 21

Comprehensive Sustainability and Regional Economics Analysis:
Based on the proposed models and algorithms in the previous research "Integrating Environmental and Social Impacts into Optimal Design of Guayule and Guar Supply Chains", we extended the economic analysis, as well as the analysis of environmental and social impacts, to the America Southwest, including Texas, New Mexico and Arizona, for both Guar and Guayule supply chains (see figures below for preliminary results).

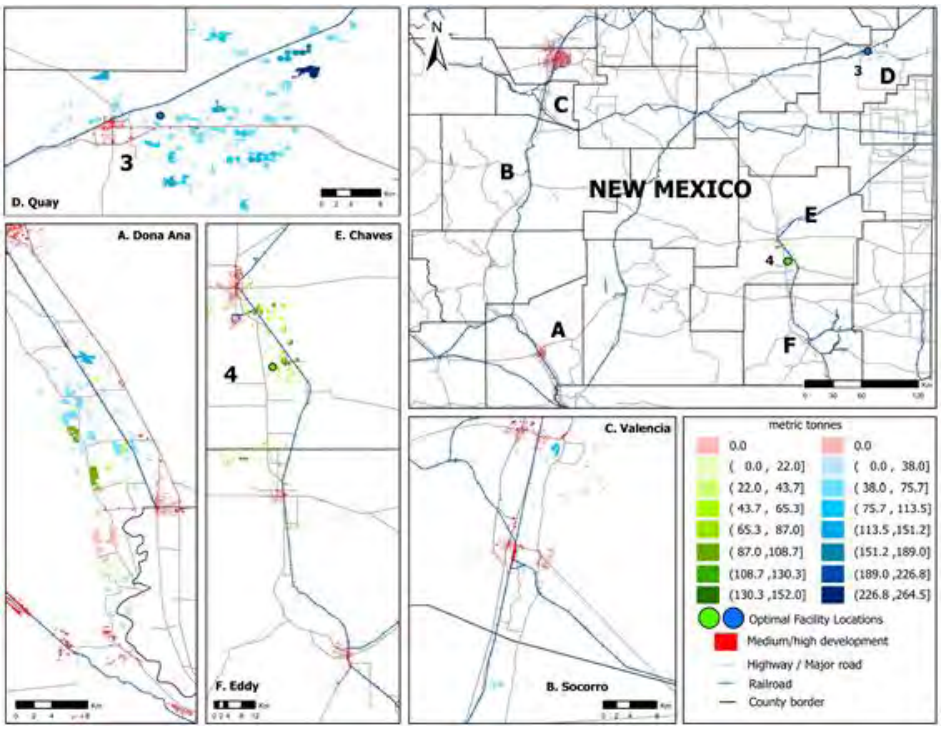


Figure 54. *Preliminary results of facility locations for guayule and guar supply chains in New Mexico.*

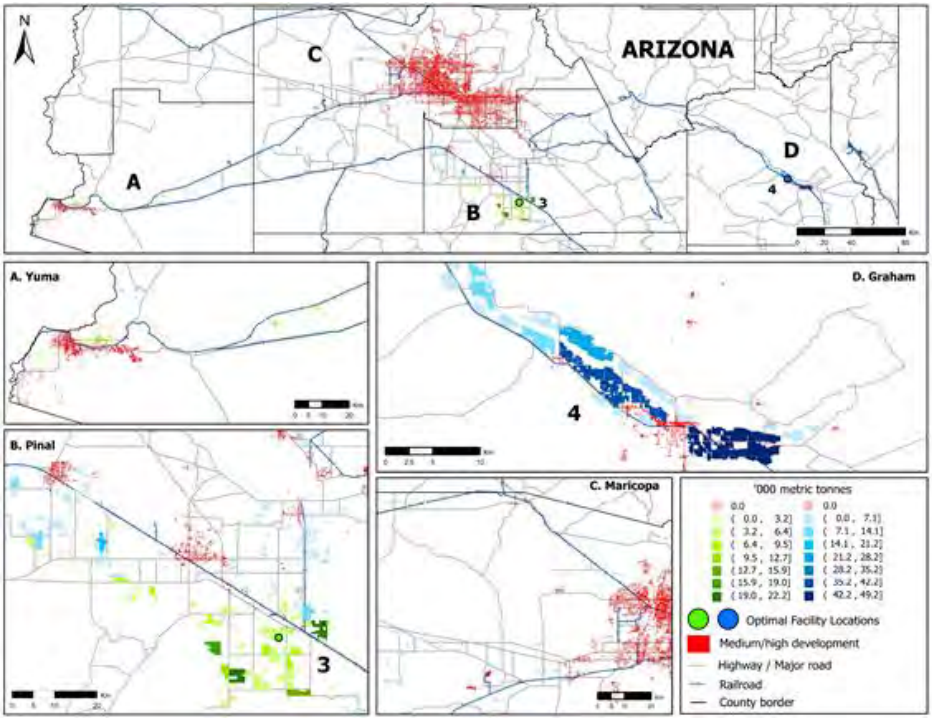


Figure 55. *Preliminary results of facility locations for guayule and guar supply chains in Arizona.*

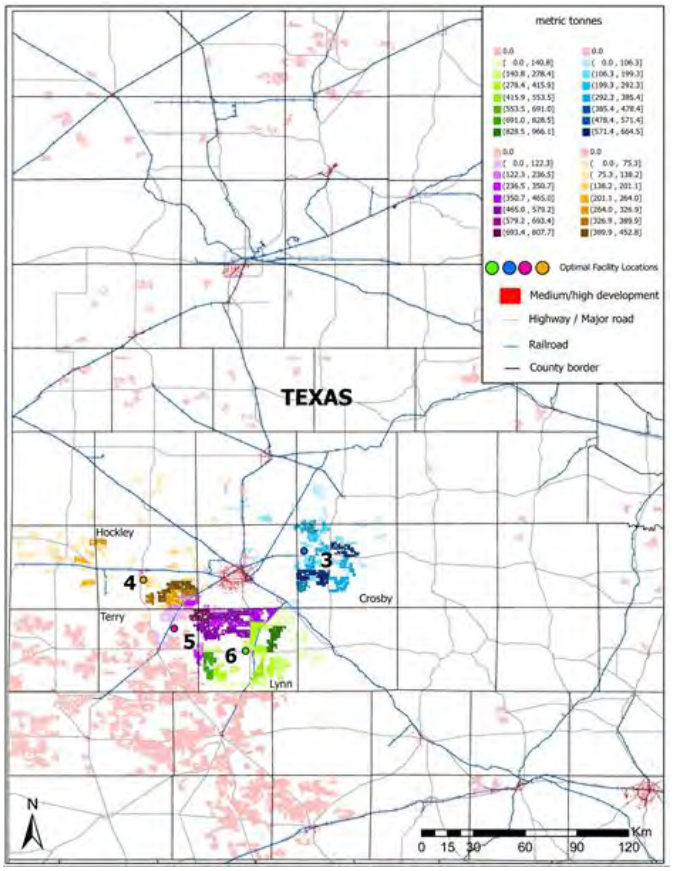


Figure 56. *Preliminary results of facility locations for guayule and guar supply chains in Texas.*

Preliminary results were presented to the SBAR UA Research group on April 7, 2021 and Sustainability group on March 17, 2021 and we received very valuable feedbacks, ranging from updating parameters, additional information sources, and different assumptions and comparisons that could be included to increase further the research contributions. Currently, we work on the final edits and checks before journal/conference submission for dissemination of the outcomes.

In Quarter 2, based on the feedback from the presentations to the SBAR Research and Sustainability Teams, the results for the Optimal Design of Guayule and Guar Supply Chains for the American Southwest research were updated as shown below.

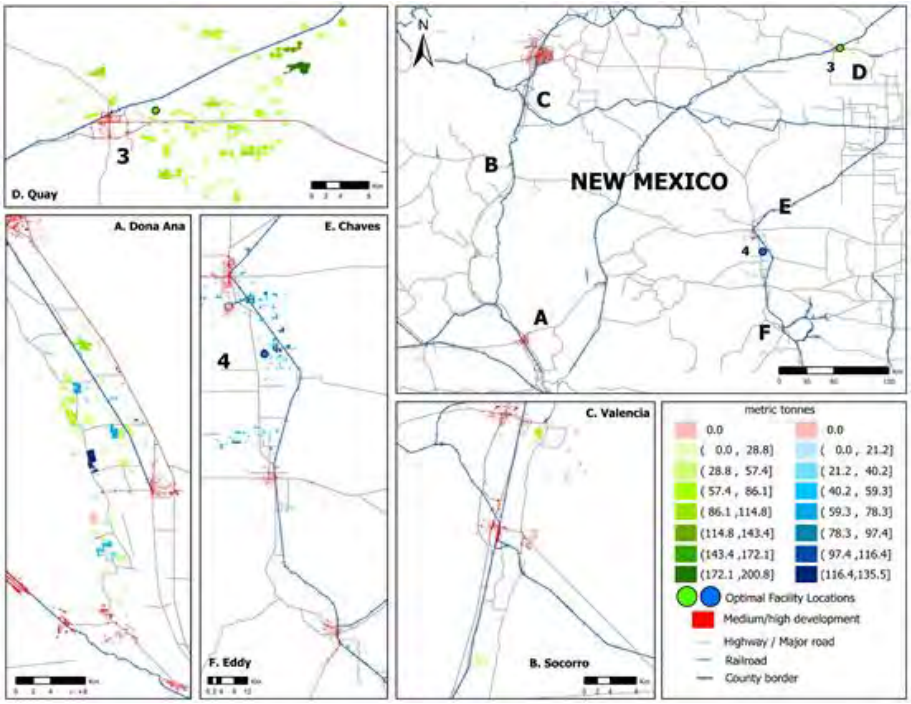


Figure 57. *Updated preliminary results for New Mexico facility locations for guayule and guar supply chains for the American Southwest.*

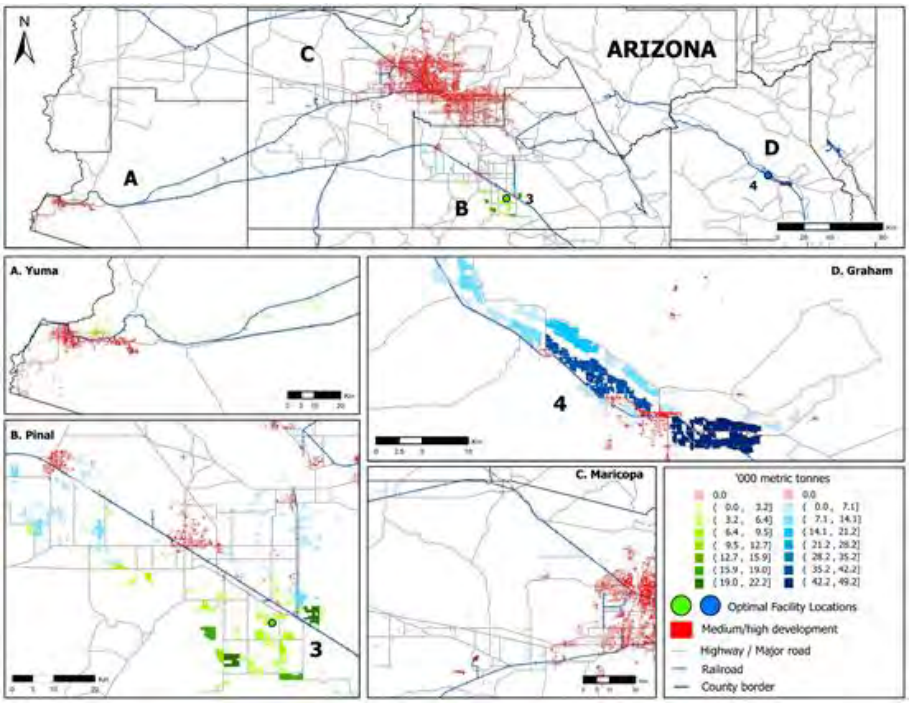


Figure 58. *Updated preliminary results for Arizona facility locations for guayule and guar supply chains for the American Southwest.*

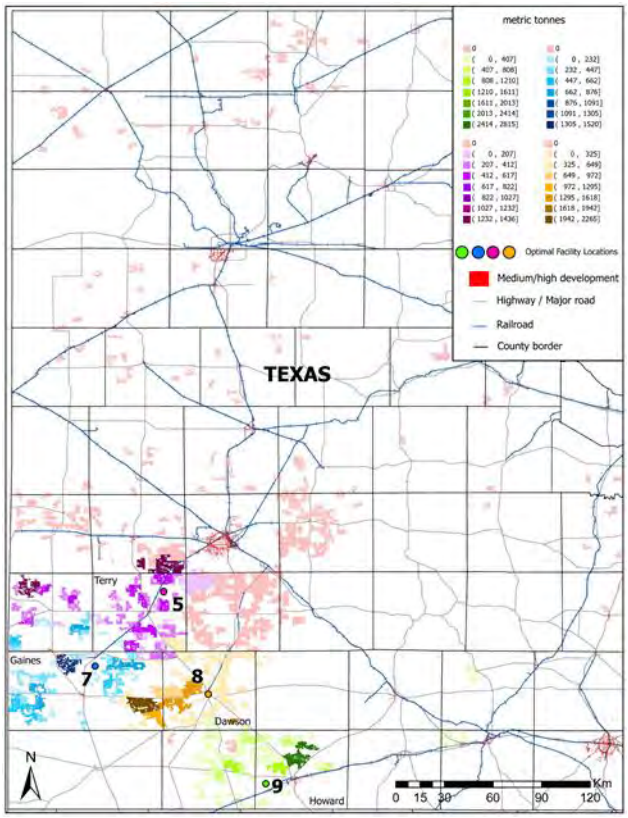


Figure 59. *Updated preliminary results of the Texas facility locations for guayule and guar supply chains for the American Southwest.*

Preliminary results were presented to the SBAR UA Research group on April 7, 2021 and Sustainability group on March 17, 2021 and we received very valuable feedback, ranging from updating parameters, additional information sources, and different assumptions and comparisons that could be included to increase further the research contributions.

The abstract of the updated version of this paper is submitted to 32nd AAIC Annual Meeting and the full version of this paper is planned to be submitted for the special issue on *Industrial Crops and Products* after this conference.

Integer Optimization Approaches for Smart Farm Production/Scheduling:
Based on the preliminary results of Year 3, Visual Basics for Applications (VBA) and CPLEX have been identified to integrate the three optimization models for guar and guayule supply chains. The three optimization models can be integrated directly through CPLEX using C++ and we are still working on the integration of models.

Integration of the input parameters for the optimization modules of guayule and guar supply chain (smart facility planning and transportation, smart farm production and scheduling, and sustainability and economics analysis) has been performed using macros with Visual Basics for Applications (VBA) designed to meet the CPLEX model's requirements. (See below)

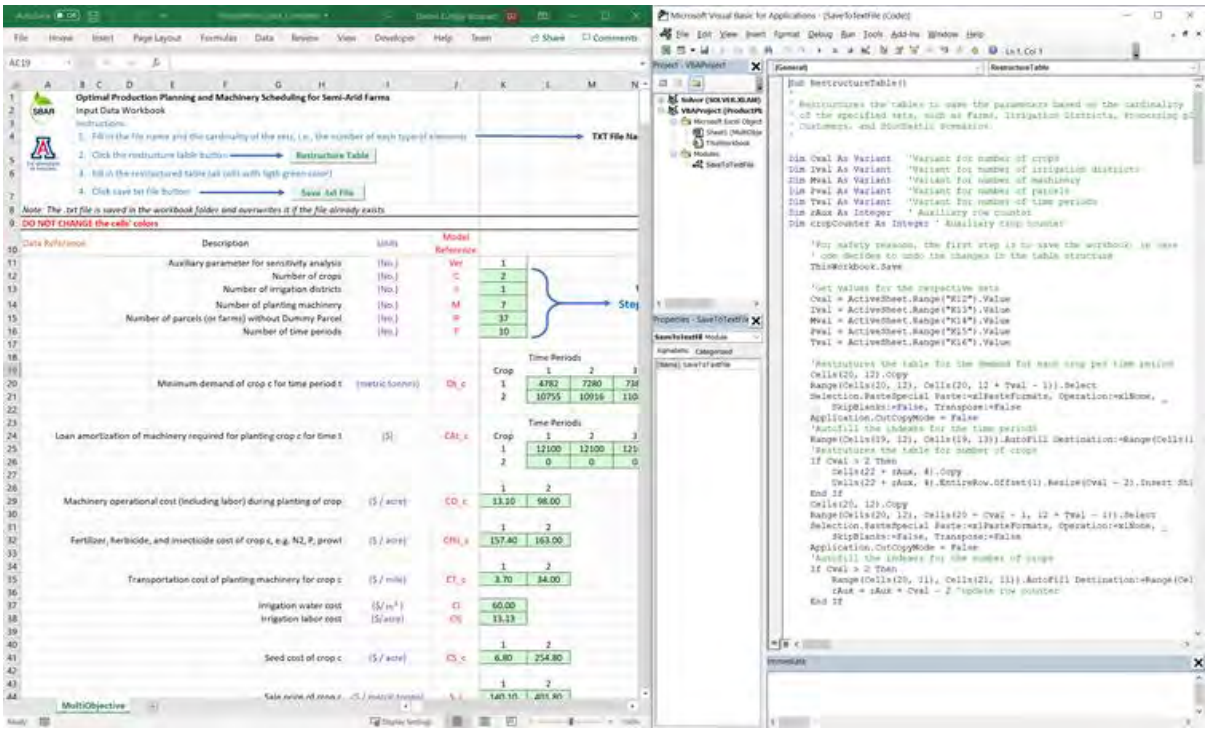


Figure 60. *Screenshot of the optimization input parameter integration.*

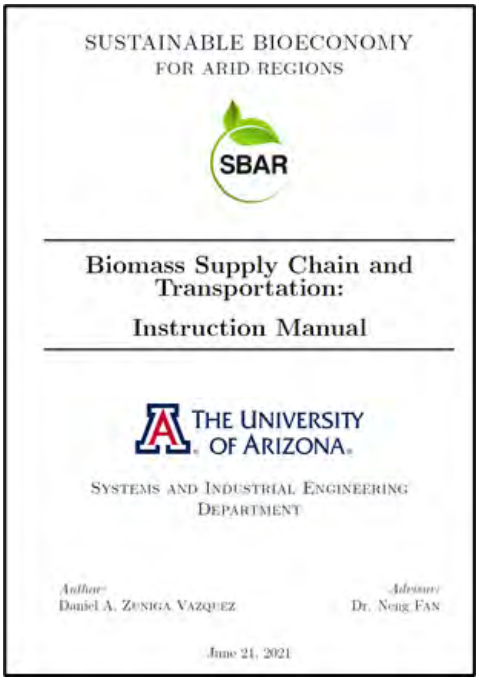
System-level Model/Algorithm for Decision Support:

A Python-based platform is being analyzed as a potential candidate to integrate the GIS with the transportation system-level modeling and the feedstock logistic optimization modeling. Geoprocessing tools can be created and coded to address the specific requirements for the system-level model. We have continued the work and analysis on the initial trials for the creation of geoprocessing tools for ArcGIS Pro based on Python using Spyder and CPLEX as shown below.

Figure 61. *Geoprocessing/optimization software diagram.*

An initial draft of instruction manual for the biomass supply chain and transportation (BSCT) optimization tool is being performed. The instruction manual will provide a walkthrough through the entire optimization analysis from the accessing of online CropScape information, its

implementation in ArcGIS Pro, to obtaining the optimal solution using a High-Performance Computer (HPC) and the interpretation of results.


SUSTAINABLE BIOECONOMY
FOR ARID REGIONS

SBAR

Biomass Supply Chain and Transportation:

Instruction Manual

THE UNIVERSITY OF ARIZONA

SYSTEMS AND INDUSTRIAL ENGINEERING DEPARTMENT

Author: Daniel A. ZUNIGA VAZQUEZ

Advisor: Dr. Neng FAN

June 21, 2021

Figure 62. *Initial draft of instruction manual for the biomass supply chain and transportation optimization tools.*

EXTENSION & OUTREACH

Project Coordination: Dr. O. John Idowu (New Mexico State University) and Blase Evancho (University of Arizona) continue to serve as the co-leads for the Extension & Outreach working team. When the larger Education and Extension & Outreach components jointly meet, Dr. Idowu and Evancho work with Dr. Chavarria to draft meeting agendas. Cara Duncan Shopa (UA) assists with coordinating meeting details as well as ensuring that notes are captured and maintained in the Box folder for future access/reference.

The Extension & Outreach team has two main foci – youth development (through 4-H activities and STEM mini-camps), and grower education/outreach. These two sub-groups meet at least once per month to discuss tasks and to improve component integration. The combined Education and Extension & Outreach teams meet once monthly to provide updates and address larger concerns regarding over-arching tasks that facilitates seamless project implementation in Arizona and New Mexico.

Issues/Risks:
Angadi: In spite of COVID-19 delay, we are trying to catch up. All field trial data were processed. Have made significant progress in developing videos and time lapse videos of guar germination, growth, and harvest. Final products are delayed but will be completed soon. However, field-based demonstration may be delayed due to prolonged drought.

Evancho: While progress is still being made in several areas the impacts have been greatly reduced due to implications from COVID-19 protection protocols and will continue to be impacted until resolved. Pinal County has just entered phase III, which has greatly reduced regulations and should begin to increase stakeholder interactions.

Plant population and guayule documents were delayed due to lack of data submission. Data has now been delivered and document preparation has begun. Guayule background and introduction document was delayed by a declaration of a shortage on the Colorado River, which required some higher level expertise from the WRRC to review and edit the document. Edits have now been returned and it is 99% complete.

There is also a risk of Native American Extension not occurring. Native American communities still lack interest in guayule and have seen exceptionally high impacts from COVID, further complicating our ability to deliver information.

Grover: Although there was no specific funding obtained for extension this year 4, the guar station trial was harvested and completed at Lyendecker Plant Science Center, Las Cruces. Face-to-face interactions have been restricted due to COVID.

Idowu: Due to COVID-19 pandemic restrictions, all of the traditional commodity conferences were cancelled in New Mexico during January to March. This prevented our team from having in-person contacts with farmers as we have done before the pandemic. We hope that as the pandemic wave decreases, we will be able to get back to in-person delivery of extension programs in the fall. We are also having difficulties in recruiting farmers for on-farm trials due to the pandemic and the exceptional drought that we are experiencing in New Mexico.

Due to COVID-19 restrictions, many summer meetings were cancelled in New Mexico. However, there is a great prospect for field days in the fall, during which we will be able to share the SBAR achievements. We have already signed up for three of such field days. We are having a hard time establishing guar trial in Tucumcari, NM, because of the problem with the irrigation system of the research center. The direct-seeded guayule trial that we attempted in Las Cruces using the seeds from Bridgestone has failed this season. We could not get any farmer to partner with us to conduct on-farm demonstration trial partly due to the pandemic stress that growers are facing in New Mexico.

Miller: An internal objection to providing scholarships for students younger than college age was made from our University Foundation office. The Assistant Dean of Business and Resource Planning has requested guidance from our Office of General Counsel. Donations for the Agri-Science contest have been received, more will be requested pending resolution.

Morris: Curriculum development on the Arid Lands has been paused. My leadership has been side tracked due to focus on the ambassador training and work with the NM team members to complete some projects that are closer to finished products. I intend to package the curriculum work into a form that can be completed in 2022 by our new AZ 4-H Curriculum Specialist.

Overall, the impact is not significant to the proposed scope of work as we have been adapting SBAR content to 4-H contexts in the form of the Guardians of the Biosphere afterschool curriculum, FFA lessons, and through presentations and infographic work.

Rock: During the last quarter University guidelines were shifted to phase 0 where we could not safely bring student interns to campus. Because our grant objectives specifically target in-person training and education for student interns, our project team is waiting patiently to bring students back to campus when it is safe to do so. With that in mind, our team is currently reached out to faculty mentors to identify projects that could be completed on-line or remotely. Very few faculty were receptive of the idea of on-line or remote delivery of internships. Ideas such as creation of fact-sheets and data analysis were proposed as possible alternatives, however, in order to have the best experiences for both the students and the mentors, we aim to post-pone deployment until Spring or Summer 2022.

As stated previously, we have worked with the project PI to postpone the intern experiences to 2022. This would allow our research and extension team to re-schedule interns for semesters when faculty, staff, and students return to campus, and allow the project team to full-fill remaining project objectives. This of course may change based on University guidance in coming months as well as student availability.

Seavert: COVID-19 pandemic has stalled in-person meetings; however, we continue planning for online programs continues. Waiting for Extension team to lead this effort; will cooperate when needed.

Teegerstrom: COVID-19 is still very active and restricting extension and in-person meetings, but we are moving to small in-person meetings along with continued on-line meetings.

Objective 1. Produce Extension bulletins and web materials to inform growers of agronomic and irrigation requirements.

Task #	Description of Task	Deliverable	Target Completion Date
1 Angadi	Guar photographs and videos	Obtain photographs of guar growth stages Create videos of guar germination and growth	31 Dec 20 31 Dec 20
2 Angadi	Guar agronomy research	Gather/analyze data; develop peer-reviewed article on N and P fertilization study	31 Mar 21
3 Angadi	Guar critical stage irrigation study	Produce report on guar crop growth based on irrigation management	28 Feb 21
4 Evan	Produce guayule newsletter articles	At least 2 guayule articles drafted and published – targeting AZ growers	31 Aug 21
5 Evan	Develop outreach documents for guayule	Background and introduction of guayule Guayule yield by variety Plant population management Guayule weed management Infographics for use in materials	31 Apr 21 30 Jun 21 30 Jun 21 31 Aug 21 31 Aug 21
6 Grover	Establish guar trial and showcase guar as potential crop in NM	Collect data; results synthesized Generate peer-reviewed publication	30 Jun 21 31 Aug 20
7 Grover	Guar demonstration	Identify farm willing to host a demonstration field trial Plant demonstration trial Harvest demonstration trial	31 May 21 31 Jul 21 31 Dec 21
8 Idowu	Travel to conferences	Present SBAR info/materials at 4-5 grower commodity conferences	31 Aug 21
9 Idowu	Establish guayule and guar trials in Las Cruces, Los Lunas, Clovis, and Tucumcari, NM	Showcase trial experiments at field days Gather data/synthesize results (toward generating an Extension bulletin)	31 Aug 21 31 Aug 21 31 Aug 21

		Generate trial summary (published on SBAR website)	
10 Idowu	Establish on-farm demonstration trials	Collect and summarize planting data for on-farm trials Final report prepared for website	31 Aug 21 31 Aug 21
11 Idowu	Newsletters to inform stakeholders	Distribute fall newsletter Distribute spring newsletter	31 Dec 20 31 Jul 21
12 Idowu	Design/schedule/implement E&O evaluation	Fall evaluation data gathered Spring evaluation data gathered Summer eval data gathered Eval info synthesized; report generated	31 Dec 20 31 May 21 31 Jul 21 31 Aug 21
13 Miller	Develop Extension programs/reports for guar and guayule	Finalize 3 extension bulletins: guayule and guar production costs; guar market/ transportation; farm-level scenarios	31 May 21
14 Seav	Validate/Revise Sensitivity Analysis Model for use in Extension meetings; Participate in grower workshops	User manual for model targeting Extension educators Workshop hosted (Title: The Costs and Benefits of Producing Alternative Crops in NM and AZ: Guayule and Guar)	31 Oct 20 30 Nov 20
15 Seav	Develop percentage of returns for tenant-landowner contributions	Draft Extension publication re: equitable lease arrangements; target audience: SW tenant/landowners	31 Aug 21
16 Seav	Demonstrate trade-offs of machinery ownership to custom hiring operations	Draft Extension publication re: machine needs and options for guayule and guar	31 Aug 21
17 Seav	Develop enterprise budgets for all crops in Sensitivity Analysis Model	Generate six Extension cost of production bulletins for AZ and NM Generate one Extension cost of production bulletin on growing hemp Hemp budgets accessible online via *AgBiz Logic*	31 Mar 21 31 Aug 21 31 Aug 21
18 Teeg	Generate an interactive farm-level economic and financial model (guar and guayule)	Validate and revise BENCO Model for use in Extension/Outreach meetings Develop PPT/guide for using the farm-level economic financial mode	31 Jul 21 31 Jul 21

19 Teeg	Participate in Extension meetings; disseminate economic info for guar and guayule	Provide 2 presentations to growers in NM Provide 2 presentations to growers in AZ	31 Aug 21 31 Aug 21

Guar Photographs and Videos:
We made good progress during the quarter. I finally found a suitable lab assistant, Ms. Mallory Nielson, who is also interested in video and photo editing.

We started working on the video showing guar crop growth in response to different deficit irrigation strategies. The main part of the video is done. Now, we are working on putting some captions, some info and voice over. Second video of guar harvest using plot combine was developed by using videos shot during field harvest. It shows sequence of events including cutting guar plants, feeding into combine, threshing it, separating into seed and trash, collecting seeds and dropping trash to the ground. We need to add some captions and voice over to make the video useful in K-12 or undergraduate education. We also have developed a time lapse video of guar germination in comparison to other traditional crops. We will put some caption and add some commentary to it.

===
M. Nielson was hired as a research assistant, and she will assist with guar extension and outreach projects.

Photo 7. *Image from a guar production video demonstrating the use of a plot combine in Clovis, New Mexico.*

Final version of video of guar harvest using plot combine was completed and uploaded to SBAR web page. We continued to work on developing some animations and editing of video showing guar crop growth in response to different deficit irrigation strategies. We are working on putting some captions, some info and voice over. We also shot a time lapse video of guar germination in comparison to other traditional crops. We will put some caption and add some commentary to it. We are also recording weekly photos and additional time lapse of guar plant growth, flowering, etc. to complement our earlier videos.

Guar Agronomy Research:
Guar N and P fertilization study was completed. Second year data was sent to D. Pruitt and Dr. J. Idowu. Two-year multiple location trial will be compiled and report will be prepared by D. Pruitt and Dr. J. Idowu.

A fact sheet was developed from the work by D. Pruitt and J. Idowu. This work was also part of D. Pruitt's thesis research, which she successfully defended.

Guar Critical Stage Irrigation Study:
Nothing new to report.

Produce Guayule Newsletter Articles:
The SBAR Newsletter was sent to 319 subscribers in Pima, Pinal and Maricopa counties through the regional Crop Rotator newsletter in January. There will be a second SBAR Newsletter to update stakeholders this summer.

The second SBAR Newsletter was sent to 319 subscribers in Pima, Pinal, and Maricopa counties through the regional Crop Rotator newsletter in June.

Develop Outreach Documents for Guayule:
Background and introduction on guayule document rough draft is complete. It will be sent for edits and revision then submitted to UA Extension FastTrack for Publication. Extension documents on variety trials, plant population, and weed control have been started are on track for publication this summer. An additional publication on nitrogen management in guayule will also be developed this summer due to newly available data. Infographic development had to be moved up in priority due to the loss of key collaborator Nick Morris in May. This will be completed earlier than anticipated.

===
Extension documents on variety trials and plant population were slowed by delays in data delivery, but are in progress. Weed control document has been started and will be completed in Q3. An additional publication on nitrogen management in guayule will also be developed in Q4. Infographic development is underway and a draft of the guar infographic has been completed.

Showcase Guar as Potential Crop in New Mexico:
Threshing of plant samples completed and data collected on final seed yields, biomass and harvest index. Single plant threshing and data collection on seed yield attributing characteristics completed, the collected data will be analyzed and results summarized in coming weeks.

Developed Guar production information for SBAR website as agreed upon between the EEO group. Photos provided as well for the relevant topics.

Two extension manuscripts as co-author are currently in revision. 1) Laje et al., Natural Products in the Desert Southwest: Guayule (*Parthenium argentatum*) and Guar (*Cyamopsis tetragonolobus*); 2) Khandal et al., Enterprise Budgets for Guar Production. Another extension manuscript focusing on guar production practices is in process for submission to the NMSU system.

Guar Demonstration:
Due to the ongoing pandemic, it was conveyed by the SBAR Leadership team not to pursue these goals. Efforts will be devoted in collaborating with other members of extension team and partners.

Travel to Conferences:
Nothing new to report.

Establish Guayule and Guar Trials in New Mexico:
Preparations are on-going for the on-station multilocational guar trials in New Mexico and another trial for establishment of a guayule field transplants in Las Cruces.

On-station multilocational guar trials were established at Clovis, Los Lunas, and Las Cruces, NM.

Photo 8. *Guayule demonstration plot in Las Cruces, New Mexico.*

Establish On-Farm Demonstration Trials:
Guayule field demonstration trial was established in Q2 with transplants in Las Cruces, NM. Guayule cold tolerance study in collaboration with Bridgestone was also expanded in Las Cruces, NM during Q2.

Newsletter to Inform Stakeholders:
A newsletter Volume 2, Issue 1 was released in January 2021 and distributed to stakeholders in New Mexico and Arizona. A fact sheet titled "Guar as Rotation Crop" was released and hosted on SBAR website. Another factsheet and an extension publication are in preparation.

A newsletter Volume 2, Issue 2 was released in June 2021 and distributed to stakeholders in New Mexico and Arizona.

Information on guar cultural practices was produced and provided on the SBAR website. The second fact sheet titled "Guar Fertilization" highlighting the results of nitrogen and phosphorus study performed at four locations in New Mexico was released and hosted on the SBAR website.

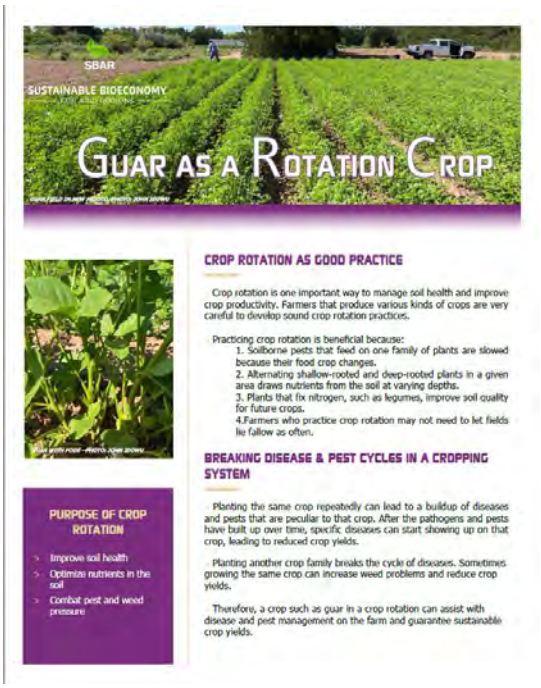


Figure 63. *"Guar as a Rotation Crop" Fact Sheet available on the SBAR website.*

Design and Implement Extension & Outreach Evaluation:
Nothing new to report.

Develop Extension Programs/Reports for Guar and Guayule:
New task began in January 2021. Research continues as planned; nothing new to report.

Validate Sensitivity Analysis Model for use in Extension/Outreach Meetings:
Changes to the BENCO Model continue, U of A and NMSU each have a BENCO Model that they can revise to reflect farm-level specifics for each agricultural region. Each university can

now begin developing cost of production crop budgets for publication. Writing a user-guide, with a PowerPoint to follow, is underway for Extension educators. COVID continues to delay workshops for producers, but the model is ready for extension use in 2021. Working with Economic Team to confirm meeting dates for online presentations. Future of in-person presentations depends on COVID-19 virus restrictions.

Improvements to the BENCO Model during Q2 included adding equipment to the mix of machinery, expanded the number of crops that can be added to a farm, developed a breakeven and input/resource table for all crops as acres of guar and guayule increase/decrease replace existing crops. Manual for Extension educators will be postponed to the 2021-22 year due to several changes to the model mentioned above.

Develop Percentage of Returns for Tenant-Landowner Contributions:
Completed the modeling for establishing equitable lease calculations for crop-share and annual cash rent leases for guar and guayule. Also including flexible cash rent lease calculations as an alternative lease option; this lease option estimates annual payments based on expected and actual price and yields, which can reduce financial risk to tenants and landowners.

Included the calculations for a flexible cash rent lease in the BENCO Model that complements crop-share and annual cash rent leases for guar and guayule. Users now have the ability to evaluate three lease options to determine which lease is more aligned with their financial and production risks in growing guar and guayule. This feature can be used by both tenants and landowners.

Demonstrate Trade-Offs of Machinery Ownership to Custom Hiring Operations:
Entering custom machinery rates into the BENCO Model is complete, however, until harvest methods are explored, and options chosen, the extension publication is on hold.

Completed the option to include custom machinery rates into the BENCO Model. Based on recent research, Bridgestone provided custom rates to harvest guayule, trials will continue in July. Publication on machinery will be postponed due to this new information in to the 2021-22 year.

Develop Enterprise Budgets for all Crops in Sensitivity Analysis Model:
Guar and guayule enterprise budgets have completed their review at NMSU and U of A and waiting publication numbers.

Q2 - Guar and guayule enterprise budgets are complete, other crops are underway by team members in AZ and NM.

Interactive Farm-Level Economic and Financial Model (Guar and Guayule):
Continue to add and update relevant extension model scenarios and data. Now working on adding adjusted harvest information and cost.

Dissemination of Guayule and Guar Economic Information through Extension Meetings:
Continue to work with AZ and NM Extension team, with inclusion of new crop options with the current baseline for whole farm analysis to be used in the presentations during the

extension/outreach activities. Future of this task depends on COVID-19 restrictions and preferred delivery method. One Extension publication for NM should be out soon with AZ following.

Completed the introduction section of leasing analysis within the whole farm too. In-person meeting with two local producers to ground-truth some of the machinery assumptions used in the model. Developed the plan for integration of the whole farm adoption tool and collected information during the 4 grower presentations.

Objective 2. Hold workshops throughout the region on sustainable practices to expand crop production to new rural regions and Native Nation lands.

Task #	Description of Task	Deliverable	Target Completion Date
1 Angadi	Arrange guar field day/field walk at Agricultural Science Centers, NM	Present guar crop information to ~100 producers in the region	31 Dec 20
2 Angadi	Educate local growers	Establish guar demonstration on a local farmer's field	31 Dec 20
3 Evan	Hold workshops and present information to growers in Arizona	Host two presentations on guayule agronomic production and irrigation at regional extension events	31 Aug 21
4 Evan	Present guayule production intormation to Native American farming communities	Presentation to Native American Farm Boards	31 Aug 21
5 Evan	Communicate with AZ growers and producers	Maintain relationships with local growers to share SBAR/guayule information	31 Aug 21
6 Fields	Track Grower Extension Team activities monthly	Compiled contact data totals submitted quarterly	31 Aug 21
7 Grover	Hold workshops and present information to growers	Host 2 presentations on guar agronomic production as an interim step to bulletin Present SBAR project information and materials	31 Aug 21 31 Aug 21

Educate Local Producers about Guar:
Initiated some work on guar web page for reaching producers. Have completed major part of work on guar cultivars and final revision needed. Participated in two guar factsheets of Dr. John Idowu. Have initiated putting together two more factsheets from my work, one on temperature effect on germination and the other on deficit irrigation management.

We are planning to present our guar research in the upcoming field day at Agricultural Science Center at Clovis on 3 August 2021. If in person field day was not arranged due Covid-19, the research will be presented in virtual outreach event. Senator Martin Heinrich visited our science center and took a tour of our research activities.

Establish Farm Demonstration Site in New Mexico:
Prolonged drought started in fall of 2019 is still continuing. Most farmers including irrigated farmers are stressed from it. It will negatively affect farmers interest in our guar research and extension activities this year. Our plan to conduct a field scale demonstration of guar in 2021 may be affected by extreme dry season. We will make an effort to recruit farmers for the demonstrations in 2021.

===
Prolonged drought seems to be ending. We received significant rain in the last week of June and first week of July. But, damage for 2021 season has already occurred. Most farmers including irrigated farmers were very cautious on what they are planting and were least receptive for alternative crops. We are concerned that it will negatively affect farmers interest in our guar research and extension activities. Our plan to conduct a field scale demonstration of guar in 2021 was also affected by very late relief of drought. We will make an effort to recruit farmers for the demonstrations in 2022.

In the spring, we initiated developing guar web page for producers. I have to give final touch on guar cultivars section. I am working on irrigation section, which is partly linked to manuscript that my farmer graduate student is working. Need to complete those web pages in the next couple of weeks. Participated in two guar factsheets of Dr. John Idowu. Have initiated putting together two more factsheets from my work, one on temperature effect on germination and the other on deficit irrigation management. They will be submitted for review soon.

Grower Workshops in Arizona:
Due to COVID early season conferences were limited in scope to specific crops and 2 events were canceled. SBAR & guayule information was delivered virtually at the USDA Arid Lands Research Center Stakeholders meeting (info attached). Presented information on SBAR project at Pima County Cooperative Extension monthly faculty meeting. Bridgestone Grower Field Day is tentatively scheduled for Fall and will be more concrete when Bridgestone COVID restrictions are loosened.

SBAR & guayule information was presented to the Pinal County Advisory board (Oliver Anderson, Orlenda Roberts, Richard Carino, Carlos Carranza, Rick Miller, Le Smith, Joel Belloc), and the Bridgestone Guayule Field Day is tentatively scheduled for October 6 or 7.

Photo 9. *Guayule Field Day participants learn about guayule crop production in Eloy, Arizona.*

Guayule and Native American Communities:
Native American communities still lack interest in guayule and have seen exceptionally high impacts from the coronavirus further complicating our ability to deliver information. However, there has been some progress made with Tohono O'Odham Farm Director. Discussions will continue with hopes to present to the farm board and a potential guayule planting next spring.

Communications with Arizona Growers:
Discussed guayule production with ag producers, industry professionals and Extension faculty.
Discussed SBAR & guayule production during regional Helena agronomy meeting.
Discussed SBAR and guayule production during Maricopa County Tent Talk (25ppl), Desert Agriculture Conference (40ppl), and Pinal County Stakeholders (7ppl).

Track Grower Extension Team Activities Monthly:
The table below quantifies outreach by event during Q1 2021. Due to the ongoing impact of the COVID-19 pandemic, no events were scheduled. Growers have indicated that they were not interested in meeting via a zoom format, and given the economic uncertainty and economic decline due to the impacts of COVID, there is currently little interest in exploring alternative crops with no known positive financial certainty, even if considering rotator crops. This economic strain has also made it difficult, likely impossible, to recruit on-farm trials by local/regional growers. No significant personal contacts were made.

Table 11. *Outreach events conducted during Q1 2021 in Arizona and New Mexico.*

	Event	Date	Number participating
AZ	None to report	N/A	0
NM	None to report	N/A	0

Grower Workshops in New Mexico:
Nothing new to report.

Objective 3. Involve youth in internships, 4-H projects, and STEM summer camps.

Task #	Description of Task	Deliverable	Target Completion Date
1 Fields	Design/schedule evaluation tools, protocols, and metrics for all Extension & Outreach activities	Fall tools developed/refined; evaluation data gathered Spring tools developed/refined; evaluation data gathered Summer tools developed/ refined; evaluation data gathered Data synthesized; evaluation report generated	31 Dec 20 31 May 21 31 Jul 21 31 Aug 21
4 Miller	Provide training for FFA teacher and 4-H Extension Agents	Host workshop for FFA teachers to support Agri-Science fair students	28 Feb 21
5 Miller	Finalize SBAR/FFA activities	Separation of Mixture Plant Chemicals that Fight Free Radicals	31 Mar 21 30 Jun 21 31 Aug 21

		Thin Layer Chromatography of Pepper Pigments	
6 Miller	Lead creation of 4-H youth science project development re: bio economy	Create formal proposal for 4-H Leadership Initiate 4-H curriculum review process	31 Mar 21 31 Aug 21
7 Miller	Co-lead development of *Guardians of the Biosphere* curricula and activities	Draft bioeconomy-related 4-H project curricula for grades 5-7; initiate curriculum review	31 Aug 21
8 Morris	Adapt existing curriculum for 4H program	Two existing 4H curricula adapted for SBAR topics (bioeconomy)	15 Nov 20
9 Morris	Develop county level STEM Ambassador Program (SBAR-related)	Host focus group meeting with STEM Camp Counselors in June Ambassador guidebook for county implementation	31 Dec 20 31 Dec 20
10 Morris	Design STEM volunteer training program; recruit volunteers	Recruit 5 STEM certified volunteers Host 3 STEM volunteer trainings	31 Dec 20 31 Dec 20
11 Morris	Develop STEM internship program plan, recruitment plan, evaluation plan	Completed internship program plan, recruitment plan, and evaluation plan	31 Jan 21
12 Rock	Develop SBAR internal factsheets on *Project Puente*	Generate *Project Puente* resource document(s) for SBAR faculty	28 Feb 20
13 Rock	Recruit students for summer *Project Puente* internships	Update application materials to highlight on-going SBAR research opportunities Recruit 6 students for Yr3 cohort of *Project Puente* interns	pending
14 Rock	Recruit faculty mentors for summer *Project Puente* internships	Recruit 5 faculty mentors for Yr3 cohort of *Project Puente* interns	pending
15 Rock	*Project Puente* student project development and deployment	Work with SBAR faculty to identify appropriate internship projects (research and extension) Facilitate SBAR internship projects; final poster presentations highlighting student work	pending
16 Rock	*Project Puente* case study video	Design and develop short video highlighting student/mentor experiences for future training needs	pending

Design and Implement Evaluation Tools:
During Q1 of 2021, the primary tasks related to the evaluation of the EEO components of the SBAR project were centered around continued attendance at team meetings to follow and document project processes and outcomes, develop the timeline for each evaluation component based on the revised evaluation plan (given project shifts from COVID and general evolution of the project), the development of research tools and protocols including the drafting of potential interview and survey questions, reviewing curricular and website materials, and scheduling interviews with various graduate fellows and teachers for the three case studies planned for a publication. That work will continue through the summer since it involves travel to NM sometime during the late summer or early fall if COVID restrictions are eliminated and extension field days are scheduled.

Q2 of 2021, the primary tasks related to the evaluation of the EEO components of the SBAR project were centered around continued process evaluation to assess progress towards objectives and outcomes; curricular and pedagogical review of select EEO materials and artifacts; qualitative research and evaluation including individual and focus group interviews and other evaluation methods to capture data from teachers and fellows.

Grower-Focused Extension – For the grower-focused extension team, they continue to face COVID related challenges in AZ and NM in regards to their outreach efforts, as described below. Because of this, they have been focusing more on developing content for the website. More progress has been made with the guar related content. Likewise, the NM extension team is working on a number of publications. One will be a fully peer-reviewed extension publication, but several are 'fact sheets' aimed at growers and will relay particular growing information (irrigation, weed control, harvesting.) The NM team is planning for planting on-station trials and hopes to resume in person field days in the late summer/early fall. The AZ extension team is working on website content, using the template for the guar content, and will examine a recent paper for elements that can become a guayule fact sheet. In AZ, they will also explore the possibility of an in-person Bridgestone field day in the fall.

For the grower-focused extension team (during Q2), prgramatically work continued on website development, publications, and planning of outreach events now that COVID restrictions are lessening. Growers continue to indicate concerns about the economic uncertainty and economic decline due to the ongoing impacts of COVID. Although the perception is that interest in exploring planting guar and or guayule with no known positive financial certainty remains tentative at best. This economic strain limited the ability to do on-farm trials this year. However, NM is planning for a number of field days to demonstrate research plots to interested growers and the community. Additionally, in year 5 we will develop a follow up survey to assess changes from the needs assessment distributed in year one.

Youth Development Extension – For the Youth Development team, efforts over Q1 included more work on the website, recruitment and training of STEM ambassadors, and planning for summer activities. The proposed internship program was canceled for this summer due to the ongoing difficulties with in-person experiential learning due to the COVID-19 pandemic. STEM Ambassadors however will begin incorporating SBAR

related activities and content into science activities taking place in their communities. In NM, they are also exploring how to create a 4-H curriculum out of the materials used during the '*Guar*-dians of the Biosphere' out of school time program developed by two of the original SBAR teachers from NM. This will constitute part of the case study.

For the Youth Development team, efforts over Q2 included recruitment and training of STEM ambassadors, around SBAR related materials, working collaboratively with the NM team to develop materials for ongoing use in 4-H activities that are adapted from the '*Guar*-dians of the Biosphere' after school program implemented in NM by participating SBAR teachers.

Training for FFA Teachers and 4H Extension Agents:
This task was initiated in January 2021. Work continues as planned; nothing new to report.

Approximately 18 out of the 41 registrants attended the Agri-science workshop held on February 21, 2021. Several repeat communications with the faculty that led the breakout sessions have occurred. The following NMSU faculty donated time to lead the breakout rooms: Dr Ivey, Animals; Dr Robinson, Ag Marketing; Dr Torell, Data Analysis; Dr Sabillon; Food; Dr Brewer, Chemicals; Dr Gifford, Animals; Dr Boeing, Nature; Dr Hertzman, Food; and Dr Faist, Plants

One "SBAR toolkit" was delivered to Kim O'Byrn, an FFA teacher in Hatch because of contacts made in the workshop. There has been a focus on small rural schools to receive these kits.

- Hatch Middle School – town population 1,955 (received)

Requested kits (chemicals will be removed)

- Roy School – town population - 188
- Des Moines School – town population – 115

Contacted Dana Stanley, Principle at Lydia Ripley school in Aztec, NM to help identify interested teachers on the Navajo Nation.

Figure 64. *Screenshot of Spanish language video, "Guayule Como Cultivo Alternativo."*

Finalize SBAR/FFA Activities:
The curriculum/Activity project titled "Separation of a Mixture" is completed. Per consultation with Rogstad, we may adjust the other two FFA/curriculum projects to instead focus on smaller video elements providing basic scientific information on Guar and Guayule in ways that explain related scientific concepts. For example, one will include a discussion about how legumes fix nitrogen. These will not be full curriculum, but short clips to augment teacher instructions with some of the key elements of what was taught in the material Laura has already developed. Ideally, these will be done in Spanish and English.

Guar and Guayule videos recorded with 3 bilingual Arizona 4-H Ambassadors. These have been edited and separated into three versions 1) English only; 2) Spanish only; and 3) Spanglish

Create 4H Youth Science Project Development re: Bioeconomy:
Brewer and I met with Craig Painter and Laura Bittner from NM 4-H State Office to discuss development of a 4-H Agri-Science project on February 5th. They suggested that existing curriculum be used as a model. We have begun working on draft material to include in the curriculum, including an approach that would augment and link to other existing STEM-related projects that are already part of NM 4-H curriculum. Obtained three sample curriculum kits from the NM 4-H office: *Be a germ detective; Sew – Read;* and *Agriculture – it gives us more than food.* I also have the NM 4-H Projects and Literature Handbook and Curriculum Kits order form to identify links between the proposed Agri-science project and existing curriculum kits.

Met with Travis Brown, the Fair Manager for Southern New Mexico State Fair and Rodeo. Provided him with a presentation to show his board members explaining the concept for an Agri-Science and Public Speaking contest. Developing draft rules for Board approval. The rules include discussion of Bioeconomy projects as a category. This has tentative approval and will likely be added to the fair this September. Waiting on direction from NMSU Office of General Counsel about scholarships as prizes for the contests.

Approximately 18 out of the 41 registrants attended the Agri-science workshop held on February 21, 2021. Several repeat communications with the faculty that led the breakout sessions have occurred. The following NMSU faculty donated time to lead the breakout rooms: Dr Ivey, Animals; Dr Robinson, Ag Marketing; Dr Torell, Data Analysis; Dr Sabillon; Food; Dr Brewer, Chemicals; Dr Gifford, Animals; Dr Boeing, Nature; Dr Hertzman, Food; and Dr Faist, Plants

One “SBAR toolkit” was delivered to Kim O’Byrn, an FFA teacher in Hatch because of contacts made in the workshop. There has been a focus on small rural schools to receive these kits.

- Hatch Middle School – town population 1,955 (received)

Requested kits (chemicals will be removed)

- Roy School – town population - 188
- Des Moines School – town population – 115

Contacted Dana Stanley, Principle at Lydia Ripley school in Aztec, NM to help identify interested teachers on the Navajo Nation.

===
The 4-H Science Fair project is partially developed. Currently a draft record-book and example record-book, outlining a hypothetical science fair project related to SBAR (guar water use experiment) have been completed. The remaining task is to complete a project manual and to work with New Mexico 4-H office to adopt the project. Per consultation with Nick Morris, I have requested collaboration with an extension agent to complete this part.

The Southern New Mexico State Fair and Rodeo will include a new Agri-Science and Public Speaking contest, with a specific SBAR/bioeconomy category. To date, I have raised $4,500 for prizes and scholarships. Contest promotion is ongoing. The State Fair of New Mexico will hold these contests for the second year, to date $3,500 of donated scholarship funds. These will

serve to generate interest in the 4-H agri-science project that is being developed. SBAR will be announced as part of the support for contest development at both award ceremonies.

Luis Ramos-Coronado has accepted an offer to work with the SBAR E-O project. He has an undergrad in Agronomy, has a background from a family farm in Mexico, and is bilingual. He will begin work in August and will start with the development of the bilingual SBAR Agri-business videos for use in Junior-high education. He will also be working with the Guardians of the Biosphere project, pending approval from LCPS teachers and administration.

Develop *Guar-dians of the Biosphere* Curricula and Activities:
The Curriculum review process, from the discussion with Painter and Bittner, might be slightly more ad-hoc. The interactions and process will still be documented, but in may not be a useful document to people with other curriculum ideas. The document will be provided to NM 4-H in case they are interested in using it to support other future curriculum development ideas.

Adapt Existing Curriculum for 4H Program:
First three lessons are in draft form and paused as the STEM ambassador training was being delivered. Several committee members are now leaving the 4-H program and I am not confident that we will deliver on this curriculum in time. I am planning to package and preserve the existing work in a form that allows the new Arizona 4-H Curriculum Specialist (starting late spring 2021) to continue its development.

While the Arid lands curriculum idea is stalled, I have been able to work with our New Mexico partners so that the Guardians of the Biosphere curriculum is streamlined and prepped for use in 4-H afterschool programming.

Additionally, I have worked with Dr. L. Rodriguez of NMSU to complete guar and guayule presentations in both English and Spanish that would be useful in sustainability-focused 4-H curriculum. On a parallel effort, I am also working with B. Evancho on SBAR infographics (English and Spanish) for extension and 4-H use.

===
First three lessons are back in the adaptation process and should be completed by August 31st. Adaptation of *Guar*-dians of the Biosphere content will begin again in September as NMSU partners are able to assist again. Additionally, I have served in advisory role for SBAR lesson development by the NMSU team.

Guar and guayule presentations (videos) are in the final edit form and will soon be finalized. Infographics are now in draft form.

Develop County-Level STEM Ambassador Program (SBAR-related):
Eight STEM youth participated in the STEM ambassador training between February and April. These youth have content expertise in at least one of four different STEM content areas and will begin delivering content to peers and younger youth beginning late spring 2021. Additional activities are in development as well as complementary equipment and material toolkits. These will be put to use beginning in Fall of 2021.

A recent addition to this project is the creation of lessons based on previous SBAR work and the provision of related equipment and materials for ambassadors to begin delivering SBAR in Fall 2021.

STEM ambassador training will begin again for second cohort in September. We have begun ordering equipment and materials for the Ambassador kits. We will complete the ordering by the end of July. Kits will be assembled and delivered for use beginning in August.

A recent addition to this project is the creation of lessons based on previous SBAR work and the provision of related equipment and materials for Ambassadors to begin SBAR in Fall 2021. Lessons are currently in completed drafts and are in final adaptation focused on branding.

Design STEM Volunteer Training Program; Recruit Volunteers:
Volunteers were invited for the ambassador trainings as well. However, we had no adult volunteer participants.

In addition to my leadership, four 4-H staff were instrumental in the training delivery and the STEM ambassador program is now incorporated into the AZ 4-H state STEM pathway and will be sustained beyond the SBAR programming.

Volunteer training programs are being developed and are planned for delivery in year 5 SOW. Recruitment of volunteers will expand to include out-of-school time professionals in addition to existing 4-H volunteer members.

Develop STEM Internship Program, Recruitment, and Evaluation Plans:
Promotions, applications, and program outcomes are approved. Evaluation still needs to be developed. Internship and SBAR leadership have decided to delay until 2022 due to challenges in recruiting prospective interns and hosts.

The internship team is committed to move the program (both Jr. and Sr. internships) forward in 2022. Natalie Brassill Sr. internship coordinator will continue her involvement and Arizona 4-H is interested in continuing the project in beyond Nick Morris's time with the project.

The College of Ag and Life Sciences has committed to partnering in 2022 for recruitment of intern hosts and to build sustainability to the program.

Internal Factsheets on *Project Puente* Internships:
Nothing new to report.

Project Puente Internship Student Recruitment:
Nothing new to report.

Project Puente Internship Faculty Recruitment:
During the last four reporting periods the extension team had continued to work to recruit additional SBAR faculty to participate in *Project Puente* for

Photo 10. *Materials to advertise for the next Project Puente Internship Program are under development.*

Summer of 2020. However, due to COVID19 concerns as well as university shut down, our team switched gears to offer internship during the 2021 semesters in two alternate forms. We continued to share new resource documents for SBAR faculty on expectations of mentors, expectations of students, timelines, reporting structure, among other topics. We recently disseminated content directed at recruitment of faculty to participate in the program as well as to be used as an advertisement of the program to the broader campus community (as appropriate). Our initial goal was to increase participation to a total 6 student interns and associated SBAR faculty to participate in the project in year three.

Project Puente Student Project Development and Deployment:
Nothing new to report.

Project Puente Case Study Video:
The extension team is continuing with the plan to create a short case study video to highlight the success of the program for broad dissemination once internships are deemed 'ok'.

EDUCATION

Project Coordination: Dr. Sara Chavarria (University of Arizona) serves as the lead for the Education Team, which meets once monthly to cover broader topics related to specific Education objectives and tasks. Smaller working groups meet as-needed for specific action items (such as planning and coordinating the weekly SBAR Fellow Seminar). The Education Team also meets monthly with the Extension & Outreach Team to ensure that selected curriculum and activities is integrated for associated workshops and camps.

Issues/Risks:
Brewer: Singh and Pruitt maintained contact with their respective partner teachers (Strand and Daugherty), however, the shift from completely remote to partial in-person/hybrid instruction in both school districts resulted in no meaningful SBAR lesson implementation or vetting was accomplished this quarter. Singh will switch to 100% research this summer in order to complete publications for a spring 2022 defense and will not be available to serve as a fellow during the 2021-2022 school year. Brewer will meet with the UA education team in April to re-evaluate the goals for Year 5 for teacher partnerships/in-classroom content implementation to determine if a new graduate fellow should be recruited.

Usrey took a full-time position in late May, meaning that he will have to complete his MS degree part-time over the 2021-2022 academic year and, for the most part, will not be available to assist with SBAR activities. Brewer met with the UA Education Team in April to re-evaluate the goals for Year 5 and to revise scopes of work and budgets (based on these changes).

In subsequent meetings with Miller to address changes with fellow availability, the decision was made to have Miller recruit a new graduate student (from Ag. Econ/Ag. Business) to focus on documentation and development of the after school/4-H components based on *Guar*-dians of the Biosphere. Brewer confirmed interest from past SBAR Teacher partners, Cathy Bradley and Tracie Mikesell, to assist with the GOB activities they had started previously, scaled back during the pandemic, and are now restarting at Lynn Middle School and Mesilla Valley Leadership Academy, respectively.

Brewer will recruit a new graduate student (from Food Science and Technology) to work with Alan Daugherty at Melrose Middle School; the scope of that student's work will be discussed with Fields and Brewer visit Melrose in early August as part of the travel for the Clovis Ag Science Center Field Day.

Objective 1. Train teams of students and teachers with focus on rural and under-represented groups.

Task #	Description of Task	Deliverable	Target Completion Date
1 Chav	Plan/Design/Coordinate Fall 2020 and Spring 2021 SBAR Fellow seminar for hybrid approach	Plan Fall 2020 semester digital content	31 Aug 20 31 Jan 21

		Plan Spring 2021 semester digital content	
2 Chav	Visit classrooms for observations (delivery of SBAR content)	Implement Fall teacher observation Implement Spring teacher observation	30 Nov 20 30 Apr 21
3 Fields	Design/Schedule classroom evaluation tools, protocols and metrics for all Education activities	Fall tools developed/refined; evaluation data gathered Spring tools developed/refined; evaluation data gathered Summer tools developed/ refined; evaluation data gathered Data synthesized; evaluation report generated	31 Dec 20 31 May 21 31 Jul 21 31 Aug 21

SBAR Fellow Seminar (Fall 2020 / Spring 2021) / hybrid approach:

The Spring 2021 semester began with a weekly Seminar courses on Wednesdays from 1-2PM. An All SBAR Fellow meeting was held on 1.13.21 where AZ and NM SBAR Fellows discussed NM priority areas:

A. Where the templates are located for lesson plans, PPT, etc.
B. Questions concerning single lessons with multiple sessions vs. multiple separate lessons
C. Rules for how to organize files and communication location/status
D. Discussion comparing video storage/editing options

This meeting set the tone for the semester where Dr. Brewer, Dr. Miller and the NM SBAR Fellows joined the weekly seminar.

Our COVID Pivot: Because the majority of the SBAR Fellows are still not able to work with teachers due to COVID, our focus has been on digital lesson development.

The focus of the end of the Spring Seminar has been:

1. The development and refinement of Community Share profiles for the UA SBAR Fellows to connect with local teachers. Community Share (https://www.communityshare.us/) is an online platform where community members can create a profile and teachers can go to look for people to visit their classroom (virtually during COVID).
2. Sessions on emphasizing the story of our lesson plans and science. This included an assignment to identify all questions that are asked in each of the five themes. Reviewing these questions allowed us to clarify the “stories” the different themes are telling and evaluate if the questions are simple enough to be relevant to middle school classrooms.
3. Refining SBAR Fellow selected lesson plans for publication. This process included:
    a. Feedback from Chavarria, Knox and Anderson

b. Lesson plans workshopped during the seminar
c. SBAR Fellows paired with each other to provide additional feedback
d. The development of a Lesson Plan Tracking form to keep track of where each lesson is in the revision process
e. Copy editing from Shopa
f. Detailed review from Rogstad
g. One-on-one in-depth meetings with fellows and Anderson/Knox to review/incorporate suggestions from the review process and prepare for publication

Classroom Observations (Delivery of SBAR Content):
While we have not been able to visit schools in person, we have worked on several efforts to broaden our connections during this quarter. The Education team progress is tracked on our padlet page (https://padlet.com/spchavar/SBAREducation). Chavarria introduced and led a workshop on how to use padlet to organize the efforts of the EEO team.

Other Education (outreach) efforts include:
- Knox, Morris, Brewer, and Miller submitting a proposal to a 4-H conference.
- Knox submitting a conference proposal to ASA, CSSA and SSSA Annual Meeting
- Identifying conferences to present at in the future
    - NAAEE-AZ Association for Environmental Education
    - TENWEST in Tucson – STEM Day (for teachers)
    - TRI-Conference – begin discussions of what this session would be across SBAR EEO Team
    - Arizona and New Mexico Science Teacher Association
    - ASTA – will email about offering a workshop
    - NMSTA – will email about offering a workshop
    - Register/submit abstract(s) for 2022 NSTA (National Science Teacher Association) conference
    - January 2022 ASTE (Association for Science Teacher Education) International Conference – proposals due July 2021

Within SBAR, the Education Team has worked to support the efforts of the NM Education group/EEO. This has involved the weekly sharing of resources, activities, and feedback at the UA SBAR Seminar. Knox provided L. Rodriguez-Uribe with courtesy review and feedback of lesson and a folder of curriculum resources.

Design and Implement Classroom Evaluation Tools:
During the Q4 of 2020, the primary tasks related to the evaluation of the EEO components of the SBAR project were centered around attending team meetings to follow and document project processes and outcomes, develop the timeline for each evaluation component based on the revised evaluation plan (given project shifts from COVID and general evolution of the project), the development of research tools and protocols including the drafting of potential interview and survey questions, reviewing curricular and website materials, and scheduling interviews with various graduate fellows and teachers for the three case studies planned for publication. That work will continue through the summer since it involves travel to NM sometime

during the late summer or early fall if COVID restrictions are eliminated and extension field days are scheduled.

For the Education team, efforts in AZ over Q1 continue to focus on finalizing curriculum lessons and posting them on the website for use by teachers (ED team and graduate fellows) They have also developed several conference abstracts for submission where they will be able to disseminate both the models they have used in working with graduate student fellows, and to build awareness of the curriculum materials among AZ teachers. The NM ED team has continued to work on curriculum development and in particular has added materials that specifically address any safety and disposal concerns. They have hosted a training session with educators and have distributed one science kit to a K-12 teacher who has been exposed to the materials and has agreed to pilot the lesson plans with students. The 'separation of a mixture' lesson is ready for distribution, the two final lesson plans will undergo some edits and be ready for distribution in May.

Other research and evaluation under development includes a 'deep dive' into the graduate student experience. This will include various interviews with select graduate students (both education fellows and scientific researchers) as well as a survey for all graduate student participants that is intended to be implemented during the retreat with the currently active graduate students and via email to reach 'former' students that we have contact info for.

During Q2 of 2021, the primary tasks related to the evaluation of the EEO components of the SBAR project were centered around continued process evaluation to assess progress towards objectives and outcomes; curricular and pedagogical review of select EEO materials and artifacts; qualitative research and evaluation including individual and focus group interviews and other evaluation methods to capture data from teachers and fellows.

Much of the qualitative research was to collect data and inform planned publications. Select teachers were interviewed individually to document their overarching experience with the project. Additional interviews have been scheduled. A trip to NM is planned for the first week in August. During that trip, teachers, graduate fellows and staff in Las Cruces will be interviewed, and we will travel to the Clovis area to attend the field demonstration day and interview researchers and extension agents working in Clovis as well as the SBAR teacher who resides in the area.

Fellows participating in a 2-day planning retreat completed a feedback activity each day where they described the impact and learning outcomes associated with the techniques and approaches implemented in their seminar course. This data is being transcribed and analyzed for future publications. Additionally, a summative survey is under development to distribute to all graduate fellows to gain feedback about their overarching experience and their personal skills development.

For the Education team, activity in AZ over Q2 continued to focus on finalizing curriculum lessons and posting them on the website for use by teachers (ED team and graduate fellows) They have submitted several conference abstracts to promote awareness of the curriculum materials among AZ teachers. The NM ED team has faced some challenges with turnover of

graduate fellows and are slightly behind their own timeline on curriculum development, but are seeking the additional students required.

Objective 2. Develop and disseminate agricultural bioenergy and bioproduct K-12 modules.

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Create/Refine SBAR digital resources	Ready-to-use SBAR lesson and activity resources available on SBAR website	31 May 21
2 Brewer	Support creation/refinement of 4H youth development activities based on *Guar*-dians of the Biosphere	Draft bioeconomy-related 4H project curricula for grades 5-7; initiate review process	31 Aug 21
3 Brewer	Communicate SBAR resources to NM educators	Participate in remote/in-classroom activities (as feasible) Developed recommendations for dissemination in Yr5	31 Aug 21 31 Aug 21
4 Chav	Edit Cohort 2 lessons and materials for online publication	Edit lessons Prep for digital posting	30 Nov 20 31 Dec 20
5 Chav	Support lesson plan design by teacher-Fellow partnerships	Fall lesson plans from each Fellow developed Spring lesson plans from each Fellow developed Advice and support NM teach as requested/needed Draft lesson plans from Cohort 2 teachers	30 Nov 20 30 Apr 21 31 May 21 31 Jul 21
6 Chav	Design, scheduling and implementation of evaluation tools and metrics	Fall evaluation data gathered Spring evaluation data gathered Evaluation report complete	31 Dec 20 31 May 21 31 Aug 21

Refine SBAR Digital Resources:

Quarter 1 began the use of the revised Year 4 statement of work, which was drafted in collaboration with Miller and was approved in February. Towards the youth outreach goals, Brewer and the SBAR fellows participated in a science fair project virtual workshop for middle and high school students that Miller hosted. Miller and Morris have participated in NM fellows' weekly meetings to coordinate efforts between education and youth outreach.

NM Fellows participated in the UA Fellow's Seminar course activities for communication development, and review and revision of their lesson plans.

Create/Refine 4H Youth Development Activities Based on *Guar-dians of the Biosphere*:
Brewer and the NM fellows worked with the UA education team to develop lesson plans for Theme 5 related to chemistry, engineering, and processing. A dashboard of the lesson plans in progress and their respective statuses was created, and will be used to guide completion and posting of lesson plans by the end of Year 4.

Photo 11. *SBAR Extravaganza participants included Dr. Miller, O.Omotayo, D. Pruitt, Dr. Brewer, Dr. Morris, and J. Usrey in Las Cruces, NM (and the UArizona team in Tucson, AZ on the screen).*

In Q2, NM Fellows, Brewer, Miller and Morris continued to meet weekly to coordinate efforts between the Education and Youth Outreach goals for lesson plans, 4-H/after-school activities, and plans for Year 5. They held an in-person workshop at NMSU on May 17-18th to coincide with the meeting of the UA Fellows in Tucson, AZ. The workshop focused on reorganization of some of the lesson plans for Theme 5 into smaller, stand-alone components and review of existing drafts. The goal is still to have six lesson plans posted ot the SBAR website by the end of August.

Communicate SBAR Resources to New Mexico Educators:
NM Fellows participated in the UA SBAR Fellows seminar course activities. Usrey completed revisions of lesson plans for Combustion/Pyrolysis and for Fermentation, which included separating some components into stand-alone lesson plans. These are currently under review with Brewer and/or the UA team. He completed an initial draft for a Transesterification (for biodiesel) lesson plan and is now working on the associated presentation. Pruitt continued revisions of the lesson plan for Plant Polymers in collaboration with the education team. Singh continued revisions of the lesson plan for Water for Food Crops to be included in Theme 4 (Sustainable Crops/Plant Science), including incorporation of videos from guar growth/harvest. While progress has been made, the needed polishing/reviews will likely result in the lesson plans being posted to the SBAR website by August rather than May.

Cohort #2 Lessons and Materials:
There are currently five lessons posted on the SBAR Educational Resources page with two new lessons in the final revision process before posting.

There are fourteen videos posted on the Educational Resource Page, including videos of Interviews with Bioeconomy Professionals:

- SBAR Interview with Ms. Valentina "Tina" Andrews
- SBAR Interview with Dr. Dennis Ray

- SBAR Interview with Dr. Dave Dierig
- SBAR Interview with Mr. Blase Evancho
- SBAR Interview with Dr. Catherine Brewer

SBAR Teachers/Classroom Connections Videos:

- Sustainable Bioeconomy for Arid Regions in the Classroom, Jaime Camero
- SBAR Ecological Sampling Activity, Melissa Wilburn & Arisbeth Ibarra Nieblas

SBAR After School and Summer Camp Video:

- SBAR 4-H Biofuel Summer Camp Video

About SBAR Education Videos:

- SBAR Teacher + Fellow Partnerships: Educating for the Future
- SBAR Guardians of the Biosphere
- Presentation at the Sky Bar, Ashton Leo

Support Lesson Plan Design for Digital Transition by Teacher-Fellow Partnerships:

The Spring SBAR Seminar ended with:

1. Fellows presenting the lessons they were refining and seeking feedback from the team. These workshopped lessons were then revised by SBAR Fellows. This was then followed by one-on-one in-depth meetings with Fellows and Knox/Anderson to review and incorporate suggestions from the review process and prepare for publication.

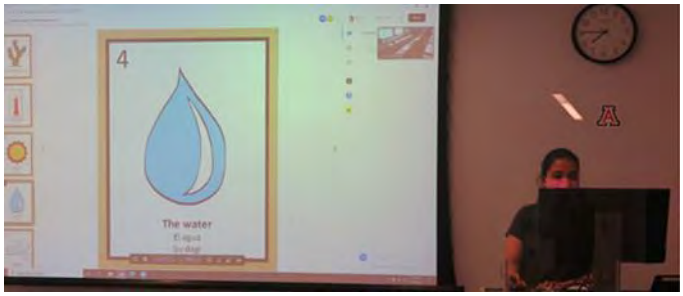


Photo 12. *SBAR Fellows presented their designed lesson and received feedback from the Seminar participants for refinement.*

2. Students were asked to reflect on their assignment where Fellows answered the following prompts:
    a. How will the SBAR Fellow experience impact your career as a scientist or science communicator?
    b. What skills and/or knowledge did you improve or gain from the experience of being an SBAR Fellow?
    c. Reflect on the big themes in science communication we've discussed over the last few years such as cultural relevance, 5Es, place-based learning, the importance of science storytelling, student agency and student voice, or any other concepts that stood out to you. Please discuss how you think one or more of these philosophies/concepts is important for learning and engaging in science for youth or adults and how you incorporated that idea(s) into your lesson(s).
    d. What is something you are proud of that you created as an SBAR Fellow and why? It could be an activity, slide, diagram, interview, etc. Be ready to share with us during the last class.
3. Fellows were asked to share SBAR Resources they are proud of and lead a discussion with the group about their work throughout the semester.
4. Development of work plans for the SBAR Extravaganza

The SBAR Extravaganza was a two-day in-person workshop hosted on May 17-18 at the University of Arizona. This workshop included individualized workplans, prioritizing which lessons to finish and the needed edits and additional materials to include. Feedback from Chavarria, Knox and Anderson was provided to each SBAR Fellow and the group. SBAR Fellows gained hands-on experience presenting revised lesson plans and Power Points to the group for feedback from the Fellows and Education Team. There were also daily meetings hosted with NMSU Education Team to discuss progress on the lessons and to strategize on the needs for remaining lessons (to fill gaps). These meetings allowed Brewer and Miller to clarify the work on the labs for Theme 5 and how they overlapped with the work being done by the UA team on Themes 1-4.

Photo 13. *SBAR Extravaganza participants at the University of Arizona included (front row, l-r) Arisbeth Ibarra Nieblas, Tenzin Phakdon, Karina Martinez, Ali Yaylali, (back row, l-r) Cara Shopa, Torran Anderson, Dr. Corey Knox, and Dr. Sara Chavarria.*

Design, Scheduling and Implementation of Evaluation Tools and Metrics:

The SBAR Extravaganza included two sessions with the External Evaluator (Fields). Chavarria, Knox and Anderson met with Fields to discuss the evaluation needs for the education component (of SBAR). During the 2-day working sessions, SBAR Fellows wrote on post-it notes how they incorporated different aspects of the SBAR Seminar into their teaching/resource development. The areas of the SBAR Seminar that were written about and discussed included – The 5 E's, NGSS Standards, Case Study Method, Storying Science, Valuing and Elevating Community Knowledge/Experience, Reversing Knowledge (Students as Teachers), Contextualization (Culture, Place, Youth Culture), Science Talk, Vocabulary/Literacy. Along with the benefits of evaluating and discussing the team's past work, the Education Team worked with the Fellows to plan for the final year of the SBAR project work.

Photo 14. *Students reflected on their experiences participating as an SBAR Fellow.*

Objective 3. Develop a biofuel certificate program at the university level.

Task #	Description of Task	Deliverable	Target Completion Date
1 Molnar	Develop MS and/or PhD education opportunities within the University of Arizona	At least 2 tracks (study concentration areas) within UA GIDPs	

	around the theme of “Sustainable Bioeconomy”		

Development of Education Opportunities:
This task is complete.

The certificate program description is accessible on the SBAR website:
https://sbar.arizona.edu/education/students/graduate-interdisciplinary-program

AWARDS

Items appearing in blue font are new in this quarter.

2021

2020

Ibarra Nieblas, A. *2nd Place, American Institute of Chemical Engineers (AIChE) K-12 STEM Outreach Competition.* Awarded in the Professional/Combined category for her innovative classroom lesson, “Exploring Bioproducts: Glue for Piñatas”. December.

Ossanna, L. *National Science Foundation Graduate Research Fellowship.* Awarded 3 years of funding to complete a PhD.

Wilburn, M. *Middle School Science Teacher of the Year, Arizona Science Teacher Association*. Awarded for Arizona Competition. December.

2019

Bayat, H.; Hoare, D.; Moreno, L.; Singh, J.; Steichen, S.; Summers, H.; Wright, A. *SBAR Interdisciplinary Face-Off – Silver Lightning Award for Best Overall Design*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona.

Bayat, H.; Hoare, D.; Moreno, L.; Singh, J.; Steichen, S.; Summers, H.; Wright, A. *SBAR Interdisciplinary Face-Off – Smooth Moves Award for Most Creative Concept*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona.

Brown, K.; Dehghanizadeh, M.; Lohr, P.; Singh, P.; Soto, A.; Zuniga-Vasquez, D. *SBAR Interdisciplinary Face-Off – Ninja Visionary Award for Best Overall Concept*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona.

Katterman, M.; Ossanna, L.; Pruitt, D.; Soliz, N.; Sproul, E. *SBAR Interdisciplinary Face-Off – Energy Zone Award for Overall Audience Favorite*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona.

Wilburn, M. *Honorable Mention, Science Teacher Association*. Awarded in the Middle School Science Teacher of the Year Competition in Arizona. December.

PRODUCTS GENERATED.
September 2017 – June 2021

PUBLICATIONS, CONFERENCE PAPERS AND PRESENTATIONS

Items appearing in blue font are new in this quarter.

Publications

1. **Abdell-Haleem H.; Luo Z.; Ray, D. 2019.** Chapter 6. Genetic Improvement of Guayule (*Parthenium argentatum* A. Gray): An Alternative Rubber Crop. *In.* J. Al-Khayri (ed.). Advances in Plant Breeding Strategies: Industrial and Food Crops. Springer Nature Switzerland AG (Invited Book Chapter). p.151-178.
2. **Chen, Y.; Martinez, A.; Cleavenger, S.; Rudolph, J.; Barberán, A. 2021.** Changes in soil microbial communities across an urbanization gradient: a local-scale temporal study in the arid southwestern USA. *Microorganisms* 9:1470. DOI:10.3390/microorganisms9071470.
3. **Chen, Y.; Neilson, J.W.; Kushwaha, P.; Maier, R.M.; Barberán, A. 2020.** Life-history strategies of soil microbial communities in an arid ecosystem. *International Society of Microbial Ecology Journal (ISME J).* DOI:10.1038/s41396-020-00803-y
4. **Cheng, F.; Bayat, H.; Jena, U.; Brewer, C.E. 2020.** Impact of feedstock composition on pyrolysis of low-cost, protein and lignin-rich biomass: a review. *Journal of Analytical & Applied Pyrolysis*, 147, 104780, DOI: 10.1016/j.jaap.2020.104780.
5. **Cheng, F.; Brewer, C.E. 2021.** Conversion of protein-rich lignocellulosic wastes to bio-energy: review and recommendations for hydrolysis + fermentation and anaerobic digestion. Renewables & Sustainable Energy Reviews, 146, 111167. DOI:10.1016/j.rser.2021.111167
6. **Cheng, F.; Dehghanizadeh, M.; Audu, M.A.; Jarvis, J.M.; Holguin, F.O.; Brewer, C.E. 2020.** Characterization and evaluation of guayule processing residues as potential feedstock for biofuel and chemical production. *Industrial Crops and Products*, 150, 112311. DOI: 10.1016/j.indcrop.2020.112311.
7. **Cheng, F.; Jarvis, J.M.; Yu, J.; Jena, U.; Nirmalakhandan, N.; Schaub, T.M.; Brewer, C.E. 2019.** Bio-crude oil from hydrothermal liquefaction of wastewater microalgae in a pilot-scale continuous flow reactor, *Bioresource Technology*, 294, 122184, DOI:10.1016/j.biortech.2019.122184.
8. **Cheng, F.; Le-Doux, T.; Treftz, B.; Miller, J.; Woolf, S.; Yu, J.; Jena, U.; Brewer, C.E. 2019.** Modification of a pilot-scale continuous flow reactor for hydrothermal liquefaction of wet biomass. *MethodsX*, 6, 2793-2806, DOI:10.1016/j.mex.2019.11.019.
9. **Dehghanizadeh, M.; Cheng, F.; Jarvis, J.M.; Holguin, F.O. Brewer, C.E. 2020.** Characterization of resin extracted from guayule (*Parthenium argentatum*): A dataset including GC-MS and FT-ICR MS. *Data in Brief*, 31, 105989. DOI:10.1016/j.dib.2020.105989.
10. **Dehghanizadeh, M.; Mendoza-Moreno, P.; Sproul, E.; Bayat, H.; Quinn, J.; Brewer, C.E. 2021.** Guayule (*Parthenium argentatum*) resin: A review of chemistry, extraction techniques and applications. *Industrial Crops & Products*. 165 (2021) 13410. DOI:10.1016/j.indcrop.2021.113410.

11. **Khanal, S.; Gutierrez, P.; Seavert, C.; Bhandari, P.; Grover, K.; Teegerstrom, T.; Blayney, D. N.D.** Enterprise Budgets for Guar Production. *New Mexico State University Extension Publication*. [In Review]
12. **Khanal, S.; Robbs, J.; Gutierrez, P.; Seavert, C.; Teegerstrom, T.; Wang, S.; Dierig, D. N.D.** Guayule Enterprise Budget: Establishment, Growing and Harvesting. *New Mexico State University Extension Publication*. [In Review]
13. **Khanal, S.; Seavert, C.; Gutierrez, P.; Teegerstrom, T.; Summers, H.M.; Sproul, E. N.D.** Enterprise Budgets: Guar, Flood Irrigation, Southern New Mexico Production. *New Mexico State University Extension Publication*. [In Review]
14. **Luo, Z.; Thorp, K.R., Abdel-Haleem, H. 2019.** A high-throughput quantification of resin and rubber contents in *Parthenium argentatum* using near-infrared (NIR) spectroscopy. *Plant Methods* 15, 154 (2019) DOI:10.1186/s13007-019-0544-3.
15. **Nelson, A.D. L.; Ponciano, G.; McMahan, C.; Ilut, D.C.; Pugh N.A.; Elshikha, D.E.; Hunsaker, D.J.; Pauli. D. 2019.** Transcriptomic and evolutionary analysis of the mechanisms by which *P. argentatum*, a rubber producing perennial, responds to drought. *BMC Plant Biology*. 19:494. https://bmcplantbiol.biomedcentral.com/articles/10.1186/s12870-019-2106-2
16. **Rodriguez-Uribe, L.; Von Cruz, V.M.; Willette, S.; Gil, S.; Khadijeb, M.; Dierig, D.A.; Holguin, F.O. N.D.** Untargeted metabolome profiling of guayule (*Parthenium argentatum* A.Gray) to identify metabolic biomarkers for cold-acclimated and freezing temperature tolerance. *Industrial Crops and Products*. [Submitted 31 Dec 2020; In Review]
17. **Sandhu, D.; Pallete, A.; Pudussery, M.V.; Grover, K.K. 2021.** Contrasting responses of guar genotypes shed light on multiple component traits of salinity tolerance mechanisms. *Agronomy*. 11(6). Article 1068. DOI:10.3390/agronomy11061068.
18. **Sproul, E.; Summers, H.M.; Seavert, C.; Robbs, J.; Khanal, S.; Mealing, V.; Landis, A.E.; Fan, N.; Sun, O.; Quinn, J.C. N.D.** Integrated Techno-Economic and Environmental Analysis of Guayule Rubber Production. *Journal of Cleaner Production* [In Press]. Accepted June 2020.
19. **Singh, J. N.D.** Guar Growth and Development Under Pre-Irrigation and In-Season Irrigation Management in the Southern High Plains. *Journal of Industrial Crops and Products*. Accepted June 2020.
20. **Singh, J.; Guzman, I.; Begna, S.; Trostle, C.; Angadi, S.V. 2021.** Germination and early growth response of guar cultivars to low temperatures. *Industrial Crops and Products*. Volume 159, 2021, 113082, ISSN 0926-6690. DOI:10.1016/j.indcrop.2021.113082
21. **Sun, O.; Fan, N. 2020.** A Review on Optimization Methods for Biomass Supply Chain: Models and Algorithms, Sustainable Issues, Challenges and Opportunities. *Process Integration and Optimization for Sustainability*, published online first, 3/2020. DOI:10.1007/s41660-020-00108-9
22. **Summers, H.M.; Sproul, E.; Seavert, C.; Angadi, S.; Robbs, J.; Khanal, S.; Gutierrez, P.; Teegerstrom, T.; Zuniga Vasquez, D.A.; Fan, N.; Quinn, J.C. 2021.** Economic and Environmental Analyses of Incorporating Guar into the American Southwest. *Agricultural Systems*, Volume 191, 2021,103146, ISSN 0308-521X. DOI:10.1016/j.agsy.2021.103146.

23. **Teegerstrom, T.; Seavert, C.; Gutierrez, P.; Summers, H.A.; Sproul, E. N.D.** Guayule Enterprise Budget: Guayule, Flood Irrigated, Southern Arizona. *University of Arizona, Extension Publication*. [In Review]
24. **Wang, S.; Lynch, A.; VonCruz, M.; Heinitz, C.; Dierig, D. N.D.** Temperature Requirements for Guayule Seed Germination. *Industrial Crops and Products* [In Press] [Accepted September 2020]
25. **Xu, Y.; Madasu, C.; Liu, E.M.; Wijeratne, K.; Dierig, D.; White, B.; Molnár, I.; Gunatilaka, A.A. 2021.** Cycloartane and Lonostane Type Triterpenoids from the Resin of Guayule (*Parthenium argentatum*), A Byproduct of Bridgestone Rubber Production. *ACS Omega* 6:15486-15498, 2021.DOI:10.1021/acsomega.1c01714, PMID: 34151127, PMCID: PMC8210430.
26. **Zuniga-Vasquez, D.A.; Sun, O.; Fan, N.; Sproul, E.; Summers, H.M.; Quinn, J.C.; Khanal, S.; Gutierrez, P.; Mealing, V.A.; Landis, A.E.; Seavert, C.; Teegerstrom, T.; Evancho, B. 2021.** Integrating Environmental and Social Impacts into Optimal Design of Guayule and Guar Supply Chains. *Computers and Chemical Engineering*. DOI: 10.1016/j.compchemeng.2021.107223.
27. **Zuniga-Vasquez, D.A.; Fan, N.; Teegerstrom, T.; Seavert, C.; Summers, H.M.; Sproul, E.; Quinn, J.C. 2021.** Optimal Production Planning and Machinery Scheduling for Semi-Arid Farms. *Computers and Electronics in Agriculture*. DOI:10.1016/j.compag.2021.106288, 6/2021.

Number of Graduated SBAR Students (Undergraduate, Masters, and PhD)

Student Classification	**CSM**	**CSU**	**NMSU**	**UA**	**Other**
Undergraduate (BS, BA)		3	7	5	
Masters			7	6	1
PhD		2	2	2	

**Totals are through July 2021.*

Capstone Projects, Theses, and Dissertations

1. **Ledesma, J.*; Ossanna, L; Pacido, D.; El-Shikha, D.E.; Dong, C.; Ponciano, G.; McMahan, C.; Maier, R.M.; Neilson, J.W. 2020.** *Associations between soil rhizosphere bioavailable phosphorus, phosphorus solubilizing microorganisms, and guayule growth stage and rubber production*. Senior Capstone Thesis, University of Arizona, Tucson, Arizona.
2. **Pruitt, Darien. 2021.** *Guar Growth and Yield as Affected by Mycorrhizal Colonization, Soil Amendment Applications, and Fertility Management*. Master of Science Thesis, New Mexico State University, Las Cruces, New Mexico.
3. **Singh, Jagdeep. 2020.** Guar growth and development under pre-irrigation and in-season irrigation management in the Southern High Plains. Master of Science Thesis, New Mexico State University, Las Cruces, New Mexico.
4. **Sproul, Evan. 2020.** *Integrated Techno-Economic and Life-Cycle Analysis of Emerging Technologies with Temporal Resolution*. Ph.D. Dissertation. Colorado State University, Fort Collins, Colorado.

5. **Summers, Hailey. 2021.** *Evaluating the Sustainability of Agricultural Systems Using Life Cycle Assessment and Techno-Economic Analysis*. Ph.D. Dissertation. Colorado State University, Fort Collins, Colorado.
6. **Sun, Ou. 2019.** *Novel Integer Optimization Methods and their Applications in Biomass Supply Chain and Power Dominating Set*. Ph.D. Dissertation, University of Arizona, Tucson, Arizona.
7. **Zuniga-Vazquez, Daniel A. 2021.** *Large-Scale Optimization for Planning of Reliable Power Systems and Design of Sustainable Biomass Supply Chains*. Ph.D. Dissertation, University of Arizona, Tucson, Arizona.

Conference Papers

1. **Audu, M.; Dehghanizadeh, M.; Cheng, F.; Bayat*, H.; Holguin, O.; Jena, U.; Brewer, C.E. 2019.** *Co-Products and Biofuels from Guar and Guayule Processing Residues*. 2019 ASABE Annual International Meeting. Boston, Massachusetts. 8 July. Paper #1900361.
2. **Cruz, V.M.V.; Lynch, A.; Wang, G.S.; Dittmar, S.; Sullivan, T.; Prock, R.; Niaura, W.; Dierig, D.A. 2019.** *Guayule germplasm characterization for variation in ploidy and biomass production.* In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.).Tucson, Arizona. 8-11 September. p. 36.
3. **Dehghanizadeh, M.*; Cheng, F.; Jarvis, J.M.; Holguin, F.O.; Brewer, C.E. 2019.** *High Resolution Mass Spectrometry for Characterization of Resin from Guayule (Parthenium argentatum).* In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.). Tucson, Arizona. 8-11 September. p. 39.
4. **Dehghanizadeh, M.*; Brewer, C.E. 2020.** *Guayule resin: chemistry, extraction, and applications,* 2020 ASABE Annual International Meeting, Virtual. 13-15 July. DOI: 10.13031/aim.202001143.
5. **Dierig, D.A.; Wang, G.S.; El-Shikha, D.E.M.; Sullivan, T.; Dittmar, S.; Cruz, V.M.V. 2019.** *Guayule growth and yield over time at two locations at high and low irrigation treatments.* In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.).Tucson, Arizona. 8-11 September. p. 31.
6. **Dong, C.; Ponciano, G.; Wang, Y.; Huo, N.; Hunsaker, D.; El-Shikha, D.E.M.; Gu, Y.Q.; McMahan, C. 2019.** *Gene expression of guayule field plants under drought stress: A comparative RNA-Seq study.* In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.).Tucson, Arizona. 8-11 September. p. 35.
7. **El-Shikha, D.E.M.*; Waller, P.M.; Hunsaker, D.J.; Dierig, D.A.; Wang, G.S.; Cruz, V.M.V.; Thorp, K.R.; Bronson, K.F.; Katterman, M.E. 2019.** *Growth and yield of direct-seeded guayule under SDI and furrow irrigation.* In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.).Tucson, Arizona. 8-11 September. p. 30.
8. **Khanal, S.; Robbs, J.; Acharya, R.; Gutierrez, P. 2019.** *Import demand and potential for domestic production of guar.* In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.).Tucson, Arizona. 8-11 September. p. 43.

9. **Maqsood, H.; Waller, P.; El-Shikha, D.E.M.; Hunsaker, D.; Katterman, M.E.; Dierig, D.A.; Wang, G.S.; Ogden, K. 2019.** *Assessment of irrigation requirement for guayule using WINDS model.* In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.).Tucson, Arizona. 8-11 September. p. 32.
10. **Maqsood, H.; Angadi, S.; El-Shikha, D.E.M.; Waller, P.; Singh, J.; Hunsaker, D.; Barau, B. 2019.** *Evaluating crop water status for guar using WINDS model.* In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.).Tucson, Arizona. 8-11 September. p. 42.
11. **McCloskey, W.; Wang, G.S. 2019.** *Guayule (Parthenium argentatum A. Gray) seedling tolerance to topically applied carfentrazine-ethyl herbicide.* In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.). Tucson, Arizona. 8-11 September. p. 34.
12. **Placido, D.F.; Dong, N.; Pham, T.; Huynh, T.; Amer, B.; Baidoo, E.; McMahan, C. 2019.** *Down-regulation of squalene synthase in guayule (Parthenium argentatum).* In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.).Tucson, Arizona. 8-11 September. p. 37.
13. **Seavert, C.; Teegerstrom, T.*; Gutierrez, P.; Khanal, S. 2019.** *Whole farm analysis tool for evaluating the adoption of guayule and guar into southwest producers' current operation.* In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.).Tucson, Arizona. 8-11 September. p. 40. Best Oral Presentation Award for the Rubber and Resin Division.
14. **Wang, G.S.; Dierig, D.A.; Ray, D.T. 2019.** *Guayule response to plant population*. In: 31st Annual Meeting Program and Abstracts of the Association for the Advancement of Industrial Crops. Cruz, V.M.V. and Berti, M. (eds.). Tucson, Arizona. 8-11 September. p. 38.
15. **Zuniga-Vasquez, D.A.; Fan, N.; Teegerstrom, T.; Seavert, C.; Summers, H.M.; Sproul, E.; Quinn, J.C. 2021.** *Optimal Design of guayule and guar supply chains for the American Southwest*. 32nd Association for the Advancement of Industrial Crops. Annual Meeting for the special issue on *Industrial Crops and Products*, 6/2021.

Scholarly Presentations

1. **Angadi, S.V. 2018.** *Sustainable Bio-economy for Arid Regions: Growing Guar.* Extension Field Day. Clovis, New Mexico. 9 August.
2. **Angadi, S.V.; Singh, J.; Guzman, I.; Begna, S. 2020.** *Germination temperature for expanding guar acres to cooler regions.* American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America (ASA-CSSA-SSSA) Joint International Annual Meeting. Virtual. 8-11 November.
3. **Angadi, S.V.*; Begna, S.H.; Singh, S.; Katuwal, K.; Singh, J.; Gowda, P.; Ghimire R. 2018.** *Multiple Approaches to Sustain Ogallala Aquifer in the Southern Great Plains of the United States of America*. Agrosym 2018. Jahorina, Bosnia. 4-7 December.
4. **Angadi, S.V.*; Begna, S.H.; Singh, S.; Katuwal, K.; Singh, P.; Singh, J.; Umesh, M.R. 2019.** *Crop Diversification and Critical Stage-Based Irrigation to Sustain Ogallala*

Aquifer. UCOWR/NIWR Annual Water Resources Conference, Snowbird, Utah. 11-13 June.

5. **Angadi, S.V.*; Begna, S.H.; Umesh, M.R. 2018.** *Crop diversification for sustainable soil and water resources use in semi-arid regions of USA*. XXI Biennial National Symposium of Indian Society of Agronomy, Udaipur, India. 24-26 October.
6. **Angadi, S.V.*; Singh, J.; Begna, S.H. 2019.** *Crop growth stage based deficit irrigation management in guar crop*. Annual Report, Agricultural Science Center at Clovis, New Mexico. 20 February.
7. **Angadi, S.V.; Singh, J.*; Begna, S.H. 2020.** *Crop growth stage-based deficit irrigation management in guar crop*. Annual Report, Agricultural Science Center at Clovis, New Mexico. 29 February.
8. **Angadi, S.V.; Singh, J.*; Begna, S.H. 2020.** *Germination temperature for expanding guar across to cooler regions*. ASA, CSSA and SSSA International Annual Meetings (Virtual). 8-11 November.
9. **Angadi, S.V.; Singh, J.; Gowda, P.; Singh, P.; Begna, S.; Guzman, I.; Idowu, J. 2021.** *Deficit Irrigation Strategies to Fit Desert Crop Guar in the Southern High Plains Cropping Systems*. Universities Council on Water Resources (UCOWR) Annual Meeting (Virtual). 8-11 June.
10. **Audu, M.*; Dehghanizadeh, M.; Cheng F.; Bayat H.; Holguin, O.; Jena U.; Brewer, C.E. 2019.** *Co-Products and Biofuels from Guar and Guayule Processing Residues*. ASABE Annual International Meeting, Boston, Massachusetts, 7-10 July.
11. **Bayat, H.*; Cheng, F.; Jena, U.; Brewer, C.E. 2019.** *Introduction to low-cost protein-rich lignocellulosic biomass for advanced biofuels.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
12. **Brewer, C.E. 2018**. *Pairing biomass residues with conversion technologies*. Advanced Bioeconomy Leadership Conference, Washington, D.C. 28 February.
13. **Brewer, C.E. 2018**. *Polymerization and guar gum bubbles*. Outreach event activity. New Mexico 4-H State Conference. 11 July.
14. **Brewer, C.E. 2018**. *Identifying Co-Products from Guar and Guayule Processing Residues*. 2018 American Institute of Chemical Engineers Annual Meeting. Pittsburgh, Pennsylvania. 30 October.
15. **Brown, K.S. 2021.** *Fungal Pathogens and Guayule (Parthenium argentatum): Optimizing Crop Production in an Arid Environment*. UA ENViSion Annual UA Earthweek Symposium. Online. 31 March.
16. **Brown, K.S. 2020.** *Soil chemistry … and other topics*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 25 March.
17. **Brown, K.S. 2020**. *Pathogens and Guayule (Parthenium argentatum): Literature Review*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. [virtual] 18 November.
18. **Brown, K.S.*; Neilson, J.W.; Waller, P.M.; Ray D.T.; Dierig, D.; Maier, R.M. 2018.** *Microbial contributions to soil health: Optimizing guayule (Parthenium argentatum) production in an arid environment*. SWESx Earthday Symposium. Tucson, Arizona. 15 April. [poster]
19. **Brown, K.S.*; Neilson, J.W. 2018.** *Microbial contributions*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. April.
20. **Brown, K.S.*; Neilson, J.W.; Waller, P.M.; Ray D.T.; Dierig, D.; El-Shikha, D.;Maier, R.M. 2019.** *Microbial contributions to soil health: Optimizing guayule*

(Parthenium argentatum) production in an arid environment. SWESx Earthday Symposium. Tucson, Arizona. 27 March. [poster]

21. **Brown, K.S.*; Neilson, J.W.; Waller, P.M.; Ray, D.T.; Wang, S.; Dierig, D.; El-Shikha, D.E.M.; Maier, R.M. 2019.** *Soil health and guayule microbial community metrics.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
22. **Brown, K.S.*; Neilson, J.W.; Waller, P.M.; Ray, D.T.; Wang, S.; Dierig, D.; El-Shikha, D.E.M.; Maier, R.M. 2020.** *Fungal pathogens and guayule (Parthenium argentatum): Optimizing crop production in an arid environment.* University of Arizona ENViSion Virtual Earth Week Conference, Tucson, Arizona. April.
23. **Cheng, F.*; Audu, M.; Dehghanizadeh, M.; Treftz, B.; Le-Doux, T.; Jena, U.; Brewer, C.E. 2018.** *Characterization and Conversion of Guar and Guayule Bagasse as Potential Resources for Biofuels Production.* Symposium on Thermal and Catalytic Sciences for Biofuels and Bio-based Products. Auburn, Alabama. 9 October.
24. **Cheng, F.; Le-Doux, T.; Jena, U.; Brewer, C.E.* 2018.** *Characterization and Conversion of Guar Bagasse.* Symposium on Thermal and Catalytic Sciences for Biofuels and Bio-based Products. Auburn, Alabama. 9 October.
25. **Cheng, F. 2018.** *Hydrothermal Liquefaction of Microalgae in Batch and Continuous Flow Reactors.* PhD Dissertation Defense. New Mexico State University, Las Cruces, New Mexico. 24 October.
26. **Cheng, F.*; Rosalez, R.; Dehghanizadeh, M.; Brewer, C.E. 2019.** *Co-Hydrothermal Liquefaction of Guayule Bagasse and Wastewater Treatment Microalgae*. American Institute of Chemical Engineers (AIChE) Annual Meeting, Orlando, Florida. 10-15 November.
27. **Cheng, F.*; Le-Doux, T.; Treftz, B.; Woolf, S.; Guillen, S.; Usrey, J.; Martinez Bejarano, C.; Bayat, H.; Jena, U.; Brewer, C.E. 2018.** *Characterization of Flow and Heat Transfer Parameters in a Continuous Flow Hydrothermal Liquefaction Reactor.* 2018 American Institute of Chemical Engineers Annual Meeting, Pittsburg, Pennsylvania. 1 November.
28. **Cheng, F.*; Rosalez, R.; Dehghanizadeh, M.; Brewer, C.E. 2019.** *Co-Hydrothermal Liquefaction of Guayule Bagasse and Wastewater Treatment Microalgae.* 2019 American Institute of Chemical Engineers Annual Meeting, Orlando, Florida. 10-15 November.
29. **Creegan, E.; Grover, K.*; DuBois, D.; Khan, N. 2020.** *Global climate change mitigation and resiliency: Agriculture Curriculum Collaborations.* North America Colleges and Teachers of Agriculture Virtual Conference, Online. 15-18 June.
30. **Dehghanizadeh, M.*; Cheng, F.; Jarvis, J.M.; Holguin, F.O.; Brewer, C.E. 2019.** *High Resolution Mass Spectroscopy for Characterization of Resin from Guayule*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
31. **Dehghanizadeh, M.*; Brewer, C. 2020.** *Guayule resin: Advanced extraction techniques and promising commercial applications*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
32. **Dehghanizadeh, M.; Brewer, C. 2020.** *A study on chemistry and fractionation of guayule resin as a source of secondary metabolites and energy*. AIChE Annual Meeting (virtual). 15 November.

33. **Deirig, D. 2017.** *Bridgestone's perspective on a domestic source of natural rubber in the desert.* Invited Speaker at the New Mexico Sustainable Agriculture Conference. Los Lunas, New Mexico. 13 December.
34. **Dong, C.; Ponciano, G.; Wang, Y.; Huo, N.; Hunsaker, D.; Elshikha, D.; Gu, Y.Q.; McMahan, C. 2019.** *Transcriptome analysis of guayule reveals rubber biosynthesis pathways' response to drought stress*. SBAR Annual Retreat, University of Arizona, Tucson Arizona. 11-13 September. [poster]
35. **El-Shikha, D.E.M. 2018.** *Update – Guayule irrigation experiments at Maricopa Agricultural Center*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 12 September.
36. **El-Shikha, D.E.M.*; Waller, P.M.; Hunsaker, D.J.; Dierig, D.; Wang, S.; Cruz, V.M.V.; Bronson, K.F.; Katterman, M.E. 2019.** *Direct seeded guayule grown in Arizona under furrow and subsurface drip irrigation.* American Society of Agricultural and Biological Engineers (ASABE) Annual International Meeting, Boston, Massachusetts. 8 July. [poster]
37. **El-Shikha, D.E.M*.; Waller, P.M.; Hunsaker, D.J.; Dierig, D.; Wang, G.S.; Cruz, V.M.V.; Thorp, K.R.; Katterman, M.E.; Bronson, K.F.; Wall, G. 2019.** *Growing direct-seeded guayule with furrow and subsurface drip irrigation in Arizona.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
38. **Evancho, B.*; Teetor, V.H.; Willmon, J.; Bennett, M.C.; Montes, M.; Schmaltzel, C.; Ray, D.T. 2018.** *Root structure differentiation between common guayule planting methods.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 2 August. [poster]
39. **Evancho, B. 2018.** *Guayule Fuels the Future*. IES – Energy Talks Seminar, Sky Bar, Tucson, Arizona. 9 October.
40. **Evancho, B. 2019.** *Guayule: How Close Are We?* Marana Winter Field Crops Clinic. Marana, Arizona. 10 January.
41. **Evancho, B. 2019.** *Guayule: How Close Are We?* Casa Grande Winter Field Crops Clinic. Casa Grande, Arizona. 15 January.
42. **Evancho, B. 2019.** *Comparing direct-seeded and transplanted guayule roots*. SBAR UA Research Team Seminar, University of Arizona, Tucson, Arizona. 13 November.
43. **Evancho, B. 2020.** *Growth response of guayule to a gradient of nitrogen fertilizer*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 29 April.
44. **Evancho, B. 2021.** *Determining guayule minimum nitrogen requirements*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 5 May.
45. **Evancho, B.*; Lewis, M.; Schmalzel, C.; Teetor, V.; Ray, D. 2020.** *Agronomic investigations to improve guayule production.* SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
46. **Evancho, B.*; Moreno, L.; Peck, A.; Teetor, V.H., Schmalzel, C.; Ray, D.T. 2019.** *Root structure differentiation between guayule planting methods.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
47. **Fan, N. 2018.** *Review on Optimization Methods for Biomass Supply Chain*. SBAR UA Research Team Seminar. University of Arizona, Tucson, Arizona. 28 November.
48. **Fan, N.; Sun, O. 2019.** *GIS-based, two-stage stochastic facility location problem considering planting plan uncertainty*. American Institute of Chemical Engineers (AIChE) Annual Meeting, Orlando, Florida. 11 November.

49. **Garcia, A.*; Grover, K.; Stringam, B.; Schutte, B.; VanLeeuwen, D. 2018.** *Growth and performance of guar (Cyamoposis tetragonoloba L.) under various irrigation regimes in semi-arid region of New Mexico*. 73rd SWCS International Annual Conference, Albuquerque, New Mexico. 29 July – 1 August.
50. **Garcia, A.*; Grover, K.; Stringam, B.; Schutte, B.; VanLeeuwen, D. 2018.** *Growth and performance of guar under various irrigation regimes in semi-arid region of New Mexico*. Annual SBAR Retreat, University of Arizona, Tucson, Arizona. 1-3 August. [poster]
51. **Garcia, A.*; Grover, K.; Stringam, B.; Schutte, B.; VanLeeuwen, D. 2018.** *Performance of guar under various irrigation regimes in southern New Mexico*. Extension Field Day, New Mexico State University Agricultural Science Center, Artesia, New Mexico. 23 August.
52. **Garcia, A.*; Grover, K.; Stringam, B.; Schutte, B.; VanLeeuwen, D. 2018**. *Performance of guar under various irrigation regimes in southern New Mexico.* New Mexico Sustainable Agriculture Science Conference, Los Lunas, New Mexico. 12 December.
53. **Garcia, A.*; Grover, K.; Schutte, B.; Stringam, B.; VanLeeuwen, D. 2018.** *Growth and performance of guar under various irrigation regimes*. Proceedings of the 2018 Annual Meeting of the American Society of Agronomy, Crop Science Society of America and the Soil Science Society of America. Baltimore, Maryland. 4-7 November.
54. **Garcia, A.*; Grover, K.; Schutte, B.; Stringam, B.; VanLeeuwen, D. 2019.** *Growth and performance of guar under different irrigation regimes*. NMSU College of Agriculture, Consumer and Environmental Sciences (ACES) Open House. 6 April. [poster]
55. **Gardia, A.* Grover, K.; Stringam, B.; Schutte, B.; VanLeeuwen, D. 2020.** *Growth and performance of guar genotypes under various irrigation regimes and addition of biogenic silica in Southwest New Mexico.* SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
56. **Gloria, T.*; Grover, K.; Garcia, A. 2018.** *Guar: a potential alternative crop in New Mexico*. Annual SBAR Retreat, University of Arizona, Tucson, Arizona. 1-3 August. [poster]
57. **Gloria, T.*; Grover, K.; Garcia, A. 2018.** *Guar: a potential alternative crop in New Mexico*. Extension Field Day, New Mexico State University Agricultural Science Center, Artesia, New Mexico. 23 August.
58. **Gloria, T.*; Grover, K.; Garcia, A. 2018.** *Guar: a potential alternative crop in New Mexico.* New Mexico Sustainable Agriculture Science Conference, Los Lunas, New Mexico. 12 December.
59. **Gloria, T.*; Flores, M.; Allen, R.; Valenzuela, V.; Ben, G.; Moore, K.; Castillo, P.; Garcia, A.; Grover, K. 2019.** *Evaluating guar as a potential alternative crop in New Mexico.* NMSU College of Agriculture, Consumer and Environmental Sciences (ACES) Open House, Las Cruces, New Mexico. 6 April. [poster]
60. **Godfrey, D.J; Bennett, M.C.*; Willmon, J.; Waltz, Q.; Coronado, G.; Teetor, V.H.; Schmalzel, C.; Ray, D.T. 2018**. *Vegetative propagation of Parthenium argentatum (Guayule).* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 2 August. [poster] Won first place for undergraduate posters.

61. **Godfrey, D.*; Willmon, J.; Teetor, V.H.; Schmalzel, C.; Ray, D.T. 2018.** *Vegetative propagation of guayule*. 2018 Annual Conference, American Society for Horticultural Science, Washington D.C. 30 July – 3 August 2018.
62. **Gonzalez, C.; Dierig, D.A.; Cruz, V.M.V.* 2019.** *Pollen studies in guayule: Comparison of staining and sampling procedures and survey of pollen size variation.* 31st Annual Meeting for the Association for the Advancement of Industrial Crops. Tucson, Arizona. 8-11 September. [poster]
63. **Gonzalez, C.*; Cruz, V.M.V.; Dierig, D.A. 2019.** *Pollen viability and size variation in guayule germplasm.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
64. **Grover, K. 2017.** *Guar as a potential alternative crop in New Mexico*. Invited Speaker at the New Mexico Sustainable Agriculture Conference. Los Lunas, New Mexico. 13 December.
65. **Grover, K. 2018.** *Sustainable agriculture and guar production in New Mexico*. New Mexico State 4-H Conference, Las Cruces, New Mexico. 10 July.
66. **Grover, K. 2018**. *An overview of guar and other research in the Plant and Environmental Sciences Department*. A presentation to student ambassadors of College of Agriculture, Consumer and Environmental Sciences, New Mexico State University, Las Cruces, New Mexico. 8 August.
67. **Grover, K. 2018**. *Guar as an alternative crop in New Mexico.* Extension Field Day, New Mexico State University Agriculture Science Center, Clovis, New Mexico. 9 August.
68. **Grover, K. 2018**. *Guar as an alternative crop in New Mexico.* Extension Field Day, New Mexico State University Agriculture Science Center, Artesia, New Mexico. 23 August.
69. **Grover, K. 2018**. *Guar and Sustainable Crop Production.* An invited presentation to students of *AGRO/HORT 100 Introductory Plant Sciences*. New Mexico State University, Las Cruces, New Mexico. 31 August.
70. **Grover, K. 2018**. *Guar and Sustainable Crop Production.* An invited presentation to students of *AXED 466V: "John Muir: Lessons in Sustainability."* New Mexico State University, Las Cruces, New Mexico. 25 September.
71. **Grover, K. 2019.** *Guar as an alternative rotation crop in the chili production system of New Mexico.* New Mexico Chili Industry and Researcher Meeting, Las Cruces, New Mexico. 5 February.
72. **Grover, K. 2019.** *Guar: A potential alternative crop in New Mexico.* Climate Change Strategies for a Changing World Workshop, New Mexico State University, Las Cruces, NM. 5 February. [invited speaker]
73. **Grover, K. 2019.** *Do you know what plants are these and what's in them?* Future Farmers of America (FFA), New Mexico Chapter Presentation. Las Cruces, New Mexico. 5 April.
74. **Grover, K. 2019.** *Guar: A potential alternative crop in New Mexico*. New Mexico Master Gardener's Meeting. Las Cruces, New Mexico. 8 May.
75. **Grover, K. 2019.** *Guar as an alternative crop in New Mexico*. New Mexico Sustainable Agriculture Field Day. Las Cruces, New Mexico. 26 June.
76. **Grover, K. 2019.** *Guar as an alternative crop in New Mexico*. SBAR Train-the-Trainer Workshop. Las Cruces, New Mexico. 2 July.

77. **Grover, K. 2019.** *Guar as an alternative crop in New Mexico*. SBAR Train-the-Trainer Workshop, Las Cruces, New Mexico. 2 July.
78. **Grover, K. 2019.** *Guar research and extension program in New Mexico*. Departmental External Review, Las Cruces, New Mexico. 10 October.
79. **Grover, K. 2020.** *Guar as an alternative crop in southwest USA*. 18th International Congress of Soil Science, Sindh Agriculture University, Tandojam, Pakistan. 11-13 Februrary. [invited speaker]
80. **Grover, K. 2020.** *Guar in changing climate*. Climate Change Strategies for a Changing World, New Mexico State University, Las Cruces, New Mexico. 3 March. [invited speaker]
81. **Grover, K. 2020.** *Guar as a potential alternative crop*. Introductory Plant Sciences course (AGRO/HORT 100G), New Mexico State University, Las Cruces, New Mexico (Online). May. [invited speaker]
82. **Grover, K. 2020.** *Evaluating performance of guar genotypes*. Special Problems/Special Topics Seminar (AGRO 449/AGRO 500), New Mexico State University, Las Cruces, New Mexico (Online). May. [invited speaker]
83. **Grover, K. 2020.** *Teaching principles of plant growth and development.* Teaching Assistant Training and Supervised University Teaching Experience (AGRO 697), New Mexico State University, Las Cruces, New Mexico (Online). May. [invited speaker]
84. **Grover, K. 2020.** *Evaluating guar for its adaptability in New Mexico.* Research and Education Training Workshop. New Mexico State University, Las Cruces, New Mexico (Online). May. [invited speaker]
85. **Grover, K. 2020.** *Growth and Performance of Guar Under Various Moisture Stress Regimes*. Proceedings of the 2020 Annual Meeting of the American Society of Agronomy, Crop Science Society of America and the Soil Science Society of America. [Virtual Meeting] 9-11 November.
86. **Grover, K.*; Garcia, A. 2018.** *Evaluating guar as a potential alternative crop in New Mexico*. University Research Council Meeting, New Mexico State University. Las Cruces, New Mexico. 15 February.
87. **Grover, K.*; Garcia, A.; Schutte, B.J.; Stringam, B.; Darapuneni, M.K.; VanLeeuwen, D. 2019.** *Response of guar to various irrigation regimes*. ASA-CSSA-SSSA International Annual Meetings, San Antonio, Texas. 12 November.
88. **Grover, K.*; Garcia, A.; Schutte, B.J.; Stringam, B.; Darapuneni, M.K.; VanLeeuwen, D; Flynn, R.P. 2020.** *Growth and performance of guar under various moisture stress regimes.* Western Crop Science Society of America Annual Virtual Conference, Online. 7 July.
89. **Grover, K.*; Stovall, S. 2020.** *Integrating experiential learning in a crop production course.* North America Colleges and Teachers of Agriculture Virtual Conference, Online. 15-18 June.
90. **Grover, K.*; Torres, S.; Cazarez, K. 2020.** *Response of Guar to Various Seeding Rates.* Proceedings of the 2020 Annual Meeting of the American Society of Agronomy, Crop Science Society of America and the Soil Science Society of America. [Virtual Meeting] 9-11 November.
91. **Gutierrez, P.; Khanal, S.; Seavert, C.; Teegerstrom, T. 2020.** *Economic impacts of producing alternative crop: guar, guayule and industrial hemp in New Mexico*. Alternative Crops Conference. Portales, New Mexico. 10 March.

92. **Hoare, D.M. 2018.** *Irrigation Sensors and the WINDS Model.* SBAR UA Research Team Seminar Series, Tucson, Arizona. 26 September.
93. **Hoare, D.M.*; Katterman, M.; Waller, P. 2019.** *Development of a remote crop condition sensing system utilizing Internet of Things.* 31st Annual Meeting of the Association for the Advancement of Industrial Crops. Tucson, Arizona. 8-11 September. [poster]
94. **Huynh, T.*; Resendiz, M.; McMahan, C.; Dong, N. 2019.** *The Content and State of the In-Vitro Guayule Inventory in Tissue Culture and Opportunities to Improve our Methods*. Seminar Presentation and Discussion, USDA-ARS WRRC, Albany, California. 18 November.
95. **Idowu, O.J. 2018.** *Introduction to the SBAR Project*. Las Cruces, New Mexico. 6 Feb.
96. **Idowu, O.J. 2018.** *Sustainable Bio-economy for Arid Regions: Update*. Extension Field Day, Clovis, New Mexico. 9 August.
97. **Idowu, O.J. 2018.** *Sustainable Bio-economy for Arid Regions: Guar and Guayule*. Extension Field Day, New Mexico State University Agricultural Science Center, Artesia, New Mexico. 23 August.
98. **Idowu, O.J. 2020.** *Potential of guar for Eastern New Mexico (Sustainable Bioeconomy for Arid Regions Project).* Tucumcari Agricultural Science Center Virtual Field Day, Tucumcari, New Mexico.6 August.
99. **Idowu, O.J.*; Pruitt, D. 2019.** *Sustainable Bio-economy for Arid Regions*. Extension Field Day. Fabian Garcia Research Center, Las Cruces, New Mexico. 26 June.
100. **Katterman, M. 2020.** *Guayule sensor and irrigation modeling + SBAR Education update*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 18 March.
101. **Khanal, S. 2020.** *Industrial uses of guar as a rural economic development strategy in the Southwest.* SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
102. **Khanal, S.*; Gutierrez, P. 2020.** *The economic impact of the alternative crops: Guar and guayule production in the Southwest.* Agricultural and Applied Economics Association (AAEA) 2020 Virtual Meeting. 10-11 August. [poster]
103. **Khanal, S.*; Gutierrez, P. 2019.** *Farm-level impact analysis of growing guar (at 5% total acres adoption rate) in Dona Ana, New Mexico*. SBAR System Performance and Sustainability Team Seminar, Colorado State University, Ft. Collins, Arizona. 11 November.
104. **Khanal, S.*; Gutierrez, P.; Robbs, J.; Acharya, R. 2019.** *The Economic Potential of Producing Guayule in the Southwest.* Department of Agricultural Economics and Agricultural Business, New Mexico State University, Las Cruces, New Mexico. [poster]
105. **Khanal, S.; Gutierrez, P.; Seavert, C.; Teegerstrom, T. 2020.** *The economic impacts of producing guar using the input-output model.* New Mexico Alternative Crops Conference, Portales, New Mexico. 10 March. [poster]
106. **Khanal, S.; Gutierrez, P.; Seavert, C.; Teegerstrom, T. 2020.** *Guar research manuscript update.* SBAR System Performance and Sustainability Seminar. Colorado State University, Fort Collins, Colorado. 15 April.
107. **Khanal, S.; Seavert, C.; Gutierrez, P.; Teegerstrom, T.* 2019.** *The economic potential of producing guayule in the Southwest.* 31st Annual Meeting of the Association for the Advancement of Industrial Crops. Tucson, Arizona. 8-11 September. [poster]

108. **Ledesma, J.*; Ossanna, L; Pacido, D.; El-Shikha, D.E.; Dong, C.; Ponciano, G.; McMahan, C.; Neilson, J.W.; Maier, R.M. 2020.** *Associations between soil bioavailable phosphorus and guayule plant growth and rubber production*. 31st Annual Undergraduate Biology Research Program Conference, University of Arizona, Tucson, Arizona. 25 January.
109. **Ledesma, J.*; Ossanna, L; Pacido, D.; El-Shikha, D.E.; Dong, C.; Ponciano, G.; McMahan, C.; Maier, R.M.; Neilson, J.W. 2020.** *Associations between soil bioavailable phosphorus, phosphorus solubilizing microorganisms, and guayule growth stage and rubber production*. University of Arizona ENViSion Virtual Earth Week Conference, Tucson, Arizona. April. [poster]
110. **Leo, A. 2019.** *Microbial adaptations for arid regions and middle schoolers*. Institute for Energy Solutions (IES) Energy Talks public lecture series, Sky Bar, Tucson, Arizona. 14 March.
111. **Levy, T.*; Rock, C.; Idowu, O.J.; Dery, J.; Brassil, N.; Zozaya, S. 2019.** *Growers' perceptions and comprehension of biofuel, bioproducts, and guar in the Southwest Arid Region.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
112. **Lewis, M. 2019.** *Salt stress tolerance in guayule*. SBAR UA Research Team Seminar, University of Arizona, Tucson, Arizona. 23 October.
113. **Lewis, M.*; Judkins, A.; Teetor, V.H.; Ray, D.T. 2019.** *Evaluating guayule germplasm for salt tolerance.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
114. **Lohr, P. 2020.** *AquaCrop modeling of guayule*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 5 February.
115. **Lohr, P*; Ogden, K. 2020.** *Modeling guayule: Adapting AquaCrop model for a perennial crop*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
116. **Lopez, E. 2018.** *Sustainable Bioeconomy for Arid Regions: Activities for education, extension and outreach*. American Institute of Chemical Engineers Rocky Mountain Regional Student Conference. Provo, Utah. 23 March.
117. **Lopez, E.*; Fox, S.; Brewer, C.E. 2018.** *GK-12 Lesson Documentation Spreadsheet*. American Institute of Chemical Engineers Annual Meeting, Pittsburg, Pennsylvania. 29 October.
118. **Madasu, C.*; Gunatilaka, L. 2020.** *Semi-synthesis and cytotoxicity evaluation of some pyrimidine analogues of argentatins A-C isolated from guayule (Parthenium argentatum) resin*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
119. **Maqsood, H. 2018.** *Guar Crop Coefficient Development for New Mexico Environments*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 7 November.
120. **Maqsood, H. 2020.** *Model parameterization for guar irrigation schedule and biomass estimation using remote sensing*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 1 April.
121. **Maqsood, H.*; Angadi, S.; El-Shikha, D.E.M.; Waller, P.; Singh, J.; Hunsaker, D.; Barua, B. 2019.** *Evaluating crop water status for guar using WINDS model.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]

122. **Maqsood, H.*; Waller, P.; El-Shikha, D.; Katterman, M.; Hoare, D.S.L.; Angadi, S.; Dierig, D. 2020.** *Analysis of soil moisture and crop vegetation for guayule and guar using irrigation models and remote sensing techniques*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
123. **Marinez, C.*; Lopez, G.U.; Cabrera D.d.J. 2019.** *The University of Arizona Cooperative Extension 4H Program Collaborating Statewide in Preparing the Next Generation of STEM Innovators.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
124. **McCloskey, W. 2018.** *Weed Trial Results for Guayule*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 14 November.
125. **McCloskey, W. 2019.** *Guayule Weed Control Research.* The 9th Annual Central Arizona Farmer Field Day. Maricopa Agricultural Center (MAC), Maricopa, Arizona. 8 October.
126. **McCloskey, W. 2020.** *2019 Herbicide Progress Report: Aim herbicide experiments and preemergence herbicide experiment failures*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 29 January.
127. **McMahan, C. 2018.** *Flowering Reduction in Guayule*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 19 September.
128. **McMahan, C. 2019.** *USDA-ARS Rubber Lab Update*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 27 March.
129. **McMahan, C.*; Placido, D.; El-Shikha, D.E.M.; Dong, C.; Ponciano, G.; Neilson, J.W. 2019.** *Dormancy and the guayule (Parthenium argentatum A. Gray) soil microbiome*. 31st Annual Meeting of the Association for the Advancement of Industrial Crops. Tucson, Arizona. 8-11 September. [poster]
130. **McMahan, C.*; Placido, D.; Resendiz, M.; Ponciano, G. 2020.** Flowering downregulation in guayule. Update to SBAR Advisory Board. Online presentation. 12 February.
131. **McMahan, C.*; Placido, D.; Resendiz, M.; Ponciano, G.; Dong, C. 2020.** Flowering downregulation in (*Parthenium argentatum*). SBAR UA Research Team Seminar Series, Tucson, Arizona. 9 December.
132. **Mealing, V. 2018.** *An overview of sustainability analysis methods of a new biofuel feedstock: bagasse from guar*. 6th Colorado School of Mines Graduate and Discovery Symposium. Golden, Colorado. 5 April.
133. **Mealing, V. 2019.** *Criteria, Methods, Opportunities, and Needs for Social Sustainability of Emerging Technology*. 7th Colorado School of Mines Graduate Research and Discovery Symposium. Golden, Colorado. April.
134. **Mealing, V. 2019.** *Sustainability assessment of guayule agriculture: Potential processing improvements for guayule co-products*. USDA-ARS, Western Regional Research Center, Albany, California. 3 July. [invited speaker]
135. **Mealing, V. 2019.** *Field Data Collection and Integration*. SBAR System Performance and Sustainability Seminar, Colorado State University, Golden, Colorado. 13 November.
136. **Mealing, V. 2020.** *Field data collection update*. SBAR System Performance and Sustainability Seminar, Colorado State University, Golden, Colorado. 19 February.
137. **Mealing, V. 2020.** *Field data integration update*. SBAR System Performance and Sustainability Seminar, Colorado State University, Golden, Colorado. 25 June.

138. **Mealing, V. 2020.** *A framework for assessing the social sustainability of guar agriculture.* Congress on Sustainability and Engineering (ICOSSE) (virtual). Golden, Colorado. 3 August.
139. **Mealing, V. 2020.** *Towards a holistic sustainability assessment of guar and guayule*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
140. **Mealing, V. 2020.** *Agricultural LCA of guar: Comparing N&P fertilizer scenarios from field trials.* American Center for Life Cycle Assessment Conference (ACLCA) (virtual). Golden, Colorado. 22 September.
141. **Mealing, V. 2020.** Sustainability assessment of guar and guayule cultivation: Utilizing unique field trial data. USDA Rubber Lab Meeting (virtual). Golden, Colorado. 10 December.
142. **Mealing, V.*; Harris, T.; Landis, A.E. 2019.** *Criteria, Methods, Opportunities, and Needs for Social Sustainability of Emerging Technology*. 15th International Conference on Environmental, Cultural, Economic and Social Sustainability. Vancouver, Canada. February.
143. **Mealing, V.*; Summers, H.M.; Sproul, E.; Eranki, P.L.; Landis, A.E.; Quinn, J.C. 2018.** *Life Cycle Assessment of Cultivating Guar in the American Southwest*. LCA XVIII Conference. Fort Collins, Colorado. October [poster] Won second place in graduate student posters.
144. **Mealing, V.*; Summers, H.M.; Sproul, E.; Eranki, P.L.; Quinn, J.C.; Landis, A.E.. 2018.** *Life Cycle Assessment of Cultivating Guar in the American Southwest.* National Society of Black Engineers, Fall Regional Conference. Las Vegas, Nevada. November [poster]
145. **Mealing, V.S.*; Landis, A.E. 2019.** *Life cycle assessment of guar agriculture in the Southwest, USA.* 31st Annual Meeting of the Association for the Advancement of Industrial Crops. Tucson, Arizona. 8-11 September. [poster]
146. **Mealing, V.S.*; Landis, A.E. 2019.** *SBAR Sustainability.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
147. **Mealing, V.S. 2020.** *Towards a holistic sustainability assessment of guar and guayule*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
148. **Mendoza, P.*; Sproul, E.; Quinn, J. 2020.** *High-value co-products from guayule resin and bagasse.* SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
149. **Mi, W.*; Teetor, V.H.; Ray, D.T. 2018.** *Rubber and Resin Extraction of Differentially Treated Biomass in Guayule (Parthenium argentatum)*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 2 August. [poster]
150. **Moreno, P.M.; Quinn, J.C.; Sproul, E. 2021.** *Economic and environmental sustainability assessment of thermochemical conversion of guayule bagasse to biofuels.* International Symposium on Sustainable Systems and Technology (ISSST). (Virtual) 21-25 June.
151. **Morris, N.A. 2020.** *SBAR 4-H opportunities and future directions*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 19 February.
152. **Morris, N.A. 2020.** *Arizona 4-H SBAR Capacity Building: Outcomes, progress, and plans.* SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.

153. **Morris, N.A. 2020.** *Realizing the Aim of Education for Sustainability Through 4-H*. National Association of Extension 4-H Youth Development Professionals (NAE4-HYDP) Annual Meeting. Boise, Idaho. October.
154. **Neilson, J.W. 2019.** *Soil Microbiome Resilience to Stress: How much is too much?* USDA-ARS, Western Regional Research Center, Albany, California. June. [invited speaker]
155. **Neilson, J.W.; Ossanna, L. 2020.** *Associations between the guayule rhizosphere microbiome and plant growth architecture, and rubber/resin production*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 4 March.
156. **Nieblas, A. I. 2020.** *Development of educational materials with a focus on arid regions.* SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
157. **Niu, D., 2018.** *Partial cloning of APETALA1 (AP1) gene from guayule*. cDNA Lab Seminar, USDA-ARS Western Regional Research Laboratory. 28 March.
158. **Ogden, K. 2017**. *Introducing new USDA NIFA CAP grant awardees – Developing regional AJF supply chains: Sustainable Bioeconomy for Arid Regions*. CAAFI-SOAP Jet Webinar. Hosted online. 13 October. [invited speaker]
159. **Ogden, K. 2017.** *Sustainable Bioeconomy for Arid Regions*. Biomass Research and Development Technical Advisory Board Meeting. 15 November. [invited speaker]
160. **Ogden, K. 2018.** *Sustainable Bio-economy for Arid Regions*. Southwest Indian Agricultural Association Annual Meeting. Laughlin, Nevada. 16-18 January.
161. **Ogden, K. 2018.** *Potential of the Bioproducts and Biofuels Economy*. AIChE Annual Meeting, Pittsburg, Pennsylvania. October [invited speaker]
162. **Ogden, K. 2020.** *Sustainable Bioeconomy for Arid Regions.* Grain Processing Lecture Series, Michigan Technological University, Houghton, Michigan. 17 January [invited speaker]
163. **Ogden, K. 2020.** *SBAR Project Update.* Southwest Indian Agriculture Association (SWIAA) 32nd Annual Conference, Laughlin, Nevada. 20-23 January [invited speaker]
164. **Ogden, K. 2020.** *Sustainable Bioeconomy for Arid Regions.* University of Utah, Salt Lake, Utah. 2 March. [invited distinguished lecturer]
165. **Ogden, K.*, White, R., Brewer, C.E. 2018.** *Public Private Partnerships*. ABLC Conference. Washington, D.C. 27-28 February.
166. **Omatayo, O. 2021.** *Harnessing the environmental and economic potentials of guar in arid regions.* International Arid Lands Consortium Conference (Virtual). University of Arizona, Water Resources Research Center, Tucson, Arizona. 24-26 May.
167. **Ossanna, L.*; Placido, D.; El-Shikha, D.E.M.; Dong, C.; Ponciano, G.; McMahan, C.; Maier, R.M., Neilson, J.W. 2019.** *Root-zone microbiome dynamics and guayule rubber production*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
168. **Ossanna, L.*; Brown, K.; Chen, Y.; Maier, R.; Neilson, J.; Placido, D.; Dong, C.; Ponciano, G.; McMahan, C.; El-Shikha, D.; Waller, P.; Wang, S.; Dierig, D. 2020.** *The significance of the soil microbiome to guayule production*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
169. **Phakdon, T. 2020.** *Plant adaptation in the Sonoran Desert: A lesson for middle school students.* SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.

170. **Ponciano, G.*; Dong, N.; Placido, D.; Borg, K.; Fonseca, L.; Howard, C.; Shintani, D.; McMahan, C. 2019.** *Bioengineering of guayule (Parthenium argentatum) to enhance tocopherols content.* 31st Annual Meeting of the Association for the Advancement of Industrial Crops. Tucson, Arizona. 8-11 September. [poster]
171. **Pruitt, D.*; Idowu, O.J.; Sanogo, S.; Angadi, S.; Steiner, R.L. 2019.** *The effects of mycorrhizae inoculation and soil amendments on growth of guar and pinto beans*. ASA-CSSA-SSSA International Annual Meetings, San Antonio, Texas, 13 November.
172. **Pruitt, D.*; Idowu, O.J.; Angadi, S.; Darapuneni, M.; Sanogo, S. 2020.** *Guar growth and yield as affected by nitrogen and phosphorus inputs*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
173. **Pruitt, D.J.*; Idowu, O.J.; Angadi, S.; Darapuneni, M.K.; Sanogo, S. 2020.** *Guar growth and yield as affected by nitrogen and phosphorus inputs*. ASA-CSSA-SSSA Annual Meeting (virtual), 11 November.
174. **Quinn, J.C.*; Summers, H.M.; Sproul, E.; Seavert, C.; Teegerstrom, T.; Gutierrez, P.; Robbs, J.; Mealing V.; Landis, A.E.; Fan, N.; Sun, O.; Zuniga-Vasquez, D. 2020.** *Integrated economic and environmental analysis of emerging industrial crops in arid regions of the Southwest United States*. International Symposium on Sustainable Systems and Technologies (virtual). 4 August.
175. **Quinn, J.C.*; Sproul, E.; Summers, H.M.; Seavert, C.; Gutierrez, P.; Teegerstrom, T.; Zuniga-Vazquez D.; Robbs, J.; Khanal, S.; Fan, N.; Sun, O.; Moreno, P.M. 2020.** *Integrated economic and environmental analysis of emerging industrial crops in arid regions of the Southwest United States.* American Chemical Society Fall 2020 Meeting and Expo (virtual). 17-20 August.
176. **Resendiz, M. 2020.** *Flowering downregulation of Parthenium argentatum*. USDA-ARS Lab Meeting, Albany, California. 14 May.
177. **Resendiz, M. 2020.** *Downregulation of floral identity genes in Parthenium argentatum*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
178. **Rock, C.*, Brassill, N. 2018.** *Importance of Cooperative Extension in University Research*. University of Arizona, Tucson, Arizona. 14 March.
179. **Rogstad, A. 2018.** *Real World Supply Chain Development: USDA Coordinated Agriculture Projects. SBAR Overview*. CAAFI Biennial General Meeting and Integrated ASCENT Symposium. Washington, D.C. 4-6 December. [invited speaker]
180. **Rogstad, A. 2019**. *SBAR Overview*. Association for the Advancement of Industrial Crops 31st Annual Meeting. Tucson, Arizona. 8 September. [invited speaker]
181. **Rogstad, A. 2021.** *SBAR Overview*. Arizona Institutes for Resilience: Solutions for the Environment and Society Seminar. Tucson, Arizona. 10 February [invited speaker]
182. **Rodriguez-Uribe, L.. 2020.** *Identification of metabolic biomarkers for cold-acclimation and freezing temperature tolerance in guayule (Parthenium argentatum, A. Gray).* Fall 2020 Friday Kick-off of the PES Graduate Research Seminar (virtual), Las Cruces, New Mexico. 28 August.
183. **Rodriguez-Uribe, L.*; Gutierrez, P. 2019.** *Implementing the Science of SBAR with Youth.* SBAR UA Research Team Seminar, University of Arizona, Tucson. 25 September.
184. **Rodriguez-Uribe, L.*; Gutierrez, P.; Rogstad, A.; Fields, J. 2020.** *Achievements of the SBAR Extension and Outreach Team in New Mexico.* SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.

185. **Rosalez, R.*; Brewer, C.E.; Jena, U. 2019.** *Co-Hydrothermal liquefaction (HTL) of guayue bagasse and wastewater treatment microalgae.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
186. **Sapkota, P.*; Imel, R.K.; Liu, W.; Angadi, S.; Trostle, C.; Williams, R.B.; Peffley, E.B.; Auld, D.L.; Burrow, M.D. 2019.** *Evaluation of breeding populations of guar for cultivation in Southwestern United States*. ASA-CSSA-SSSA International Annual Meetings, San Antonio, Texas, 12 November.
187. **Sehar, U.*; Rodriguez-Uribe, L.; Von Cruz, M.; Willette, S.; Mozaffari, K.; Dierig, D.; Holguin, F.O. 2020.** *Untargeted metabolome profiles on the guayule germplasms AZ-2 and W6-429 to identify metabolic biomarkers for cold-acclimation and freezing temperature tolerance*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
188. **Singh, J. 2020.** *Guar growth and development under pre-season and in-season irrigation management in the southern High Plains*. Master of Science Thesis. New Mexico State University, Las Cruces, New Mexico. 3 April.
189. **Singh, J**.*; **Angadi, S.V.; Begna, S.H. 2018**. *Crop Growth Stage Based Deficit Irrigation Management in Guar Crop.* The Western Sustainable Agriculture Conference (WSARE), University of New Mexico – Valencia Campus, Los Lunas, New Mexico. 12 December [poster]
190. **Singh, J.*; Angadi, S.V.; Begna, S.H. 2019.** *Identify guar germplasm suitable for cooler northern latitudes*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster] Won 2nd Place in graduate student poster presentation competition.
191. **Singh, J.*; Angadi, S.V.; Begna, S.H. 2020.** *Identify guar germplasm suitable for cooler northern latitudes of the Southern High Plains*. ***In***: Agricultural Science Center 2020 Annual Report. New Mexico State University, Clovis, New Mexico.
192. **Singh, J.*; Angadi, S.V.; Begna, S.H.; Guzman, I.; Idowu, O.J. 2019.** *Sustaining water resources using guar crop under different irrigation practices.* ACES-Open House, New Mexico State University, Las Cruces, New Mexico. 6 April. [poster]
193. **Singh, J.*; Angadi, S.V.; Begna, S.H.; Idowu, O.J. 2019.** *Guar as an alternative crop*. Annual Agricultural Field Day. Agricultural Science Center, Clovis, New Mexico. 8 August.
194. **Singh, J.*; Angadi, S.V.; Begna, S.H.; Idowu, O.J.; Guzman, I.; VanLeeuwen, D. 2019.** *Water extraction patters of guar under different irrigation strategies in the Southern High Plains.* Western Society of Crop Science Annual Meeting. Pasco, Washington. 25-26 June. [poster] Won 1st Place in student poster competition.
195. **Singh, J.*; Angadi, S.V.; Begna, S.H.; Idowu, O.J.; Guzman, I.; VanLeeuwen, D. 2019.** *Evaluating the effect of different irrigation practices on guar in the Southern High Plains.* Western Society of Crop Science Annual Meeting. Pasco, Washington. 25-26 June. Won 2nd Place in student oral presentation competition.
196. **Singh, J.*; Angadi, S.V.; Begna, S.H.; VanLeeuwen, D.; Idowu, O.J. 2019.** *Drought response and yield formation of guar under different water regimes in the Southern High Plains*. ASA-CSSA-SSSA International Annual Meetings, San Antonio, Texas. 10 November.
197. **Singh, J.*; Angadi, S.V.; Begna, S.H.; VanLeeuwen, D.; Idowu, O.J.; Guzman, I. 2020.** *Sustaining Irrigation Water of the Southern High Plains Using Guar*. New Mexico Alternative Crops Conference, Portales, New Mexico. 10 March. [poster]

198. **Skuse, K.*; Dery, J.; Zozaya, S.; Brassill, N.; Rock, C. 2018.** *Public interest in guayule being used as a biofuel.* University of Arizona, Maricopa Agricultural Center, Maricopa, Arizona. 26 July. [poster]
199. **Skuse, K.*; Dery, J.; Zozaya, S.; Brassill, N.; Rock, C. 2018.** *Public interest in guayule being used as a biofuel.* Oral presentation of student internship work. University of Arizona, Maricopa Agricultural Center, Maricopa, Arizona. 26 July.
200. **Smith, A. 2020.** *Valorization of guayule resin*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 22 April.
201. **Smith, A.*; Ogden, K. 2020.** *Vacuum distillation of guayule resin*. SBAR Annual Retreat (virtual). University of Arizona, Tucson, Arizona. 27-29 July.
202. **Soliz, N.*; Brewer, C.E.; Jena, U.; 2019.** *Bomb calorimetry of guayule bagasse and hydrothermal liquefaction products.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
203. **Soto, A.L.*; Placido, D.; Dong, C.; Ponciano, G.; McMahan, C.; Maier, R.M.; Neilson, J.W. 2019.** *Soil parameters that influence natural rubber production in guayule (Parthenium argentatum) during winter dormancy*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster] Won 2nd Place in intern student poster presentation competition.
204. **Sproul, E. 2020.** *Integrated Economic & Environmental Analysis of Guayule and Guar Production*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 22 January.
205. **Sproul, E. 2020.** Techno-economic analysis and life cycle assessment of guayule. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
206. **Sproul, E.*; Summers, H.M.*; Quinn, J.C. 2019.** *Techno-Economic and Environmental Impact Analysis of Guayule and Guar.* International Symposium on Sustainable Systems and Technology, Portland, Oregon. June. [poster] Won 1st Place in student poster competition.
207. **Sproul, E.*; Summers, H.M.; Mealing, V.; Landis, A.E.; Seavert, C.; Teegerstrom, T.; Gutierrez, P.; Robbs, J.; Fan, N.; Sun, O.; Quinn, J.C. 2019.** *Integrated environmental and economic assessment of guar and guayule.* American Center for Life Cycle Assessment (ACLCA) LCA XIX, Tucson, Arizona. 24-26 September. [poster]
208. **Sun, O. 2018.** *GIS-Based Two-stage Stochastic Facility Location Considering Planting Plan Uncertainty*. INFORMS Annual Meeting, Phoenix, Arizona. 5 November.
209. **Sun, O. 2018.** *GIS-Based Two-stage Stochastic Facility Location Considering Planting Plan Uncertainty*. SBAR UA Research Team Seminar. University of Arizona, Tucson, Arizona. 28 November.
210. **Sun, O. 2019.** *Optimization of a Biomass Supply chain from Economic, Environmental, and Social Perspectives*. Dr. Fan's Group Meeting, University of Arizona, Tucson, Arizona. 13 March.
211. **Sun, O. 2019.** *Biomass Supply Chain Configuration and Management*. SBAR UA Research Team Seminar. University of Arizona, Tucson, Arizona. 10 April.
212. **Sun, O. 2019.** *Integrating Environmental and Social Impacts into Biomass Supply Chain*. SBAR System Performance and Sustainability Team Seminar. Virtual meeting space, Tucson, Arizona. 2 May.
213. **Sun, O.*; Fan, N. 2018.** *Harvest scheduling*. SBAR Logistics Team Group Meeting. (webinar) New Mexico State University. Las Cruces, New Mexico. 5 February.

214. **Sun, O.*; Fan, N. 2018.** *Optimization of feedstock logistics*. SBAR UA Research Seminar. University of Arizona. Tucson, Arizona. 14 February.
215. **Sun, O.*; Fan, N. 2018.** *Optimally locating biorefineries*. SBAR Sustainability Working Group Seminar. (webinar) Colorado State University. Lakewood, Colorado. 8 March.
216. **Summers, H. 2020.** *Techno-economic analysis and life cycle assessment of guar.* SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
217. **Summers, H.; Quinn, J.C. 2021.** *Advancing water scarcity footprint methods for arid regions.* International Symposium on Sustainable Systems and Technology (ISSST). (Virtual) 21-25 June.
218. **Summers, H.M.*; Sproul, E.; Johnson, J.; Quinn, J.C. 2017.** *Sustainability assessment of bioproducts from southwest arid crops*. 21st Century Energy Transition Symposium, Colorado State University, Fort Collins, Colorado. October.
219. **Summers, H.M.*; Sproul, E.; Johnson, J.; Quinn, J.C. 2017.** *Sustainability assessment of bioproducts from southwest arid crops*. Colorado State University Graduate Student Showcase, Colorado State University, Fort Collins, Colorado. November.
220. **Summers, H.M.*; Sproul, E.; Johnson, J.; Quinn, J.C. 2018**. *Economic Viability and Environmental Impact of processing arid crops in the American Southwest.* International Congress on Environmental Modelling and Software. Colorado State University, Fort Collins, Colorado. June.
221. **Summers, H.M.*; Sproul, E.; Johnson, J.; Quinn, J.C. 2019.** *Economic and Environmental Impact Assessments of Drought Tolerant Crops in the American Southwest*. 21st Century Energy Transition Symposium, Denver, Colorado. April.
222. **Summers, H.M.*; Sproul, E.; Mealing, V.; Eranki, P.L.; Landis, A.E.; Quinn, J.C. 2018**. *Process Modeling and Life Cycle Assessment of Rubber from Guayule.* LCA XVIII Conference, Fort Collins, Colorado. October.
223. **Teegerstrom, T; Seavert, C. 2020.** *Whole farm analysis for evaluating the adoption of guayule and guar into Southwest producers' current operations*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 12 Februrary.
224. **Teegerstrom, T.*; Seavert, C.; Khanal, S.; Gutierrez, P. 2020.** *Whole farm analysis and enterprise budget tools for evaluating the adoption of guayule and guar into Southwest producers' current operation*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
225. **Usrey, J.*; Dehghanizadeh, M.; Audu, M.; Rosalez, R. 2019.** *SBAR Education/Outreach at Lynn Middle School and Mesilla Valley Leadership Academy.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
226. **Usrey, J. 2020.** *Development of middle school STEM classroom lesson plans for after school program activities*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
227. **Usrey, J.*; Rosalez, R.; Brewer, C.E. 2020.** *Development of middle school STEM classroom lesson plans and afterschool program activities to support USDA-sponsored project on alternative crop bioeconomy*. American Institute of Chemical Engineers (AIChE) Annual Meeting. (Virtual) 15 November.
228. **Waller, P. 2018.** *WINDS Model: A status report and connection to SBAR research*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 10 October.

229. **Wang, G.S.*; Lynch, A.; Cruz, V.M.V.; Dierig, D.A. 2019.** *Temperature requirements for guayule seed germination.* 31st Annual Meeting of the Association for the Advancement of Industrial Crops. Tucson, Arizona. 8-11 September. [poster]
230. **Willmon, J.*, Hu, J., Teetor, V.H., and Ray, D.T. 2018.** *Screening Parthenium argentatum for resistance to Phymatotrichum omnivorum*. 2018 Annual Conference, American Society for Horticultural Science, Washington, D.C. 30 July – 3 August.
231. **Willmon, J.; Montes, M.*; Coronado, G.; Bennett, M.C.; Teetor, V.H.; Hu, J.; Ray, D.T. 2018**. *Screening Parthenium argentatum for Resistance to Phymatotrichum omnivora*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 2 August. [poster]
232. **Wright, A.*; Brewer, C.E.; Jena, U. 2019.** *CHNS elemental analysis of guayule and products.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
233. **Zuniga-Vasquez, D. 2019.** *Two-stage stochastic multi-objective optimization for biomass supply chain integrating environmental and social impacts.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
234. **Zuniga-Vasquez, D. 2019.** *Stochastic scenarios for guayule production*. SBAR System Performance and Sustainability Seminar, Colorado State University, Fort Collins, Colorado. 8 October.
235. **Zuniga-Vasquez, D. 2019.** *Stochastic multi-objective optimization for guayule supply chain integrating environmental and social impacts*. SBAR UA Research Seminar, University of Arizona, Tucson, Arizona. 4 December.
236. **Zuniga-Vasquez, D. 2020.** *Optimization for guayule and guar logistics and transportation*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 8 April.
237. **Zuniga-Vasquez, D.*; Fan, N. 2020.** *Optimization for guayule and guar logistics and transportation*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 19 February.
238. **Zuniga-Vasquez, D.*; Fan, N. 2020.** *Integrating environmental and social impacts into optimal design of guayule and guar supply chains*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
239. **Zuniga-Vasquez, D.*; Fan, N. 2020.** *Smart farm production and scheduling design for guayule and guar*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
240. **Zuniga-Vasquez, D.*; Fan, N. 2020.** *Smart farm production and scheduling design for guayule and guar*. SBAR Sustainability Team Meeting, University of Arizona, Tucson, Arizona. 30 September.
241. **Zuniga-Vasquez, D.*; Fan, N. 2020.** *Smart farm production and scheduling design for guayule and guar*. SBAR Research Team Meeting, University of Arizona, Tucson, Arizona. 30 September.
242. **Zuniga-Vasquez, D.*; Sun, O.; Fan, N. 2020.** *Optimization for guayule and guar logistics and transportation integrating environmental and social impacts on the supply chain.* New Mexico Alternative Crop Conference, Portales, New Mexico. 10 March. [poster]

Total Audience Demographics for Project-Related Presentations (when captured)

Audience Demographic Parameter	Previous Total (Cumulative)	This Quarter Total	Cumulative Project Total
Gender			
Males	1,935	47	***2,111***
Females	912	25	***1,024***
Race/Ethnicity			
Hispanic	470	11	***487***
Asian	242	6	***250***
Native American	353	9	***365***
African American	73	2	***77***
Anglo/White	1,709	40	***1,772***
Unknown	0	4	***184***

Audience Cumulative Total *(when captured)****: 3,135 ppl***

WEBSITE(S) OR INTERNET SITE(S)

SBAR Project Website

1. .https://sbar.arizona.edu

NEW TECHNOLOGIES OR TECHNIQUES GENERATED

None this reporting period.

INVENTIONS, PATENT APPLICATIONS, AND/OR LICENSES

1. **Dec 2017.** 24c SLN Label for Gramoxone SL 2.0 Herbicide (Paraquat dichloride), for control of weeds in guayule. SLN Registration Number: AZ120005. Expiration: 31 Dec 2022. Arizona Department of Agriculture, Environmental Services Division.

2. **Dec 2017.** 24c SLN Label for Fusilade DX Herbicide (*Propanoic acid, 2-(4-((5-(trifluoromethyl)-2-pyridinyl)oxy)phenoxy)-, butyl ester, (R)-*), for control of emerged weeds in guayule. SLN Registration Number: AZ070006. Expiration: 31 Dec 2022. Arizona Department of Agriculture, Environmental Services Division.

3. **Sep 2020**. Patent # 506319647 (REEL/FRAME: 054154/0921) UA21-25 – Adhesives.

4. **Sep 2020**. Patent # 506319660 (REEL/FRAME: 054154/0977) UA21-26 – Particle Board.

OTHER PRODUCTS GENERATED

Brochures, Factsheets, and Flyers

1. **Duncan, C.M. 2018.** SBAR USDA-NIFA graduate student fellowship: UA Students. One page promotional flyer. February and March.
2. **Duncan, C.M. 2018.** SBAR USDA-NIFA graduate student fellowship: NMSU Students. One page promotional flyer. February and March.
3. **Duncan, C.M. 2018.** SBAR call for middle and high school science teachers. One page promotional flyer. February and March.
4. **Duncan, C.M. 2018.** SBAR 4-H summer camp: Biofuels powering your world. One page promotional flyer. March.
5. **Duncan, C.M. 2019.** SBAR Call for Middle & High School Science Teachers. One page promotional flyer. March.
6. **Duncan, C.M. 2019.** SBAR USDA-NIFA graduate student fellowship: UA Students. One page promotional flyer. March.
7. **Duncan, C.M. 2019.** SBAR USDA-NIFA graduate student fellowship: NMSU Students. One page promotional flyer. March.
8. **Duncan, C.**M. 2019. SBAR USDA-NIFA graduate science education fellowship. One page general recruiting flyer. April.
9. **Evancho, B. 2019.** Guayule Information & Feedback Session. One page invitation to attend field day and tour. May.
10. **Grover, K. 2018**. Guar – A potential alternative crop in New Mexico. Two page informational handout. January.
11. **Kiela, C. 2018.** Guayule. SBAR Project two-page fact sheet. March.
12. **Kiela, C. 2018.** Guar. SBAR Project two-page fact sheet. April.
13. **Kiela, C. 2018.** History of Guayule. SBAR Project two-page fact sheet. April.
14. **Rogstad, A. 2017.** SBAR – Sustainable Bioeconomy for Arid Regions. One-page informational and promotional card. November.

Press Releases and News Articles

1. 26 Sep 2017. “As NIFA awards $21.1M to grow the bioeconomy, CABLE debuts to bridge students and industry.” BiofuelsDigest. http://www.biofuelsdigest.com/bdigest/2017/09/26/as-nifa-awards-21-1m-to-grow-the-bioeconomy-cable-debuts-to-bridge-students-and-industry/

2. 16 Oct 2017. “UA to Head New Center Focusing on Biofuels and Bioproducts.” UA News. https://uanews.arizona.edu/story/ua-head-new-center-focusing-biofuels-and-bioproducts

3. 4 Nov 2017. “Biofuels, bioproducts, and an Arizona bioeconomy?” Arizona Daily Wildcat. http://www.wildcat.arizona.edu/article/2017/11/science-biofuels-and-bioproducts

4. 29 Nov 2017. “NMSU to host state sustainable agriculture conference in Los Lunas.” News Bulletin. http://www.news-bulletin.com/news/nmsu-to-host-state-sustainable-agriculture-conference-in-los-lunas/article_a45281f6-d540-11e7-9530-27dc93258a79.html

5. 16 Jan 2018. “Dr. Quinn’s Sustainability Expertise Recruited for Multi-Million Dollar DOE and USDA Grants.” Colorado State University, Mechanical Engineering Featured Projects. http://www.engr.colostate.edu/me/2018/01/16/dr-quinns-sustainability-expertise-recruited-for-multi-million-dollar-doe-and-usda-grants/

6. 21 Feb 2018. “NMSU collaborating in Sustainable Bio-economy for Arid Regions project.” New Mexico State University News Center. http://newscenter.nmsu.edu/Articles/view/12961/nmsu-collaborating-in-sustainable-bio-economy-for-arid-regions-project

7. 27 Feb 2018. “Bridgestone receives guayule research grant from USDA.” The Smithers Report - A daily and weekly tire industry news source. (4,500 daily subscribers) https://www.smithersrapra.com/publications/the-smithers-report

8. 27 Feb 2018. “Bridgestone and research partners earn $15 Million grant for guayule work.” MTD (Modern Tire Dealer). UMV: 62,085. http://www.moderntiredealer.com/news/728673/bridgestone-and-research-partners-earn-15-million-grant-for-guayule-work

Tabling Events and Workshops – Marketing and Outreach

1. 14 July 2017. New Mexico Cotton Ginners Conference. New Mexico.
2. 17 Aug 2017. SBAR Project Kick-off Meeting. Tucson, Arizona.
3. 28 Oct 2017. Rocky Mountain Zone Summit (sustainability focus). Denver, Colorado.
4. 05 Dec 2017. Valencia County (New Mexico) Forage Conference. New Mexico.
5. 13 Dec 2017. New Mexico Sustainable Agriculture Conference. Los Lunas, New Mexico.
6. 15-17 Feb 2018. SBAR Display Table. New Mexico Organic Farming Conference. Albuquerque, New Mexico.
7. 24 Feb 2018. Farm Science Day. USDA-ARS, Arid-Land Agricultural Resource Center. Maricopa, Arizona.
8. 24 Feb 2018. 2018 Engineering Fair – Recycled papermaking and guar gum bubbles activity. Las Cruces Museum of Science and Nature. Las Cruces, New Mexico.
9. 15 Mar 2018. Zia Middle School Project – Lead the Way NMSU College of Engineering Day. Recycled papermaking and guar gum bubbles activity. Las Cruces, New Mexico.
10. 22-24 Feb 2018. Southwest Ag Summit. Yuma, Arizona.
11. 19 Mar 2018. Roosevelt Irrigation District Board Meeting. Buckeye, Arizona.
12. 28 Mar 2018. Alfalfa and Forage Workshop. Maricopa, Arizona.
13. 11 Jul 2018. New Mexico 4-H State Conference – Polymerization and guar gum bubbles activity. Albuquerque, New Mexico.
14. 9 Aug 2018. Extension Field Day, New Mexico State University Agricultural Science Center, Clovis, New Mexico.
15. 23 Aug 2018. Extension Field Day, New Mexico State University Agricultural Science Center, Artesia, New Mexico.
16. 12 Dec 2018. New Mexico Sustainable Agriculture Conference, Las Cruces, New Mexico.

17. 10 Jan 2019. Marana Winter Field Crop Clinic. University of Arizona Cooperative Extension, Marana, Arizona.
18. 15 Jan 2019. Casa Grande Winter Field Crop Clinic. University of Arizona Cooperative Extension, Casa Grande, Arizona.
19. 23 Jan 2019. New Mexico Cotton Growers Association Conference, Ruidoso, New Mexico.
20. 13 Feb 2019. Desert Hills S.T.E.A.M. Night. (Science, Technology, Engineering, Art, and Math) Desert Hills Elementary School, Las Cruces, New Mexico.
21. 15-16 Apr 2019. New Mexico Organic Farming Conference, Albuquerque, New Mexico.
22. 11 Apr 2019. Spring Extension Field Day, New Mexico State University Agricultural Science Center, Clovis, New Mexico.
23. 15 May 2019. Annual Agricultural Research Congressional Exhibition and Reception. Rayburn House, Washington, D.C.
24. 30 May 2019. Market Discussion and Field Day. Bridgestone Guayule Research Farm, Eloy, Arizona.
25. 26 Jun 2019. Extension Field Day. Fabian Garcia Research Center, Las Cruces, New Mexico.
26. 2 Jul 2019. SBAR Train the Trainers Workshop. Las Cruces, New Mexico.
27. 8 Aug 2019. Annual Agricultural Field Day. Agricultural Science Center, Clovis, New Mexico.
28. 8 Aug 2019.Agricultural Science and Field Day. Agricultural Science Center, Tucumcari, New Mexico.
29. 15 Aug 2019. Annual Agricultural Field Day. Agricultural Science Center, Los Lunas, New Mexico.
30. 21 Aug 2019. USAID Cochran Fellows Visit from Mali, Clovis, New Mexico.
31. 12 Oct 2019. Cooperative Extension Day. Maricopa Agricultural Center (MAC), Maricopa, Arizona.
32. 14 Jan 2020. Winter Field Crops Meeting, Pima County, Arizona.
33. 15 Jan 2020. Winter Field Crops Meeting, Pinal County, Arizona.
34. 29 Jan 2020. New Mexico Cotton Grower's Conference, New Mexico.
35. 30 Jan 2020. NexGen Cotton Symposium, Pinal County, Arizona.
36. 3-4 Feb 2020. New Mexico Chili Pepper Conference, New Mexico.
37. 5 Feb 2020. Deltapine Seed Meeting, Pinal County, Arizona.
38. 21-22 Feb 2020. New Mexico Organic Farming Conference, New Mexico.
39. 10 Mar 2020. New Mexico Alternative Crops Conference, Portales, New Mexico.

→Total Reach via Tabling Events and Workshops (when captured): ***3,562 participants***

****Note: Due to COVID-19 restrictions, in-person events have been on hiatus since March 2020.****

YOUTH ACTIVITIES

Biofuel Lessons in Classrooms (SBAR Teacher/Fellow Cohort 2018-2019)

1. Apollo Middle School, Tucson, Arizona.
2. Mesilla Valley Leadership Academy, Las Cruces, New Mexico.
3. Pueblo High School, Tucson, Arizona.
4. Quail Run Elementary School, Marana, Arizona.
5. Sierra Middle School, Las Cruces, New Mexico.
6. Valencia Middle School, Tucson, Arizona.
7. Walter Douglas Elementary School, Tucson, Arizona.

Biofuel Lessons in Classrooms (SBAR Teacher/Fellow Cohort 2019-2020)

1. Apollo Middle School, Tucson, Arizona.
2. Camino Real Middle School, Las Cruces, New Mexico.
3. Mesa Middle School, Las Cruces, New Mexico.
4. Mesilla Valley Leadership Academy, Las Cruces, New Mexico.
5. Quail Run Elementary School, Marana, Arizona.
6. Pueblo High School, Tucson, Arizona.
7. Saguaro National Park Environmental Education, Tucson, Arizona.
8. Santa Rosa Ranch School, Sells, Arizona.
9. Sierra Middle School, Las Cruces, New Mexico.
10. Walter Douglas Elementary School, Tucson, Arizona.

Biofuel Lessons in Classrooms (SBAR Teacher/Fellow Cohort 2020-2021)

1. Camino Real Middle School, Las Cruces, New Mexico
2. Melrose High School, Melrose, New Mexico
3. Saguaro National Park Environmental Education, Tucson, Arizona
4. Santa Rosa Ranch School, Sells, Arizona
5. Sierra Middle School, Las Cruces, New Mexico
6. Valencia Middle School, Tucson, Arizona

Youth participation through classroom activities is tracked at the beginning of the school year in September because the same students are being reached each week by the teacher fellow pairs. ***NOTE****: Due to COVID-19 response, direct youth contact did not occur after March 2020.*

Other SBAR youth activities (4H camps, after school programs, Native Youth Outreach, etc.) are also included in the total when they occur.

Youth Participation Demographics for Project-Related Activities (when captured)

Youth Participation Demographic Parameter	Previous Total (Cumulative)	This Quarter Total	Cumulative Project Total
Age Level			
11-13 years	1,242	0	***1,242***
14-16 years	433	14	***487***
Gender			
Males	834	4	***862***
Females	841	10	***867***
Race/Ethnicity			
Hispanic	893	8	***904***
Asian	33	0	***33***
Native American	159	1	***184***
African American	47	0	***47***
Anglo/White	538	2	***545***
Multiracial	6	3	***17***

Youth Cumulative Total *(when captured)****: 1,729 ppl***

****Note: Due to COVID-19 restrictions, in-person and in-school activities have been on hiatus since March 2020.****

PARTICIPANTS AND COLLABORATING ORGANIZATIONS. September 2017 – June 2021

PARTNER ORGANIZATIONS

Organization Person*	Project Role	Project Component
Bridgestone Americas,		
Von Mark Cruz	Professional	Feedstock Development & Production
David Dierig	Key Collaborator	Feedstock Development & Production
Stefan Dittmar	Professional	Feedstock Development & Production
Chloe Gonzalez	*Intern*	*Feedstock Development & Production*
Amber Lynch	Professional	Feedstock Development & Production
Russell Prock	Professional	Feedstock Development & Production
Theresa Sullivan	Professional	Feedstock Development & Production
Sam Wang	Professional	Feedstock Development & Production
Jocelyn Zhu	*Intern*	*Feedstock Development & Production*
Colorado School of Mines		
Pragnya Eranki	*Post-doc*	*System Performance & Sustainability*
Amy Landis	Key Collaborator	System Performance & Sustainability
VeeAnder Mealing	Graduate Student	System Performance & Sustainability
Jane Turek	*Undergrad Student*	*System Performance & Sustainability*
Colorado State University		
Austin Banks	*Undergrad Student*	*System Performance & Sustainability*
Jack Johnson	*Undergrad Student*	*System Performance & Sustainability*
Paula Mendoza Moreno	Undergrad Student	System Performance & Sustainability
Jason Quinn	Key Collaborator	System Performance & Sustainability
Evan Sproul	Graduate Student	System Performance & Sustainability
Hailey Summers	Graduate Student	System Performance & Sustainability
New Mexico State University		
Ram Acharya	*Professional*	*System Performance & Sustainability*
Sarah Acquah	*Post-doc*	*Extension & Outreach* *System Performance & Sustainability*
Rowen Allen	*Undergrad Student*	*Extension & Outreach*
Sangu Angadi	Key Collaborator	Extension & Outreach Feedstock Development & Production
Matt Armijo	Undergrad Student	Characterizations & Co-Products
Justice Armijo	Undergrad Student	Characterizations & Co-Products
Meshack Audu	*Graduate Student Fellow*	*Education* *Characterizations & Co-Products*
Valerie Bailey	*Undergrad Student*	*Feedstock Development & Production*
Thomas Baca	Undergrad Student	Extension & Outreach
Hengameh Bayat	Graduate Student	Characterizations & Co-Products
Sultan Begna	*Professional*	*Feedstock Development & Production*
Geneva Ben	*Undergrad Student*	*Feedstock Development & Production*
Pratima Bhandari	*Graduate Student*	*System Performance & Sustainability*

Catherine E. Brewer	Key Collaborator	Education Characterizations & Co-Products
Nicolas Carrera-Little	Undergrad Student	Characterizations & Co-Products
Alyssa Castaneda	Undergrad Student	Extension & Outreach
Pedro Castillo	*Undergrad Student*	*Feedstock Development & Production*
Kenneth Cazarez	Undergrad Student	Extension & Outreach
Shivam Chawla	*Graduate Student*	*Feedstock Development & Production*
Feng Cheng	*Post-doc*	*Characterizations & Co-Products*
Murali Darapuneri	*Professional*	*Extension & Outreach*
Mostafa Dehghanizadeh	Graduate Student Fellow	Education Characterizations & Co-Products
Malachai Dehler-Egan	Undergrad Student	Characterizations & Co-Products
Barry Dungan	*Professional*	*Characterizations & Co-Products*
Dominic Flores	*Undergrad Student*	*Feedstock Development & Production*
Miguel Flores	*Undergrad Student*	*Extension & Outreach*
Leonel Fournier	*Undergrad Student*	*Feedstock Development & Production*
Sarah Fox	*Undergrad Student*	*Characterizations & Co-Products*
Ryan Fullerton	*Undergrad Student*	*Feedstock Development & Production*
Claudia Galvan	Professional	Characterizations & Co-Products
Alonso Garcia	*Graduate Student*	*Feedstock Development & Production*
Adah Gellis	*Undergrad Student*	*Extension & Outreach*
Saba Gill	*Graduate Student*	*Characterizations & Co-Products*
Thomas Gloria	*Undergrad Student*	*Feedstock Development & Production*
Kulbhushan Grover	Key Collaborator	Extension & Outreach Feedstock Development & Production
Erin Gutierrez	*Undergrad Student*	*Characterizations & Co-Products*
Maria Gutierrez	Undergrad Student	Extension & Outreach
Paul H Gutierrez	*Key Collaborator*	*Extension & Outreach* *System Performance & Sustainability*
Befekadu Habteyes	*Professional*	*System Performance & Sustainability*
Jose Hackleen	*Undergrad Student*	*Feedstock Development & Production*
Mia Herrera	Undergrad Student	Feedstock Development & Production
F. Omar Holguin	Key Collaborator	Characterizations & Co-Products
John Idowu	Key Collaborator	Extension & Outreach
Jackie Jarvis	*Professional*	*Characterizations & Co-Products*
Umakanta Jena	*Professional*	*System Performance & Sustainability*
Sita Khanal	*Graduate Student*	*System Performance & Sustainability*
Alix Knagg	*Undergrad Student*	*Characterizations & Co-Products*
Kelly Laje	Graduate Student	Characterizations & Co-Products
Travis Le-Doux	*Undergrad Student*	*Characterizations & Co-Products*
Esai Lopez	*Undergrad Student*	*Education*
Alberto Lorenzo	*Undergrad Student*	*Feedstock Development & Production*
Andrea Loya Lujan	Undergrad Student	Characterizations & Co-Products
Sicilee Macklin	*Undergrad Student*	*Education* *Characterizations & Co-Products*
Michael Mares	*Undergrad Student*	*Extension & Outreach*
Cesar Martinez-Bejarano	*Undergrad Student*	*Characterizations & Co-Products*
Maryfrances Miller	Professional	Extension & Outreach
Julie Miller	*Undergrad Student*	*Extension & Outreach*
Sa'Rae Montoya	*Graduate Student*	*Characterizations & Co-Products*
Kyle Moore	*Undergrad Student*	*Feedstock Development & Production*
Hasti Mozaffari	*Graduate Student*	*Characterizations & Co-Products*
Angel Navarro-Cruz	Undergrad Student	Feedstock Development & Production Extension & Outreach

Mallory Nielson	Undergrad Student	Extension & Outreach
Oluwatobi Omotayo	Graduate Student	System Performance & Sustainability
Mohammed Omer	Professional	Extension & Outreach
Jasmine Paquin	*Graduate Student*	*Extension & Outreach*
Kaavya Polisetti	*Graduate Student*	*Characterizations & Co-Products*
Camila Prieto	*Undergrad Student*	*Extension & Outreach*
Darien Pruitt	Graduate Student Fellow	Education Extension & Outreach
Jason Quintana	Undergrad Student	Extension & Outreach
Lucas Ramirez	*Undergrad Student*	*Feedstock Development & Production*
Rodolfo Ramirez	Undergrad Student	Extension & Outreach
Joram Robbs	*Graduate Student*	*Extension & Outreach* *System Performance & Sustainability*
Laura Rodriguez-Uribe	Professional	Extension & Outreach Characterizations & Co-Products
Alvaro Romero	Professional	Characterizations & Co-Products
Rodrigo Rosalez	*Graduate Student Fellow*	*Education* *Characterizations & Co-Products*
Kimberly Salinas	*Undergrad Student*	*Extension & Outreach*
Nathan Schavz	*Undergrad Student*	*Characterizations & Co-Products*
Tarah Schuman	*Undergrad Student*	*Characterizations & Co-Products*
Ujala Sehar	Graduate Student	Characterizations & Co-Products
Sergei Shalygin	Graduate Student	Characterizations & Co-Products
Jagdeep Singh	*Graduate Student*	*Education* *Feedstock Development & Production*
Paramveer Singh	Graduate Student Fellow	Feedstock Development & Production Education
Peter Skelton	*Professional*	*Extension & Outreach*
Nicolas Soliz	Undergrad Student	Characterizations & Co-Products
Grant Stoner	*Undergrad Student*	*Feedstock Development & Production*
David Struthers	*Undergrad Student*	*Feedstock Development & Production*
Stephen Taylor	*Undergrad Student*	*Education*
Brian Treftz	*Graduate Student*	*Education* *Characterizations & Co-Products*
Alejandra Trejo	Undergrad Student	Extension & Outreach
Stephanie Torres	*Graduate Student*	*Feedstock Development & Production*
Jacob Usrey	Graduate Student Fellow	Education Characterizations & Co-Products
Justin Valdez	*Undergrad Student*	*Characterizations & Co-Products*
Victoria Valenzuela	*Undergrad Student*	*Feedstock Development & Production*
Jorge Vega	Undergrad Student	Extension & Outreach
Stephanie Willette	*Graduate Student*	*Characterizations & Co-Products*
Scott Woolf	*Undergrad Student*	*Characterizations & Co-Products*
April Wright	*Undergrad Student*	*Characterizations & Co-Products*
Other		
Jennifer Fields	Professional	Education Extension & Outreach
Clark Seavert	Professional	System Performance & Sustainability Extension & Outreach
University of Arizona		
Torran Anderson	Professional	Education Extension & Outreach

Nick Ashley	*Graduate Student*	*Feedstock Development & Production*
Craig Bal	*Graduate Student*	*Education* *Extension & Outreach*
Gloria Villa Barbosa	*Undergrad Student*	*Extension & Outreach*
Armando Barreto	*Professional*	*Feedstock Development & Production*
Holly Barton	*Graduate Student Fellow*	*Education*
Kaitlyn Benally	*Undergrad Student*	*Extension & Outreach*
Megan Bennett	*Undergrad Student*	*Feedstock Development & Production*
Natalie Brassill	Professional	Extension & Outreach
Kyle Brown	Graduate Student	Feedstock Development & Production
Kale Burke	Undergrad Student	Characterizations & Co-Products
Daniela Cabrera	*Professional*	*Extension & Outreach*
Marielle Cascaes Inacio	Post-doc	Characterizations & Co-Products
Madasu Chandrashekar	*Post-doc*	*Characterizations & Co-Products*
Connor Chaney	Undergrad Student	Feedstock Development & Production
Sara Chavarria	Key Collaborator	Education
Yongjian Chen	Post-doc	Feedstock Development & Production
German Coronado	*Undergrad Student*	*Feedstock Development & Production*
Kamel Didan	*Professional*	*Feedstock Development & Production*
Cara Duncan Shopa	Professional	Education Extension & Outreach
Diaa El-Shikha	Post-doc	Feedstock Development & Production
Blase Evancho	Key Collaborator Graduate Student	Extension & Outreach Feedstock Development & Production
Neng Fan	Key Collaborator	System Performance & Susainability
Krista Farmer	*Undergrad Student*	*Feedstock Development & Production*
Charles Ferini	*Undergrad Student*	*Feedstock Development & Production*
Gunnar Fritz	*Undergrad Student*	*Education*
Daryan Godfrey	*Undergrad Student*	*Feedstock Development & Production*
Leslie Gunatilaka	Key Collaborator	Characterizations & Co-Products
Wolfgang Grunberg	Professional	ALL AREAS
Matthew Harmon	*Undergrad Student*	*Feedstock Development & Production*
Alejandra Hinojosa	Undergrad Student	Characterizations & Co-Products
Danielle Hoare	Graduate Student	Feedstock Development & Production
Stephanie Honeker	*Undergrad Student*	*Feedstock Development & Production*
Wanyu Huang	Graduate Student	Feedstock Development & Production
Arisbeth Ibarra Nieblas	Graduate Student Fellow	Education
Aaron Judkins	*Undergrad Student*	*Feedstock Development & Production*
Pujan Kafle	*Graduate Student*	*System Performance & Sustainability*
Matthew Katterman	Graduate Student *Fellow*	Education Feedstock Development & Production
C. Kasia Kiela	*Undergrad Student*	*ALL AREAS*
Corey Knox	Professional	Education
Trisha Lane	Undergrad Student	Characterizations & Co-Products
Jessica Ledesma	Undergrad Student	Feedstock Development & Production
Ashton Leo	*Graduate Student Fellow*	*Education*
Taylor Levy	*Intern*	*Extension & Outreach*
Myles Lewis	Professional	Feedstock Development & Production
Manping Liu	*Professional*	*Characterizations & Co-Products*
Patrick Lohr	*Graduate Student*	*Feedstock Development & Production*
Gerardo Lopez	*Key Collaborator*	*Extension & Outreach*

Jasmine Lopez	*Undergrad Student*	*Extension & Outreach*
Raina Maier	Key Collaborator	Feedstock Development & Production
Jonathan Maldonado	*Undergrad Student*	*Feedstock Development & Production*
Hadiqa Maqsood	Graduate Student	Feedstock Development & Production
Celestina Marinez	*Intern*	*Extension & Outreach*
Karina Martinez	Graduate Student Fellow	Education
William McCloskey	Key Collaborator	Feedstock Development & Production
Wenzhe Mi	*Intern*	*Feedstock Development & Production*
István Molnár	Key Collaborator	Characterizations & Co-Products Education
Madison Montes	*Undergrad Student*	*Feedstock Development & Production*
Leobardo Moreno	Undergrad Student	Feedstock Development & Production
Madison Morris	Undergrad Student	Feedstock Development & Production
Nick Morris	Key Collaborator	Extension & Outreach
Julie Neilson	Professional	Feedstock Development & Production
Andrew Nelson	*Post-doc*	*Feedstock Development & Production*
Kimberly Ogden	Key Collaborator	ALL AREAS
Huitzilin Ortiz	*Graduate Student Fellow*	*Education*
Lia Ossanna	*Professional*	*Feedstock Development & Production*
Bryan Pastor	Professional	Feedstock Development & Production
Duke Pauli	*Key Collaborator*	*Feedstock Development & Production*
Livvi Pearson	*Undergrad Student*	*Feedstock Development & Production*
Alexandra Peck	Undergrad Student	Feedstock Development & Production
Shaira Perez	*Undergrad Student*	*Extension & Outreach*
Sam Pernu	*Undergrad Student*	*Feedstock Development & Production*
Tenzin Phakdon	Graduate Student Fellow	Education
Sarocha Pradyawong	Post-doc	Feedstock Development & Production
Dennis T. Ray	Key Collaborator	Feedstock Development & Production
Jaspreet Rekhi	*Professional*	*Characterizations & Co-Products*
Channah Rock	Key Collaborator	Extension & Outreach
Alix Rogstad	Professional	ALL AREAS
Juan Salas	*Undergrad Student*	*Feedstock Development & Production*
Luis Anguiano Sanchez	*Professional*	*Feedstock Development & Production*
Carl Schmalzel	Professional	Feedstock Development & Production
Caroline Schulte	Graduate Student	Feedstock Development & Production
Zoe Scott	*Undergrad Student*	*Extension & Outreach*
David Shafer	Professional	Extension & Outreach
Rebecca Sheng	*Undergrad Student*	*Feedstock Development & Production*
Stephanie Sikora	*Professional*	*Education*
Andrew Smith	Graduate Student	Feedstock Development & Production
Ana Lucia Soto	*Undergrad Student Intern*	*Feedstock Development & Production*
Seth Steichen	*Graduate Student Fellow*	*Education*
Ou Sun	*Graduate Student*	*System Performance & Sustainability*
Trent Teegerstrom	Key Collaborator	Extension & Outreach System Performance & Sustainability
Valerie Teetor	Professional	Feedstock Development & Production
Mira Theilmann	*Undergrad Student*	*Feedstock Development & Production*
Christine Toering	*Undergrad Student*	*Feedstock Development & Production*
Gianni Velasco	*Undergrad Student*	*Feedstock Development & Production*

Tony Viola	*Undergrad Student*	*Education*
Peter Waller	Key Collaborator	Feedstock Development & Production
Quinn Waltz	*Undergrad Student*	*Feedstock Development & Production*
John Willmon	*Undergrad Student*	*Feedstock Development & Production*
Gaven Wolkon	Undergrad Student	Characterizations & Co-Products
Ya-ming Xu	*Post-doc*	*Characterizations & Co-Products*
Ali Yaylali	Graduate Student Fellow	Education
Stevi Zozaya	*Undergrad Student*	*Extension & Outreach*
Weimao Zhong	Post-doc	Characterizations & Co-Products
Daniel Zuniga-Vazquez	Graduate Student	Characterizations & Co-Products System Performance & Sustainability
USDA Agriculture Research Service – US Arid Lands Research Center, Maricopa AZ		
Hussein Abdel-Haleem	Key Collaborator	Feedstock Development & Production
Adrianna Chambers	*Undergrad Student*	*Feedstock Development & Production*
Amber Dearstyne	*Undergrad Student*	*Feedstock Development & Production*
Tristan Dunton	*Professional*	*Feedstock Development & Production*
Harmony Glover	*Undergrad Student*	*Feedstock Development & Production*
Doug Hunsaker	*Professional*	*Feedstock Development & Production*
Greg Leake	*Professional*	*Feedstock Development & Production*
Avery Luna	Undergrad Student	Feedstock Development & Production
Lily Luo	Professional	Feedstock Development & Production
Aaron Szczepanek	Professional	Feedstock Development & Production
Brandon Vera	*Undergrad Student*	*Feedstock Development & Production*
USDA Agriculture Research Service – Western Regional Research Center, Albany CA		
Milagro Adom	*Student (SEED)*	*Feedstock Development & Production*
Sheyla Aucar	*Professional*	*Feedstock Development & Production*
Brandon Bartelmie	*Student*	*Feedstock Development & Production*
Matthew Canonizado	*Professional*	*Feedstock Development & Production*
George Chong	*Professional*	*Feedstock Development & Production*
Chen Dong	*Professional*	*Feedstock Development & Production*
Niu Dong	Professional	Feedstock Development & Production
Trinh Huynh	Professional	Feedstock Development & Production
Kumiko Johnson	Professional	Feedstock Development & Production
Colleen McMahan	Key Collaborator	Feedstock Development & Production
Dante Placido	Post-doc	Feedstock Development & Production
Grisel Ponciano	Professional	Feedstock Development & Production
Mariano Resendiz	Graduate Student	Feedstock Development & Production

** Individuals no longer actively working on the SBAR project appear in italic.*

Total Active Key Collaborators: ***24***
Total Active Professional Staff: ***31***
Total Active Postdoctoral Researchers: ***6***
Total Active Graduate Students: ***26***
Total Active Undergraduate Students: ***27***
Total Active Fellows: ***7***
Total Active /Interns: ***0***

*Total Active Participants:****114***
Total Past Participants (no longer active): ***133***
Total Individuals Involved Since SBAR Inception: ***247***

COLLABORATIONS AND OTHER CONTACTS

Collaborations:

Academic Institutions:	CSM (Colorado School of Mines) - Dept. of Civil and Environmental Engineering CSU (Colorado State University) - Dept. of Mechanical Engineering FSU (Florida State University) - National High Magnetic Field Laboratory NMSU (New Mexico State University) - Cooperative Extension - Dept. of Agriculture, Consumer and Environmental Science - Dept. of Agricultural Economics and Agricultural Business - Dept. of Chemical and Materials Engineering - Dept. of Plant and Environmental Sciences - Urban Entomology Research Center UA (University of Arizona) - Arizona Institutes for Resilience - Agricultural and Biosystems Engineering - College of Agriculture and Life Sciences - College of Education - College of Engineering - Cooperative Extension - Dept. of Agriculture and Resource Economics - Dept. of Chemical and Environmental Engineering - Dept. of Language, Reading and Culture - Dept. of Soil, Water and Environmental Sciences - Dept. of Systems and Industrial Engineering - Dept. of Teaching and Teacher Education - Institute of Energy Solutions - Natural Products Center - School of Natural Resources and the Environment - School of Plant Sciences UNM (University of New Mexico) – Gallup - Dept. of Mathematics, Physical and Natural Science
Nonprofits:	Environmental Defense Fund, Phoenix AZ Asombro Institute for Science Education, Las Cruces NM

Industrial or Commercial Firms:	BASF Bridgestone Americas, Inc. Central Arizona Project (CAP) FMC Guar Resources Syngenta
Federal Government	Saguaro National Park (West), Tucson AZ - Environmental Education Department USDA – Agricultural Research Service, Western Regional Research Center, Albany CA - Chemistry (Bioproducts) - Plant Genetics USDA – Agricultural Research Service, Grassland Soil and Water Research Laboratory, Temple TX - Crop Modeling USDE – Pacific Northwest National Laboratory, Richland WA
State or Local Governments:	Arizona Department of Agriculture, Environmental Services Division
Tribal Governments:	**Ak-Chin Indian Community**, Maricopa, Arizona **Tohono O'odham Nation**, Sells, Arizona
Schools or School Systems:	**BASIS Charter Schools**, BASIS Tucson North (high school), Tucson, Arizona **Flowing Wells Unified District**, Walter Douglas Elementary School, Tucson, Arizona **Las Cruces Public Schools**, Camino Real Middle School, Mesa Middle School, Mesilla Valley Leadership Academy, and Sierra Middle School, Las Cruces, New Mexico **Marana Unified School District**, Quail Run Elementary School, Marana, Arizona **Melrose Municipal Schools**, Melrose High School, Melrose, New Mexico **Tucson Unified School District**, Pueblo High School, and Valencia Middle School, Tucson, Arizona **Santa Rosa Ranch School District**, Santa Rosa Ranch School, Sells, Arizona

	Sunnyside Unified School District, Apollo Middle School, Tucson, Arizona
Other Organizations (foreign or domestic):	

Other Contacts:

Contacts with others within recipient's organization (interdepartmental or interdisciplinary collaborations):	UA (University of Arizona) - Applied Biosciences - Arid Lands Resource Sciences - Arizona Institutes for Resilience - College of Agriculture and Life Sciences - College of Architecture, Planning and Landscape Architecture - College of Science - Water Resources Research Center
Contacts with others outside the organization:	Denver Museum of Nature and Science, Denver CO Central Arizona College, Coolidge AZ
Contacts with others outside the United States or with an international organization:	

APPENDICES

APPENDIX 1. PUBLICATIONS

Documents Included

1. **SBAR Extension and Outreach Newsletter (Volume 2, Issue 1)** – A biannual newsletter produced by the SBAR Education, Extension & Outreach (EEO) Teams. January 2021. (6p)
2. **Guar as a Rotation Crop** – SBAR Fact Sheet that describes how guar can be useful as a rotation crop in New Mexico and other arid regions. (3p).
3. **Guar Fertilization** – SBAR Fact Sheet focused on the use of applied Nitrogen and Phosphorus in guar crop production. (4p).
4. **Extension and Outreach Newsletter (Volume 2, Issue 2)** – A biannual newsletter produced by the SBAR Education, Extension & Outreach (EEO) Teams. June 2021. (6p)
5. **Guar Gum Poster** – An educational poster that explains the uses for guar gum. August 2021. (1p)
6. **Guayule Flyer** – A descriptive flyer (small poster) infographic for youth development activities. August 2021. (1p)
7. **Guayule: Potential Benefits** – SBAR two-page information sheet. August 2021. (2p)

SBAR

SUSTAINABLE BIOECONOMY FOR ARID REGIONS

Extension & Outreach Newsletter

January 2021; Volume 2, Issue 1

HIGHLIGHTS

NOTEWORTHY & NEWSY

Dr. Frannie Miller
New Mexico State University Assistant Professor in the Department of Agricultural Economics and Agricultural Business.

Frannie joined the SBAR Youth Outreach Team and will develop activities to engage 4-H participants.

Mr. Alan Daugherty
Science teacher at Melrose Jr. High and High School in Melrose, NM., and a 2019 Excellence in STEM Award recipient.

Alan joined the Education Team and will bring SBAR themed lessons into his middle school science classroom.

Accomplishments

Education Fellow Arisbeth Ibarra Nieblas won 2nd place at the 2020 American Institute of Chemical Engineers K-12 STEM Outreach Competition for her lesson "Exploring Bioproducts: Glue for Piñatas" - read more HERE

Extension Team Lead Blase Evancho hosted the Guayule Field Day in October 2020 with Bridgestone Americas and the UArizona Extension Office. Learn about guayule research and production and watch the Field Day presentations HERE

SBAR goes virtual in 2020! Read about our progress, learn about our next steps, and watch the Annual Retreat student research presentations HERE

SBAR StoryMap: A Guayule and Guar Story

As the SBAR Center of Excellence embarks on the 4th year of research, development, deployment, and community engagement, the team's accomplishments are highlighted in a new SBAR Accomplishments ArcGIS StoryMap available to the public. Some questions remain (and some new ones have been uncovered), but we are making progress toward achieving the mission to build a sustainable bioeconomy in arid regions of the Southwest! Explore the progress we've made and share the link with your colleagues! Check out our story HERE

Guar in New Mexico

FIELD DAYS

Due to COVID-19 restrictions, many Field Day events were postponed. However, Dr. John Idowu, NMSU Extension Lead, presented at the 2020 Virtual Field Day hosted at the Rex E. Kirksey Agricultural Science Center at Tucumcari, NM. SBAR research was presented in his talk: The Potential of Guar for Eastern New Mexico. Watch John's talk HERE

DEMONSTRATION TRIALS

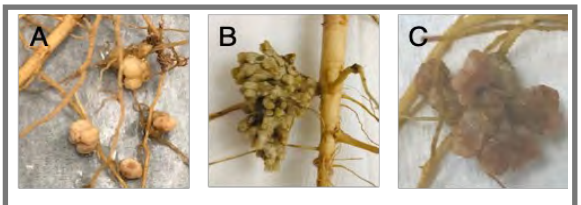
Demonstration trials were conducted on guar's response to limited irrigation in Las Cruces, NM, and Artesia, NM. Field trials evaluated plant characteristics that determine seed yield, agronomic and physiological response of guar genotypes under five drip-irrigated water regimes, and plant response with and without biogenic silica application. Biogenic silica is a naturally deposited material that can be mined and applied to the soil. It is a powdery material that has been shown to increase the soil water holding capacity, thus helping crops to be more drought resistant. In general, the I1 regime (irrigation through the entire season) produced the highest guar seed yield followed by I5 regime (terminate irrigation at flowering + biogenic silica) in Las Cruces (2016-2018) and in Artesia (2018). As compared to the I1 regime (normal irrigation), the I2 regime (no irrigation at 75% pod formation) and I3 regime (no irrigation at 50% and 75% pod formation) resulted in 20.8 % and 23.4% decline in guar seed yield, respectively. The lowest seed yield was obtained under I4 regime (terminate irrigation at flowering) which resulted in 26.4% decline in seed yield as compared to the I1 regime (irrigation through entire season). The I5 regime (terminate irrigation at flowering + biogenic silica) resulted in 17.3% higher seed yield as compared to the I4 regime (terminate irrigation at flowering) at Las Cruces. Results indicated a positive impact of biogenic silica on guar growth and seed yield under limited irrigation conditions. Dr. Kulbhushan Grover reported results.

Denotes NMSU Science Center with guar

Dr. Grover harvesting guar with students (Tucumcari, NM. Dec, 2019)

IDENTIFICATION OF *RHIZOBIUM* AND OTHER SYMBIOTIC BACTERIA IN NODULES OF GUAR IN NEW MEXICO

Guar (*Cyamopsis tetragoloba L.)* is a drought-tolerant legume that produces seeds rich in galactomannan or guar gum, a polysaccharide used as a lubricant, binder, food thickener, or hardener. Like other legumes, guar associates with symbiotic nitrogen-fixing rhizobia bacteria and form root nodules. The symbiotic nodules are specialized root organs that house rhizobia capable of using nitrogen gas (N_2) diffused into the soil from the air to produce organic nitrogen that the plant can use to grow. The rhizobia in the root nodules convert N_2 in the soil to ammonia, which is then taken up by plants to synthesize amino acids and other nitrogen compounds.



Nodules from guar plants grown at the Leyendecker, Fabian Garcia, and Los Lunas (A, B, C) Agricultural Science Centers in NM. Two types of guar nodules were identified: Determinate and indeterminate.

Guar plants with roots experiencing nodulation have been identified in the last two growing seasons (2019 and 2020) in NM at three different planting sites. In the 2019 growth season, Dr. Idowu's group identified nodule containing guar plants at the Leyendecker Plant Science Center in Las Cruces. Later, Dr. Grover's group identified 11 guar varieties showing nodulation at the NMSU Fabian Garcia Plant Science Center Las Cruces. In 2020 guar nodulating plants were found at the Los Lunas NMSU Agricultural Science Center.

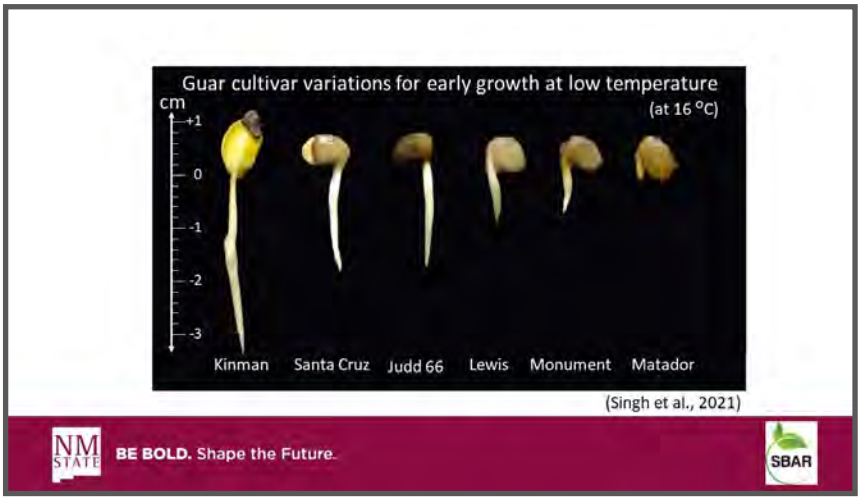
Two types of guar nodules were identified: Determinate and indeterminate. Nodules from each guar plant were provided to Dr. Laura Rodriguez-Uribe of the SBAR Characterizations and Co-Products team, who isolated the symbiotic bacteria from the guar nodules.

Three species of bacteria other than rhizobia were also identified: *Pseudomonas*, *Bordetella*, and *Agrobacterium*. Identifying the *Rhizobia* species associated with guar nodulation in NM will assist in optimizing the production of guar in the Southwest. The bacteria in nodules of different guar varieties shows that a diverse population of bacteria reside within the guar nodules. These bacteria may not be capable of fixing nitrogen but can potentially enhance legume survival, especially under environmental stress conditions.

The identified nodule associated bacteria could be used as bio-inoculants combined with *Rhizobia* to study their ability to enhance nodulation, rhizobial performance or persistence, and reduce chemical use fertilizers and pesticides for guar. Dr. Laura Rodriguez -Uribe reported results.

Guar in New Mexico

PROPER CULTIVAR SELECTION HELPS IN PLANTING GUAR IN COOLER REGIONS



Domestic supply of guar is becoming more important in the US to meet growing demand by diverse industries and to buffer supply uncertainty. Guar is a desert adapted crop and is well suited for New Mexico and Arizona. However, guar is grown in warmer regions of the world. Therefore, we studied germination and early growth of currently available guar cultivars under a range of temperatures to identify suitable cultivars for lower temperatures to potentially expand guar production to cooler regions. Lowering the temperature from 28 to 13°C decreased the overall final seed germination percentage, seed vigor index, primary root length, and speed of germination index in most of the cultivars. However, Kinman cultivar maintained a longer root and recorded higher values for most of the vigor indices at cooler temperatures. Matador cultivar had the lowest values for most of the vigor indices throughout the experiment. Results indicate with proper cultivar selection, guar area can be extended to colder regions. Kinman cultivar can be used in the cooler regions of the Southern High Plains of USA. Jagdeep Singh and Dr. Sangu Angadi reported results.

Guayule in New Mexico

COLD-ACCLIMATION AND FREEZING IN GUAYULE

A recently completed study analyzed the metabolome of leaves of the guayule germplasms AZ-2 and W6-429 exposed to cold-acclimation and freezing temperatures. Dr. Rodriguez-Uribe, a molecular biologist and research Assistant Professor in the Department of Plant and Environmental Sciences and a member of the SBAR Characterization and Co-Products research team, used the guayule metabolomes to identify metabolic biomarkers for cold-acclimation and freezing. Dr. Rodriguez-Uribe produced the manuscript "Untargeted metabolome profiling of guayule (*Parthenium argentatum* A. Gray) to identify metabolic biomarkers for cold-acclimation and freezing temperature tolerance" that includes the guayule metabolomes and metabolic biomarkers. This manuscript is the first report of metabolome profiles from leaves of the USDA guayule germplasms, polyploid AZ-2, and diploid W6-429 in cold-acclimation and freezing. It is also the first report on the identification of metabolic biomarkers associated with these environments.
The manuscript is expected to be published in the Industrial Crops and Products peer-reviewed journal soon.

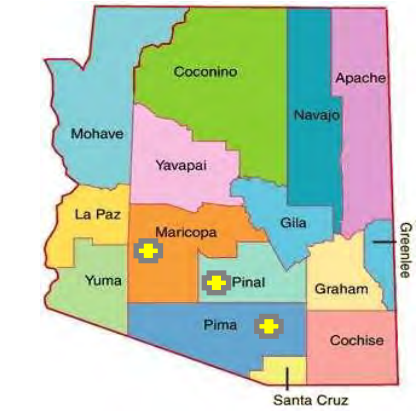
A six months old guayule W6-429 seedling gown in greenhouse at 38/23°C day/night.

Three guayule germplasms with mature plants in the field identified to have a low cold injury in Las Cruces.

A follow-up study on the guayule temperature response in leaf and bark tissues is underway to gather information on the possible sequence of events leading to rubber biosynthesis and accumulation. Three germplasm groups with mature plants in the field that Bridgestone identified to have a low cold injury in Las Cruces are being studied for their metabolic and transcriptomic response to decreasing clinal temperature. The initial samples were collected by the graduate student Ujala Sehar in September. Subsequent monthly sample collection will be carried out up to March 2021. Dr. Laura Rodriguez-Uribe reported results.

Grower Updates: Guayule Research & Activities

Guayule in Arizona



Denotes SBAR or Bridgestone plot with guayule trials

FIELD DAYS

The 2020 Virtual Guayule Field Day brought together people from all over the world to learn about guayule! The field day, originally scheduled for early summer was postponed by COVID-19. The UArizona SBAR Extension Team transitioned the event to a virtual platform and hosted over 100 people from 5 states and 2 countries and featuring several presentations discussing guayule production. We were fortunate to have presentations from University of Arizona Extension Specialists, Bridgestone researchers and SBAR researchers discussing insect pests, agronomic production, weed control and economic outlook for guayule. View presentations by Dr. Bill McCloskey on weed control, Trent Teegerstrom on guayule crop budgets, and others HERE

We thank everyone for attending and look forward to an in person field day next year.

Get Involved: Youth Outreach

INTERN WITH SBAR IN SUMMER 2021

OPEN TO HIGH SCHOOL STUDENTS IN ARIZONA

Interns gain valuable field skills while spending time with industry chemists, geneticists, engineers, or other research scientists at the University of Arizona. Interns are required to make a scientific poster about the research that they conduct during their internship, which will be presented at the 2021 SBAR Retreat in Tucson, AZ.

Learn more HERE

SBAR interns at Agriculture Field Day Event

SBAR Content with 4-H

University of Arizona 4-H Youth Development Resources

Check out SBAR 4-H virtual programming, camps and curriculum, and get involved **HERE**

4-H Ambassador Program

SBAR partners with 4-H Ambassadors, a leadership experience for 4-H teens.
Get involved **HERE**

Guardians of the Biosphere After School Clubs

Coming soon! Create a "GOB" club at your school with content by SBAR 4-H .
Initiated by New Mexico science educators Cathy Bradley and Tracie Mikesell.
Watch a GOB blurb **HERE**

SBAR Content with FFA

Future Farmers of America

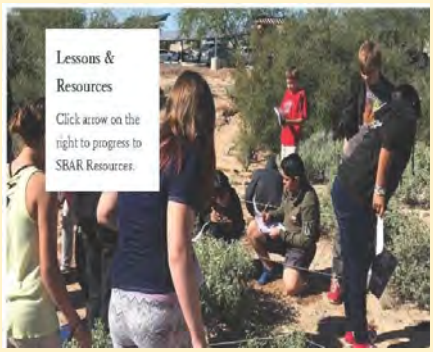
New Mexico State University researchers and educators have created SBAR lessons and activities for FFA.
Check out content and get involved **HERE**

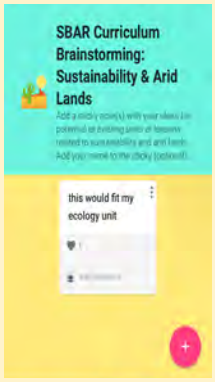
Educator Resources

EDUCATION DIGITAL CORNER

The SBAR Education Partnership offers a digital treasure trove of lessons, activities, videos and graduate students to support educators in creating and teaching arid regions themed lessons. Learn more from the interactive Story Map.

SBAR Story Map Orientation— created by Education Researcher Corey Knox, PhD





Images from SBAR Story Map

SBAR Education Partnership

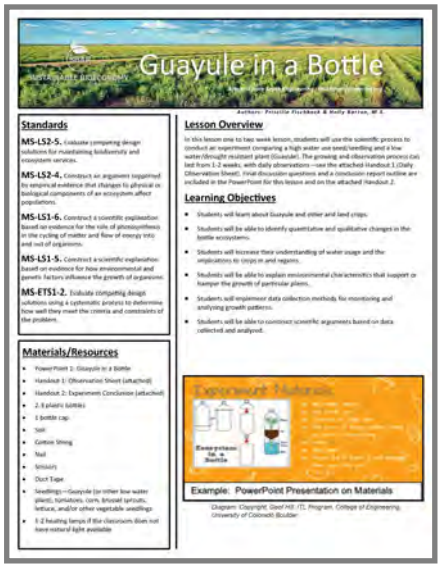
We are expanding our Education reach by going statewide and virtual. SBAR curricula align with NGSS and focus on FIVE main areas that connect to SBAR Research:

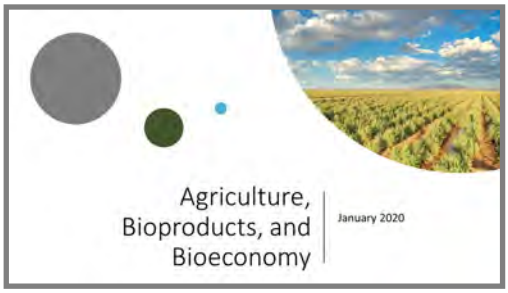
> Arid Lands, Agriculture & Sustainability
> Land Use, Farming & Culture in Arid Regions
> Building Bioeconomy in Arid Regions
> Sustainable Crops: Guar & Guayule
> Chemistry & Engineering

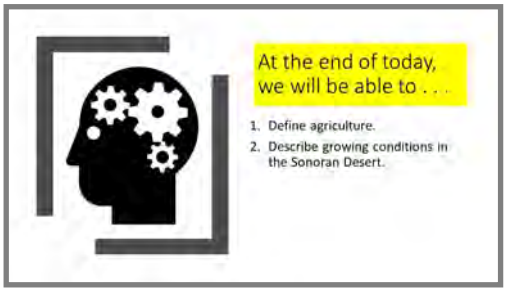
Hear what teachers say about SBAR HERE

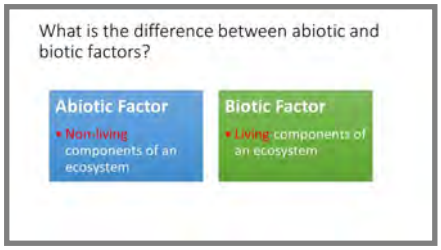
Virtual SBAR Education Content

DOWNLOAD AND USE SBAR THEMED LESSONS, VIDEOS AND ACTIVITIES HERE









These images are a few examples of the lesson plans, power point presentations and videos available for free download.

Educators Join SBAR today! Fill out an Interest Form HERE

COMING SOON!

Recruiting: Growers

SBAR is seeking growers for trial plots of guar (NM) or guayule (AZ)

Available Spring 2021

Contact: John Idowu (Guar, NM)

Contact: Blase Evancho (Guayule, AZ)

Recruiting: Educators

SBAR is seeking educators for virtual partnership

Available Fall 2021

Contact: Catie Brewer (NM)

Contact: Corey Knox (AZ)

Recruiting: 4-H Volunteers

SBAR is seeking community members as 4-H volunteers

Available Fall 2021

Contact: Laura Rodriguez-Uribe (NM)

Contact: Nick Morris (AZ)

USDA Plant Guide on Guayule

Available Spring 2021

Contact: Blase Evancho

SBAR Plant Guide on Guar

Available Spring 2021

Contact: John Idowu

SBAR Whole Farm Analysis Tool

for Evaluating the Adoption of Guayule and Guar into Your Current Operation

Available Spring 2021

Contact: Trent Teegerstrom

Contact Our Team

Education

Catie Brewer - New Mexico
cbrewer@nmsu.edu

Corey Knox - Arizona
cknox@arizona.edu

Extension

Guar - New Mexico
John Idowu
jidowu@nmsu.edu

Guayule - Arizona
Blase Evancho
bee1@arizona.edu

Youth Outreach

Laura Rodriguez-Uribe - New Mexico
FFA Contact
laurodri@nmsu.edu

Nick Morris - Arizona
4-H Contact
nmorris6@arizona.edu

Frannie Miller - New Mexico
4-H Contact
franniem@nmsu.edu

Natalie Brassill - Arizona
Internship Contact
nbrassill1@arizona.edu

Sustainability

Trent Teegerstrom - Arizona
tteegers@arizona.edu

We would love to hear from you!

Sign up for the SBAR List to receive our Newsletter and email updates. Email sbar-outreach@list.arizona.edu with SUBSCRIBE on the subject line.

Check out the SBAR website for more information, videos, publications and resources: https://sbar.arizona.edu

Any opinions, findings, conclusions or recommendations expressed in this publication/work are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.
Grant #: 2017-68005-26867

Guar as a Rotation Crop

GUAR FIELD IN NEW MEXICO. PHOTO: JOHN IDOWU

GUAR WITH PODS - PHOTO: JOHN IDOWU

PURPOSE OF CROP ROTATION

- Improve soil health
- Optimize nutrients in the soil
- Combat pest and weed pressure

CROP ROTATION AS GOOD PRACTICE

> Crop rotation is one important way to manage soil health and improve crop productivity. Farmers that produce various kinds of crops are very careful to develop sound crop rotation practices.

> Practicing crop rotation is beneficial because:

1. Soilborne pests that feed on one family of plants are slowed because their food crop changes.
2. Alternating shallow-rooted and deep-rooted plants in a given area draws nutrients from the soil at varying depths.
3. Plants that fix nitrogen, such as legumes, improve soil quality for future crops.
4. Farmers who practice crop rotation may not need to let fields lie fallow as often.

BREAKING DISEASE & PEST CYCLES IN A CROPPING SYSTEM

> Planting the same crop repeatedly can lead to a buildup of diseases and pests that are peculiar to that crop. After the pathogens and pests have built up over time, specific diseases can start showing up on that crop, leading to reduced crop yields.

> Planting another crop family breaks the cycle of diseases. Sometimes growing the same crop can increase weed problems and reduce crop yields.

> Therefore, a crop such as guar in a crop rotation can assist with disease and pest management on the farm and guarantee sustainable crop yields.

CHOOSING A ROTATION CROP

- Carefully consider options
- Identify crops that grow well in your region
- Choose crops using these factors:
  - Cost of crop production
  - Water use
  - Equipment needed
  - Crop market
  - Seed availability
  - Profitability

DRX GUAR FIELD READY FOR HARVEST PHOTO: DENNIS RAY

MANAGING SOIL HEALTH

> Apart from breaking disease cycles, introducing a diverse crop rotation into cropping systems can bring several soil health benefits.

> Incorporation of crops with deep roots, like guar, into the rotation helps alleviate compaction and enhances soil structure. Guar is a leguminous crop and can fix atmospheric nitrogen, and nitrogen can be returned to the soil through the nitrogen-rich residue that is left after harvest.

> Different crop families have different microbial communities that associate with their roots. Therefore, a rotation that contains a variety of crops will enhance the soil microbial diversity and community structure, thus improving the soil health.

ROTATIONAL CROPS - LIBRARY OF CONGRESS

IMPROVE NUTRIENT & WATER USE EFFICIENCY WHILE REDUCING POLLUTION

> Sustainability of a crop rotation can be improved by including a deep-rooted crop like guar in a rotation.

> A crop like guar with its deep roots will be able to utilize the nutrients and water from a deeper soil profile, improving nutrient and water use efficiency.

> This can also reduce environmental pollution which could result when nutrients leach into the groundwater.

CHOOSING A ROTATION CROP

> The decision to choose an appropriate rotation crop requires careful thinking.

> The rotation crop is chosen after considering cost of producing the crop, water use, equipment needed, market for the crop, seed availability, and profitability.

> Guar is one such option that can grow well in arid and semiarid regions. Farmers unfamiliar with guar should get in touch with a local agricultural or horticultural Extension Agent.

Any opinions, findings, conclusion or recommendation expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. Grant #: 2017-68005-2686

Guar as a Rotation Crop. SBAR Center of Excellence 3-page fact sheet. March 2021.

GUAR RESOURCES

> 807 N 5th Street, Brownfield, TX 79316
> Phone: 806-637-4662
> Email: info@guarresources.com

REFERENCES

> Hodges, R.J.; Kinman, M.L.; Brints, N.W.; Boring III, E.P.; Mulkey Jr., J.R. 1970. *Keys to Profitable Guar Production*. Leaflet/Texas Agricultural Extension Service; no.907.

> Singh, J. 2020. *Guar Growth and Development Under Pre-Irrigation and in-Season Irrigation Management in the Southern High Plains*. Master's Thesis, New Mexico State University, Las Cruces, NM.

GUAR AS ROTATION CROP

> Guar is a leguminous crop (bean family) with seeds that can be processed to generate guar gum, which is in high demand by the food, cosmetics, and oil/gas industries.

> Guar is a low water demanding and drought resistant crop that grows very well in semiarid and arid regions like New Mexico and Arizona.

> Since guar is an annual legume crop, it can fit into the rotation of several cropping systems in the desert southwest.

> Studies have shown that guar can be highly beneficial as a rotation crop because it can improve the yields of the next crop grown after it. A 15% yield increase of cotton planted after guar was observed in some research experiments (Hodges et al., 1970).

> SBAR research in eastern New Mexico has also shown that guar can extract soil moisture and nutrients from a deeper soil profile under limited rainfall or irrigation (Singh, 2020). The same research also showed that if guar is stressed for moisture after flowering, it will extract more water from the deeper soil layers.

WANT TO GROW GUAR?

> A contract with a seed processor before harvested guar beans can be processed is a requirement. Guar Resources is the major processor of guar beans in the New Mexico region, and is located in Brownfield, Texas. (see sidebar for contact details)

> The processor can help you with seed procurement and information on other logistics involved with getting harvested beans to the processing plant.

AUTHORS

> John Idowu, Extension Agronomist, New Mexico State University, Las Cruces, NM
> Sangu Angadi, Crop Physiologist, New Mexico State University Clovis Agricultural Science Center, Clovis, NM
> Dennis T. Ray, Geneticist/Plant Breeder/Horticulturalist, University of Arizona, Tucson, AZ

For more information: https://sbar.arizona.edu

Any opinions, findings, conclusion or recommendation expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. Grant #: 2017-68005-2686

Guar as a Rotation Crop. SBAR Center of Excellence 3-page fact sheet. March 2021.

Guar Fertilization


GUAR NODULES - PHOTO: JOHN IDOWU

NITROGEN FIXATION

> A chemical process by which atmospheric nitrogen is transformed by microorganisms as part of the nitrogen cycle.

NITROGEN AND PHOSPHORUS FERTILIZATION TRIALS

> Guar (*Cyamopsis tetragonoloba*) is a legume that grows well in the arid and semiarid desert regions of New Mexico and Arizona. It is a low-input, drought-tolerant crop, thus a potential alternative crop in areas affected by changing water availability and climate change.

> As a legume, guar can fix nitrogen. Nitrogen is an essential nutrient for the growth of all plants and is the largest nutrient applied in agriculture. It improves the growth and yield of crops and is essential for cell elongation, photosynthesis, and seed formation.

MAKING NITROGEN IN PLANTS

> Nitrogen fixation in legumes is a process whereby a plant enters into a symbiotic association with a class of soil bacteria belonging to the *Rhizobium* species. The legume secretes special substances (flavonoids) through the roots into the soil which attracts the bacteria to attach to the cells of root hairs. Once the bacteria “infect” the root hairs, the plant cells respond by dividing and forming nodules where the bacteria are retained.

> Inside the nodules, the rhizobium bacteria convert the naturally occurring nitrogen found in the air and soil into nitrates, which is the form of nitrogen that plants can readily use. The nitrates are made available to the legume while the legume provides the bacteria in the nodules with carbohydrates necessary for their growth.

17 KEY ELEMENTS FOR PLANT GROWTH

• Carbon (C) • Hydrogen (H) •
• Oxygen (O) •
• Nitrogen (N) •
• Phosphorus (P) •
• Potassium (K) • Sulfur (S) •
• Calcium (Ca) •
• Magnesium (Mg) • Boron (B) •
• Chlorine (Cl) • Copper (Cu) •
• Iron (Fe) • Manganese (Mn) •
• Molybdenum (Mo) •
Nickel (Ni) • Zinc (Zn) •

NEW MEXICO FIELD TRIALS
PHOTO: KULBHUSHAN GROVER

PURPOSE OF THE SBAR FIELD TRIALS

> There are few reports in New Mexico and Arizona of guar forming nodules under field conditions. Without adequate nodulation, guar must acquire nitrogen from other sources. The absence of nodules has been attributed to high summer soil temperatures that may inhibit the nodulation process (Liu et al., 2011).

> Another key element for plant growth is phosphorus. Phosphorus is critical in legumes for root development, nodule formation, and nutrient uptake. Thus, it is important to learn whether guar may benefit from additional phosphorus applied to the soil at planting.

TRIAL METHODS

> To find out if guar yields are affected by the addition of nitrogen and phosphorus, we conducted field trials across four locations in New Mexico: Las Cruces, Los Lunas, Tucumcari, and Clovis, NM.

> We applied two rates of nitrogen and phosphorus to the soil before planting. The rates were 22 lb N/ac or 44 lb N/ac for nitrogen; and 22 lb P_2O_5/ac or 44 lb P_2O_5/ac for phosphorus. These rates were compared to a control plot with no additional nitrogen or phosphorus added.

> The experiments were conducted over two growing seasons, with growth and yields assessed at each location.

TRIAL RESULTS: WHAT WE LEARNED

> Three observations were made from the results of these trials:

1. The response to both nitrogen and phosphorus fertilizers varied among locations.
2. The response to fertilization varied each year.
3. The response to nitrogen and phosphorus application was generally small or not significant.

> This suggests that guar yields may vary with location and can be affected by the seasonal weather patterns.

> Added nitrogen and/or phosphorus may have little effect on overall yield.

Any opinions, findings, conclusion or recommendation expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. Grant #: ***2017-68005-2686***

Guar Fertilization. SBAR Center of Excellence 4-page fact sheet. June 2021.

GUAR PLANT WITH PODS FORMING
PHOTO: JOHN IDOWU

TRIAL LOCATIONS

- Las Cruces, NM
- Los Lunas, NM
- Tucumcari, NM
- Clovis, NM

TRIAL DETAILS BY LOCATION

> In **Las Cruces** during the first year of the trial, guar bean yield was not affected by nitrogen but increased with phosphorus application compared to the control treatment that did not receive fertilizer. During the second year, guar yield was not affected by either nitrogen or phosphorus fertilizers compared to the control treatment. At Las Cruces, the highest bean yield the first trial was1165 lb/ac, while the highest yield during the second year was 867 lb/ac.

> Nitrogen and phosphorus fertilization did not affect the bean yields during both trial years in **Los Lunas**. The highest bean yield recorded for Los Lunas the first trial year was 685 lb/ac, and during the second year it was 2128 lb/ac. The very low guar yield during the first year was probably due to the early onset of colder temperatures during the guar reproductive phase.

> There were no significant effects of nitrogen and phosphorus fertilizer application during both trial years in **Tucumcari**. The highest bean yield in the first year was 951 lb/ac, while 1688 lb/ac bean yield was recorded in the second year.

> In the first trial year, nitrogen and phosphorus fertilizers did not affect guar bean yields in **Clovis**; however, during the second trial year guar responded to nitrogen with the best yield at the highest nitrogen rate, but again phosphorus did not affect bean yield. The highest yield recorded the first trial year was 1052 lb/ac, while 1336 lb/ac was recorded in the second year in this location.

LOS LUNAS, NEW MEXICO FIELD TRIALS
PHOTO: JOHN IDOWU

Any opinions, findings, conclusion or recommendation expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. Grant #: ***2017-68005-2686***

Guar Fertilization. SBAR Center of Excellence 4-page fact sheet. June 2021.

GUAR PLANT IN FLOWER
PHOTO: JOHN IDOWU

REFERENCES

> Liu, Y; Wu, L; Baddeley, J.A; Watson, C.A. **2011**. *Models of biological nitrogen fixation of legumes*. Sustainable Agriculture Volume 2, pp. 883-905.

LESSONS LEARNED

> From our trials, it appears that the yield of guar was not significantly affected by nitrogen and phosphorus fertilizers at most locations. The yield was improved in only one year in Las Cruces with the addition of phosphorus, while in Clovis the yield was improved one year by the addition of nitrogen.

> This trial suggests that guar would probably not need extra fertilizer inputs to grow well in New Mexico, but seasonal weather variation and different growing locations can affect yields.

> Another lesson learned is the need to plant as early as possible to avoid colder temperatures during the reproductive stage when the pods are actively forming.

> Although we have not seen a significant response to fertilization at most locations of our trials, it is still generally advisable for farmers to conduct a soil test before growing their crops, including guar. Soils vary across locations, and with soil testing, any nutrient deficiencies can be identified and promptly corrected.

AUTHORS

> **John Idowu**, Extension Agronomist, New Mexico State University, Las Cruces, NM
> **Darien Pruitt**, Graduate Student, Plant and Environmental Sciences, New Mexico State University, Las Cruces, NM
> **Sangu Angadi**, Crop Physiologist, New Mexico State University Clovis Agricultural Science Center, Clovis, NM
> **Robert Steiner**, Professor Applied Statistics, New Mexico State University, Las Cruces, NM

For more information: https://sbar.arizona.edu

Any opinions, findings, conclusion or recommendation expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. Grant #: ***2017-68005-2686***

Guar Fertilization. SBAR Center of Excellence 4-page fact sheet. June 2021.

SBAR

SUSTAINABLE BIOECONOMY FOR ARID REGIONS

Extension & Outreach Newsletter

June 2021; Volume 2, Issue 2

HIGHLIGHTS

NOTEWORTHY & NEWSY

Dr. Paul Gutierrez is Retiring

Happy trails to Dr. Paul Gutierrez, SBAR Sustainability Team and Extension Team Lead from New Mexico State University, Department of Agricultural Economics and Agricultural Business.

Read about Paul's many contributions on Page 2.

SBAR welcomes Dr. Maryfrances "Frannie" Miller to the Leadership Teams for the Economic Sustainability and the Extension - Youth Outreach initiatives, where she will take over for Dr. Gutierrez.

Check out these website updates!

Extension pages offer updated info on Guar and Guayule for producers

Education pages offer new lessons, learning activities, and teacher resources

Youth Outreach pages offer SBAR-themed Future Farmers of America lessons

New Videos offer updates on guar and bilingual professional interviews

Thank You & Best Wishes

Ali Yaylali - SBAR Education Fellow is a PhD candidate in Teaching, Learning and Sociocultural Studies at University of Arizona.

Darien Pruitt - SBAR Education Fellow earned an MS in Plant Sciences from New Mexico State University

Jacob Usrey - SBAR Education Fellow is earning an MS in Chemical Engineering at New Mexico State University

Felicia Hinton-Causey - SBAR Educator retired from teaching at the Santa Rosa Ranch School in Tohono O'odham Nation. Felecia piloted SBAR lessons in her classroom and helped adapt lessons for a Native American student base.

Traci Klein - SBAR Educator teaches at Valencia Middle School in Tucson, Arizona. Traci created and piloted SBAR lessons in her science classroom and participated with SBAR for three years.

Margaret Strand - SBAR Educator teaches at Camino Real Middle School in Las Cruces, New Mexico, where she taught SBAR content and piloted after school activities.

Welcome to the Extension Team

Oluwatobi Omotayo will begin work with SBAR Youth Outreach programming in Fall 2021 and contribute to the SBAR System Performance and Sustainability team. Oluwatobi is earning a Master of Science in Agricultural Economics from NMSU and aspires to help shape economic policy to improve agricultural competition and productivity for local growers.

Youth Outreach

Youth Leadership in Underrepresented Populations in STEM

SBAR Youth Development is helping put youth in leadership positions and helping create a platform for women in STEM, particularly Spanish speaking women in STEM.

Three newly trained Arizona 4-H STEM ambassadors, Ayrazan Hernandez, Laysha Gonzalez, and Pamela Salcido along with Santa Cruz County 4-H Program Coordinator Norma Elisa Ruiz from Nogales partnered with Dr. Laura Rodriguez-Uribe from New Mexico State University to record several video presentations. The videos feature Guar and Guayule, respectively, with content delivered in both English and Spanish. Youth STEM ambassadors were included on the recording so they could pose real world questions to Dr. Rodriguez-Uribe in both languages. Arizona 4-H's Dr. Nick Morris stated, "We recognized that SBAR research contains challenging vocabulary for any audience, and offering content in the native language of many youth from across Arizona and New Mexico makes this important work more accessible." He added, "this opportunity further supports equity by showing Youth and Adult Latino and Latina representation in STEM." After editing by grad student Oluwatobi Omotayo and Dr. Frannie Miller, both of NMSU, the videos will be available for viewing on the SBAR website.

~ Dr. Nicholas Morris reporting

SBAR Kits for Classrooms

Unpacking the Science of Bioeconomies

The combined Junior and Senior Future Farmers of America (FFA) members from Roy, New Mexico, unpacked their SBAR classroom kit filled with the equipment and supplies to support studying plant materials. These educational kits are provided by SBAR to support scientific exploration and opportunities in rural communities. The town of Roy certainly qualifies as rural, with a population of 188 people in town and only 441 people in all of Harding County. Two of the FFA students were winners in last year's New Mexico State Fair; one project focused on plastics in the environment and the other on cattails in livestock ponds.

We can't wait to see the science projects students develop this year, and we are glad to support their scientific prowess with kits to study the development of sustainable bio-economies in arid regions!

~Dr. Frannie Miller reporting

Photo credit to Becky Smith, science teacher and New Mexico FFA Board of Trustees Member.

Dr. Paul Gutierrez Retires

We wish Dr. Paul Gutierrez all the best in his retirement! Dr. Gutierrez is retiring from New Mexico State University, where he spent a lifetime developing unique extension programs that respond to the needs of diverse communities throughout the Western United States and into Mexico. He served in a variety of capacities, helping to shape and lead extension programs ranging from county-level experience up to Vice Provost.

Dr. Gutierrez is widely respected throughout the agricultural industry. He provided support to all styles of producer, from the smallest niche farmer of specialty crops to the largest historical ranches in the state. As a co-PI with SBAR, he worked on the Extension and Outreach team, the Research team and the Youth Development team. One of the SBAR principles is the dissemination of knowledge, which he conducted with charm and vigor. Dr. Gutierrez will be deeply missed as a mentor and teacher.

There is little doubt that Dr. Gutierrez will find plenty to do in retirement. He is an avid cyclist, he will have more time to work on his family's ranch near Gallup, and he is looking forward to more time with his grandkids.

~ Thanks to Dr. Frannie Miller for this farewell message

Fact Sheets

Read these Extension Publications

- ☐ GUAR FACT SHEET
- ☐ GUAR AS A ROTATION CROP
- ☐ GUAYULE FACT SHEET
- ☐ HISTORY OF GUAYULE FACT SHEET
- ☐ USDA PLANT GUIDE: GUAYULE

Website Updates

Updated content for Guar and Guayule

Grower Resources

Includes info from conferences, field days, and virtual events

Guar Content

Includes updated, research-based best practices for growers

Guayule Content

Includes updated, research-based best practices for growers

Guayule in Arizona

Expanding Guayule Production in Arizona

SBAR and Bridgestone Americas have been working with the Environmental Defense Fund (EDF) to generate new funding for the expansion of guayule production throughout Pinal County. Previous funding from EDF in 2018 led to a pilot project of a 40-acre guayule field in the Maricopa-Stanfield Irrigation and Drainage District. The project was instructive in terms of the commercial establishment and production of guayule and highlights the great potential of guayule for Arizona producers. While one field is a great start, it would be ideal to have several growers with small amounts of production spread throughout Pinal County, giving multiple growers some hands-on experience. This would establish local, trusted experience in every farming town where guayule could potentially be grown. SBAR hopes to develop such a network with the next step of expanding guayule production as early as spring of 2022. While we wait with high hopes for the next round of funding, Bridgestone and SBAR have been developing videos to explain the projects and the research on guayule in Arizona and New Mexico.

~ Blase Evancho reporting

Denotes SBAR or Bridgestone plot with guayule trials

Denotes NMSU Science Center with guar

Guar in New Mexico

Irrigation Trials Indicate Savings for Growers

The declining water availability in the Southern High Plains (SHP) is a primary concern for agriculture production in the region. It is crucial to adopt low water use crops like guar to sustain available water resources. Therefore, a three-year field experiment was conducted during 2018, 2019, and 2020 at the New Mexico State University Agricultural Science Center in Clovis, NM. The experiment design was a split block design with a split arrangement, where pre-irrigation and in-season growth-based irrigation treatments were strip factors and cultivars were split factors. Results showed that pre-irrigating guar improved the averaged final seed yield by 32% compared to plots that did not receive pre-irrigation. Also, withholding water during the vegetative growth stage saved 37% of water and still had a similar yield compared to plots that received irrigation throughout the crop season. Overall, the 'Kinman' cultivar that produces more branches outperformed the 'Monument' cultivar in all three years. Conclusively, farmers can save irrigation water by growing guar and skipping irrigation during the early growth stage.

~Jagdeep Singh reporting

In The Community

SBAR at the New Mexico State Fair

Two new contests will be open to youth participants of the Southern New Mexico State Fair: an Agricultural Science Fair and an Agricultural Public Speaking Contest.

Both contests feature a Sustainable Bioeconomy category that encourages students to research or advocate for the production and use of renewable biological resources. Entrants are directed to the SBAR website to find materials to help develop their research or their speeches on the topic.

Scholarships to New Mexico State University College of Agricultural, Consumer, and Environmental Sciences will be awarded to contest winners!

Contest registration deadline: Wednesday, September 1, 2021.

Contest date: Saturday, September 25, 2021.

~Contact Dr. Frannie Miller for info

Grower Field Days in New Mexico

Join the SBAR Extension Team at these field events! Learn about guar trials and best practices

August 3, 2021 - Clovis
August 18, 2021 - Los Lunas
August 25, 2021 - Las Cruces

Grower Field Day in Arizona

Join Bridgestone and SBAR Extension at the Bridgestone Guayule Research Farm to learn about guayule trials and best practices.

November TBD, 2021 - Eloy

Bilingual videos coming soon!

SBAR Education and Youth Outreach teams have been interviewing STEM professionals, farmers and other bioeconomy professionals . Teachers use these videos to highlight careers and pathways.

Many interviews are now available in Spanish, English and soon Spanglish!

Check out the ***SBAR Interviews with Bioeconomy Professionals videos*** HERE

SBAR Publications in the Pipeline

Science informs practice: Extension Specialists and Researchers are collaborating on the following publications for 2021/2022

> Guar Seed Rate Study

> Guar Nitrogen & Phosphorus Study

> Guar Germination Temperature Study - published

> Guayule Impacts on Central Arizona Agriculture

> Guayule Weed Control Study

> Guayule Yield by Variety Study

> Guayule Stand Density Study

SBAR at the Arid Lands International Conference

SBAR Research Fellow Oluwatobi "Tobi" Omotayo was lauded for his "lightning talk" at the International Arid Land Consortium Conference in May 2021. Tobi was one of only six graduate student presenters from the United States, Israel, and Jordan who made it to the final round of competition. His presentation featured a tool developed by the SBAR Sustainability and System Performance team, the BENCO model, and guar yield data collected by Dr. Sangamesh Angadi from the SBAR experimental plot in Clovis, New Mexico. Tobi's research talk, "Harnessing the environmental and economic potentials of gaur in the arid regions," was featured in the Water & Agriculture theme of the conference and was applauded for a job well done.

The Future of Water Sustainability in the Arid Southwest

Growers in the Southwest are feeling the burn from drought-related water restrictions, but there is hope. Guar and guayule can be part of the solution. Check out SBAR publications featuring innovative practices guided by research that can contribute to a healthy bioeconomy in the arid Southwest.

Educator Resources

DOWNLOAD AND USE SBAR-THEMED LESSONS, VIDEOS, AND RESOURCES IN YOUR CLASSROOM

Story Maps

Learn more about participating with SBAR through Story Maps!

SBAR - A Guayule & Guar Story

Orientation to the SBAR Educator Partnership

SBAR Classroom Connections: A Teacher's Story

Become an SBAR Education Partner [Use this sign up form]

Lesson Plans

Lesson Plans map to specific NGSS, New Mexico and Arizona state standards for science learning in grades 6 to 8.

Each lesson provides teacher presentations, student activities, worksheets, companion videos and other support materials.

Videos

A range of videos accompany and support Lesson Plans and can be used independently of SBAR lessons.

Interviews with Bioeconomy Professionals

SBAR After School and Summer Camps

Guar and Guayule Basics

And more

What Teachers Say...

Ten Science Teachers from Arizona and New Mexico have partnered with SBAR since 2018. Hear about their experience, what it's like to have an SBAR Graduate Student Fellow in the classroom, how seamless it is to incorporate SBAR-themed lessons into the curriculum, and how students love the learning activities. Watch Jaime Camero and Watch Melissa Wilburn

What Fellows Say...

Twelve Graduate Student Fellows from University of Arizona and New Mexico State University participated since 2018. Here are some of their favorite things!

Arisbeth: "I hadn't realized that cultural relevance was an important part of education. I can see now how important it can be… for students to feel included in the lessons in [order] to be interested and engaged in learning."

Darien: "The SBAR Fellowship experience has not only improved my ability to communicate difficult science topics but has also given me confidence when public speaking."

Jacob: "… science storytelling. I like relating with the [students] and hearing what they have to say, and if I can craft a story that draws the kids in and teaches them science, then that's an even bigger bonus."

Paramveer: "Communicating complex results in a simple language is an important skill for a scientist especially when you are engaged in Agricultural extension."

Karina: "Students must be given space to think, to write, and above all to ask questions. Thinking of a story or local problem to address a topic… helps students to become more interested. It helps them connect the issue with a larger situation."

Ali: "I will use this experience to develop literacy materials suitable for young learners so that they can develop their science writing abilities …"

Tenzin: "The SBAR Education fellowship helped me understand the importance of environmental outreach programs and their impact in educating the next generation. Also the SBAR community is the best!"

Guardians of the Biosphere
After School Clubs

Coming soon! Create a "GOB" club at your school with content by SBAR 4-H.
GOB was initiated by New Mexico science educators Cathy Bradley and Tracie Mikesell.

Watch a GOB student-created video **HERE**

Educators Join SBAR today! Fill out an Interest Form HERE

COMING SOON!

Recruiting: Growers

SBAR is seeking growers for trial plots

Available Fall 2021

Contact: John Idowu for guar in New Mexico

Contact: Blase Evancho for guayule in Arizona

Recruiting: Educators

SBAR is seeking educators for virtual partnership

Available Fall 2021

Contact: Catie Brewer (NM)

Contact: Corey Knox (AZ)

Recruiting: 4-H Volunteers

SBAR is seeking community members as 4-H volunteers

Available Fall 2021

Contact: Frannie Miller (NM)
Contact: Nick Morris (AZ)

SBAR Plant Guide on Guar

Available Fall 2021

Contact: John Idowu

SBAR Agronomics on Guayule

Available Summer 2022

Contact: Blase Evancho

SBAR Whole Farm Analysis Tool

for Evaluating the Adoption of Guayule and Guar into Your Current Operation

Available Fall 2021

Contact: Trent Teegerstrom

Contact Our Team

Education

Catie Brewer - New Mexico
cbrewer@nmsu.edu

Corey Knox - Arizona
cknox@arizona.edu

Extension

Guar - New Mexico
John Idowu
jidowu@nmsu.edu

Guayule - Arizona
Blase Evancho
bee1@arizona.edu

Youth Outreach

Nick Morris - Arizona
4-H Contact
nmorris6@arizona.edu

Frannie Miller - New Mexico
4-H Contact
franniem@nmsu.edu

Natalie Brassill - Arizona
Internship Contact
nbrassill1@arizona.edu

Sustainability

Trent Teegerstrom - Arizona
tteegers@arizona.edu

We would love to hear from you! Contact our team directly at the email provided.

Check out the SBAR website for more information about the program, research and resources: https://sbar.arizona.edu

Any opinions, findings, conclusions or recommendations expressed in this publication/work are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.
Grant #: 2017-68005-26867

SBAR SUSTAINABLE BIOECONOMY FOR ARID REGIONS

ARIZONA

NM STATE UNIVERSITY

Colorado State University

THE UNIVERSITY OF ARIZONA COLLEGE OF AGRICULTURE & LIFE SCIENCES Cooperative Extension

BRIDGESTONE

USDA United States Department of Agriculture National Institute of Food and Agriculture

USDA ARS Agricultural Research Service

COLORADO SCHOOL OF MINES EARTH • ENERGY & ENVIRONMENT

NM STATE College of ACES/CES

SUSTAINABLE BIOECONOMY
FOR ARID REGIONS

RESEARCH

Researchers, farmers, and industry representatives are partnering to explore the ecological, social, and economic sustainability of alternative crops for the arid regions of Arizona and New Mexico.

Guar is studied due to the multiple bioproducts it provides. If these bioproducts can be processed, marketed, and utilized, guar can contribute to a more sustainable bioeconomy in arid regions.

GUAR NATURAL HISTORY

Guar is a desert-adapted annual crop mainly grown in India and Pakistan. Guar was introduced into the United States in 1903 and has been commercially grown in Texas and southwestern Oklahoma for more than a century.

DID YOU KNOW?

GUAR GUM

- A sugar derived from the guar seed
- Improves texture and shelf life of baked goods
- A food thickener in dairy products
- A binder, preservative, and lubricating agent in meat products
- Due to the viscosity of guar gum in water, it is used in hydraulic fracturing to extract oil and natural gas from the subsurface rocks.

GUAR MEAL

- The germ and husk left over after the guar gum is extracted from the seed
- A concentrated protein source in animal feed
- A binding agent for pelletizing animal feed

GUAR HARVEST RESIDUE

- Is left in the field for soil health improvement

ANY OPINIONS, FINDINGS, CONCLUSIONS, OR RECOMMENDATIONS EXPRESSED IN THIS PUBLICATION ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEW OF THE U.S. DEPARTMENT OF AGRICULTURE. GRANT # 2017-68005-26867.

GUAYULE

GROW...

GROW 2 YEARS

HARVEST

REGROW FROM ROOTSTALK

HARVEST

REGROW FROM ROOTSTALK

HARVEST

GRIND INTO WOOD PULP (BAGASSE)

PROCESS...

CHEMICALLY EXTRACT NATURAL RUBBER & RESIN

COMMERCIAL PRODUCTS...

3% NATURAL RUBBER

7% RESIN

- INSECTICIDES
- ADHESIVES

90% BAGASSE

- FIBERBOARD
- WOOD PELLETS
- BURN FOR FUEL

SBAR

SUSTAINABLE BIOECONOMY FOR ARID REGIONS

WWW.SBAR.ARIZONA.EDU

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. Grant # 2017-68005-26867.

GUAYULE: POTENTIAL BENEFITS

LEARN MORE

- "Colorado River Shortage Fact Sheet" – Central Arizona Project https://www.cap-az.com/documents/departments/planning/colorado-river-programs/CAP-FactSheet-CoRiverShortage-041921.pdf

IRRIGATION WATER SITUATION – CENTRAL ARIZONA

> Declining water availability for agriculture in the southwestern United States necessitates new strategies to sustain rural economies. High-value crops that are drought and heat tolerant, grow on marginal lands, and that provide economic returns are crucial to the farming industry. Guayule (*Parthenium argentatum*) is a crop that meets these demands and could potentially meet the economic requirements as well.

> Central Arizona agricultural users face major water cutbacks under Tier 1 shortages expected in the coming years from the Central Arizona Project (CAP), triggered by Lake Mead's dropping water levels. Surface water losses will be offset somewhat by an increase in groundwater pumping, but agricultural production cannot be sustained without major changes to crop production.

CURRENT CROP PRODUCTION

> Currently, Central Arizona field crop production is comprised of forage crops and cotton (USDA NASS 2017). These crops require a wide range of irrigation water application from ~3.5 to 6 acre feet of irrigation water (Erie, et al. 1981).

> Many factors determine where certain crops are grown, but guayule could potentially replace some at-risk acres if its products reach the economic potential of cotton or alfalfa. Although still being studied, the anticipated maximum irrigation requirement for guayule is ~4 acre feet/year.

GUAYULE'S FUTURE POTENTIAL

- Native, desert-adapted shrub
- Requires less water than current crops
- Co-products will determine its full value
- Low requirement for herbicide application

GUAYULE'S POTENTIAL

> Since guayule is a native, desert-adapted shrub, it could potentially require less water than anticipated to produce a viable and economic crop. It will certainly require less water than other field crops currently being grown.

> The true potential for this crop will be based in the value of its products: rubber and resin. While rubber is a high-demand commodity throughout the world, guayule resin does not yet have a market.

> Guayule resin is currently being researched for several commercial products and is expected to be a high-value component co-product of guayule production.

REFERENCES

Erie, L.J.; French, O.F.; Bucks, D.A.; Harris, K. 1981. Consumptive Use of Water by Major Crops in the Southwestern United States. United States Department of Agriculture, Conservation Research Report No. 29.

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA NASS). 2019. 2017 Census of Agriculture: Arizona State and County Summary Highlights, Volume 1, Chapter 2, Table 1.

For more information: https://sbar.arizona.edu

Any opinions, findings, conclusion or recommendation expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. Grant #: ***2017-68005-2686***

Evancho, B. and Hullinger, A. 2021. Guayule: Potential Benefits. SBAR two-page information sheet. August.