



SUSTAINABLE BIOECONOMY FOR ARID REGIONS (SBAR)

Summary Report – Quarter 4, 2021

Information submitted by project partners; synthesized by:
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USDA Cover Page

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

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ACCOMPLISHMENTS

October 2021 – December 2021

INTRODUCTION AND MANAGEMENT

General Overview: Organization

The Sustainable Bio-economy for Arid Regions (SBAR) Center of Excellence has completed the fourth calendar year of activity 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 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 is scheduled to be implemented in 2022.

Advisory Board

The proprietary research requires executed non-disclosure agreements (NDA) from all participants. As of August 2021, ten Advisors remain actively engaged in the on-going research, and no future changes to the Advisory Board makeup are anticipated for the duration of the work (Table 1).

Table 1. SBAR Advisory Board members.

Advisory Board Member	Company/ Representation	Year Joined Board
Chris Cassidy	USDA, Rural Development	2018
Steve Csonka	Commercial Aviation Alternative Fuels Initiative (CAAFI)	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
Jaroy Moore	Texas A&M Agrilife Research & Extension Center	2017
Alex Muravijov	Guar Resources	2017
Paul "Paco" Ollerton	Tierra Verde Farms, AZ	2019
Ron Shaffer	Bridgestone Americas, Inc.	2021
Bob White	Bridgestone Americas, Inc.	2017

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 these meetings is to ensure that SBAR can remain agile in addressing changing priorities and circumstances.

The Advisory Board met virtually on Friday, 12 November. During the meeting, the Advisory Board discussed the outcomes of the Natural Rubber Symposium (hosted in Washington DC) and possible priorities for requesting a no-cost extension to allow the SBAR Team an opportunity to fully address research questions and complete pending publications. The next Advisory Board meeting will be scheduled in February 2022 to ensure that the final research and outcomes remain on track. It is anticipated that an additional 2 Advisory Board meetings will be held in 2022.

Budget and Financial Management

No budget issues occurred during the last quarter. 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.

As of the end of August 2021, Colorado School of Mines (CSM) completed their portion of the project and the subaward closeout is in process. All other sub-awards remain fully activated with project partner institutions: Bridgestone Americas, Inc., New Mexico State University (NMSU), 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 this quarter's reporting period, the virtual meeting space (via Zoom) was utilized 54 times for over 55 hours. The total number of participants during this quarter showed a slight decrease in participation rate for all working group meetings (n=381) as compared with previous quarters. November showed an upward tick in participation as compared with participation numbers in October and December. December participation levels dropped, which is partially attributed to the end of the year semester wind-down and breaks.

Many component working group meetings have shifted from twice-monthly to a once-monthly meeting cadence as research and other work is closer to conclusion.

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 fourth quarter, the LEADS finalized a library of SBAR Briefing Papers, reviewed and approved a new irrigation experiment plan for 2022, prioritized SBAR products for translation to Spanish, and reviewed/discussed project progress toward overall research goals and objectives to ensure continued and effective progress.

SBAR Annual Retreat

The 2022 SBAR Annual Retreat is being planned for July 2022, and will be hosted by Colorado State University in Fort Collins, Colorado. We expect that this will be the final Retreat for the SBAR Team. More information will be shared in future reports as details are finalized and become available.

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. Regular updates and general maintenance occur as needed, including highlights for specific activities or announcements of events, etc.

The SBAR webpage was visited by people in 43 different states of the USA during this 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.

State	Time Period						
	Jul – Dec 2018	Jan – Dec 2019	Jan – Dec 2020	Jan – Mar 2021	Apr – Jun 2021	Jul – Sep 2021	Oct – Dec 2021
Alabama			X	X	X	X	X
Alaska			X				
Arizona	X	X	X	X	X	X	X
Arkansas		X	X	X		X	X
California	X	X	X	X	X	X	X
Colorado	X	X	X	X	X	X	X
Connecticut			X				X
Delaware		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	Oct – Dec 2021
District of Columbia	X	X	X	X	X	X	X
Florida		X	X	X	X	X	X
Georgia		X	X	X	X	X	X
Hawaii			X	X	X	X	X
Idaho		X	X	X		X	X
Illinois	X	X	X	X	X	X	X
Indiana		X	X	X		X	X
Iowa	X	X	X	X	X	X	X
Kansas	X	X	X	X	X	X	X
Kentucky		X	X	X	X		
Louisiana			X		X		X
Maine			X			X	
Maryland	X	X	X	X	X	X	X
Massachusetts		X	X	X	X	X	X
Michigan		X	X	X	X	X	X
Minnesota		X	X	X	X	X	X
Mississippi		X	X	X	X	X	X
Missouri		X	X	X	X	X	
Montana		X	X	X		X	X
Nebraska		X	X	X		X	X
Nevada		X	X	X	X	X	X
New Hampshire			X				X
New Jersey			X	X	X	X	X
New Mexico	X	X	X	X	X	X	X
New York	X	X	X	X	X		X
North Carolina	X	X	X	X	X	X	X
North Dakota		X	X			X	
Ohio		X	X	X	X	X	X
Oklahoma		X	X	X	X	X	
Oregon		X	X	X	X	X	X
Pennsylvania		X	X	X	X	X	X
Rhode Island			X				
South Carolina	X	X	X	X	X	X	X
South Dakota		X	X			X	X
Tennessee	X	X	X	X	X	X	X
Texas	X	X	X	X	X	X	X
Utah		X	X	X	X	X	X
Vermont				X			
Virginia		X	X	X	X	X	X
Washington	X	X	X	X	X	X	X
West Virginia		X					X
Wisconsin		X	X		X	X	X
Wyoming		X	X	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	Oct – Dec 2021
Total	15	41	49	41	36	41	43

There were 1,226 unique sessions from October – December 2021. During this quarter, page views occurred in 36 different countries (top three: USA, India, and Canada), including 2 countries that have not visited the website previously (Botswana and Slovakia). Visitors from the USA accounted for 84% of site visits during this reporting period, which was an increase from the previous quarter. Site visits this period also showed a high interest from India, Canada, China, United Kingdom, Mexico, and Brazil, which accounted for another 8% of site visits overall.

There have been 15,523 unique website sessions since July 2018. Since activation, the website has had visitors from 6 continents and 92 different countries around the world (Table 3). The highest visited website pages during this reporting period included those associated with the briefing papers that were released in October, those associated with digital lessons and educational resources, those that describe our team and partnerships, and those that showcase ongoing research for feedstock development and production. Other highly visited pages included those highlighting news releases and the youth opportunities (internship programs). 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	Oct – Dec 2021
Afghanistan				X			
Algeria			X		X		
Argentina		X	X	X	X		
Australia	X	X	X	X		X	X
Austria	X	X	X	X	X		X
Bahrain			X				
Bangladesh		X	X	X	X	X	X
Belgium		X	X		X	X	X
Belize			X			X	
Bolivia			X			X	
Botswana							X
Brazil		X	X	X	X	X	X
Cameroon			X				
Canada	X	X	X	X	X	X	X
Chile		X	X		X		
China	X	X	X	X	X	X	X
Colombia		X	X	X		X	X
Congo-Kinshasa		X					
Costa Rica				X			
Côte d'Ivoire		X	X				

Country	Time Period						
	Jul – Dec 2018	Jan – Dec 2019	Jan – Dec 2020	Jan – Mar 2021	Apr – Jun 2021	Jul – Sep 2021	Oct – Dec 2021
Cyprus		X					
Denmark			X		X		X
Ecuador			X			X	
Egypt	X				X		X
Estonia		X					
Ethiopia	X		X				
Finland			X	X	X	X	X
France		X	X	X	X	X	X
Germany	X	X	X	X	X	X	X
Ghana		X	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	X	X
Indonesia		X	X			X	
Iran	X	X	X	X	X	X	X
Iraq			X				X
Ireland		X		X		X	X
Israel		X		X	X		
Italy	X	X	X	X	X	X	
Japan	X	X	X	X	X		X
Jordan			X	X			
Kenya		X	X		X		X
Kuwait	X	X	X				
Lebanon		X					
Libya			X				
Lithuania						X	
Malaysia		X	X	X		X	X
Mexico	X	X	X	X	X	X	X
Morocco		X					
Namibia		X					
Nepal	X	X	X	X			
Netherlands		X	X	X	X	X	X
New Zealand	X		X			X	
Nigeria		X	X	X	X	X	X
Norway			X	X			
Oman			X				
Pakistan	X	X	X	X	X	X	X
Papua New Guinea				X			
Paraguay		X					
Peru		X					
Philippines	X	X	X	X	X	X	X
Poland		X	X				

Country	Time Period						
	Jul – Dec 2018	Jan – Dec 2019	Jan – Dec 2020	Jan – Mar 2021	Apr – Jun 2021	Jul – Sep 2021	Oct – Dec 2021
Portugal		X					
Puerto Rico			X	X			
Qatar		X	X				
Romania			X				
Russia		X		X		X	
Saudi Arabia		X	X	X			X
Serbia			X	X	X	X	
Singapore		X	X		X	X	
Slovakia							X
South Africa		X			X	X	X
South Korea		X	X	X			
Spain		X	X	X	X	X	X
Sri Lanka		X		X			
Sweden		X	X				
Switzerland			X		X	X	X
Taiwan		X					
Thailand	X	X	X		X	X	
Tunisia			X				
Turkey	X	X	X	X	X		X
Uganda			X				
Ukraine		X					X
United Arab Emirates		X			X		
United Kingdom	X	X	X	X	X	X	X
United States	X	X	X	X	X	X	X
Vietnam		X	X		X		
Zambia		X					
Zimbabwe						X	
Total	22	60	65	43	39	36	36

FEEDSTOCK DEVELOPMENT & PRODUCTION

Project Coordination: The Feedstock Development (FD) Team holds a single 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. 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: Significant progress is made in getting manuscript out of deficit irrigation trial. First draft of manuscript on guar biomass and seed yield production in response to different deficit irrigation management strategies will be submitted for publication in a couple of months. The second manuscript on water extraction patterns and water use efficiencies under deficit irrigation management strategies will be ready for review in two weeks. Hoping to submit both before field season starts in the summer.

We are also hoping to start trial assessing temperature requirements for germination and early growth of USDA germplasm after we complete other research work. There is less interest in this work. Instead, we started a new irrigation and fertility trial with two different focuses: one on growth and yield formation, and the second on forage production and quality.

Dierig: We have experienced more rain than usual during the second season of growth.

Grover: Funding situation has been uncertain and insufficient for hiring students and staff affecting the overall progress.

McCloskey: The failure of the fall 2021 planting at MAC is a setback and means that there will be a delay in collecting a second set of post-directed herbicide tolerance data until summer 2022. We will attempt to plant guayule at MAC in spring 2022 to collect this data. We will be able to collect more post-directed herbicide data on a clay loam at Bridgestone's Eloy farm by the end of the second quarter of 2022. Contemplating the numerous planting failures we have suffered through over the course of the last four plus years, I would estimate that we have been delayed a year or more on various aspects of weed management in guayule. There is no real way to mitigate this impact other than continuing the research. (Time extension)

McMahan: Starting January 13, 2022, our USDA-ARS-WRRC laboratory access was returned to Essential/25% workforce access only. Plant maintenance will continue, along with some genotype/phenotype evaluations, but data needed to draft the SEP3 manuscript (milestone #3) is likely delayed.

Neilson: The Year 5 SOW represents a revision of the research timeline that takes into consideration all delays associated with COVID restrictions. All research is on schedule with two exceptions: (1) The manuscript draft for the Winter Dormancy study is still in preparation. A draft of this manuscript is projected to be completed by March 2022. (2) Chemical analysis of field soils collected in 2020 is still in progress. The analysis is projected to be completed by March 2022.

Waller: We are delayed in completing edits and resubmitting the WINDS papers in a timely fashion.

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	Harvest/Analysis of first growth cycle completed	30 Apr 22
2 McMah	Complete first set of phenotyping results for soil grown SEP3i plants	Dataset in charts and tables	30 Sep 21
3 McMah	Analyze rubber and resin data for FT2	Dataset in charts and tables	31 Dec 21
4 McMah	Publish results	Draft manuscript on SEP3i downregulation in guayule	30 Mar 22
5 Ray	Evaluate growth and rubber/resin content in guayule germplasm lines	Rubber/resin content determined in 21 guayule germplasm lines	30 Apr 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.

A manuscript is under preparation for the plant density on yield in two guayule lines at two different locations.

Complete first set of phenotyping results for soil grown SEP3i plants:

Flowering downregulation to increase yield:

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: Flowering Terminus (*FT2*), Sepallata (*SEP3*), and *LEAFY*.



Photo 1. Plant density study in Eloy, Arizona.

Flowering Terminus-2 (FT2):

In growth chamber evaluations, transgenic guayule plants with downregulated *FT2* had a similar number of flowers to empty vector (yellow) and wildtype (green) plants. Recall, this contrasts with results from plants with downregulated *SEP3i* which showed fewer flowers. This dataset from 3Q21 can be compared to the rubber and resin analysis.

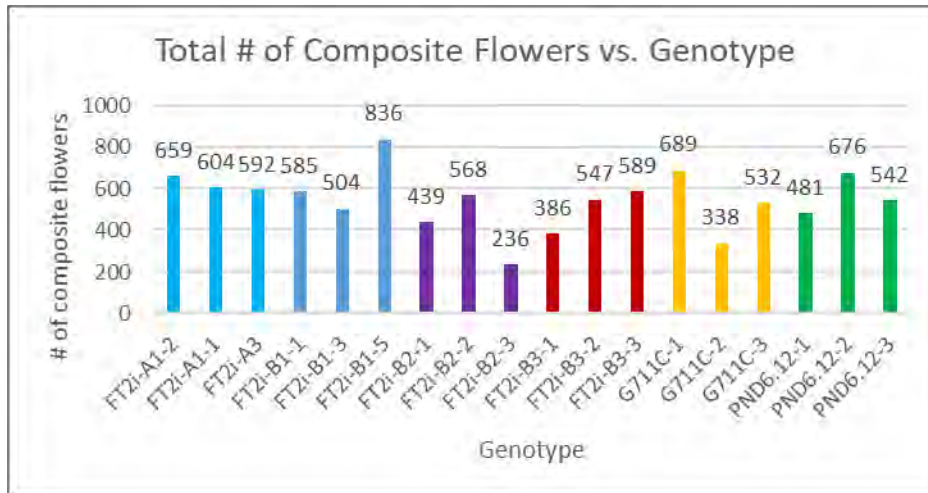


Figure 1. Total number of flowers for FT2 transgenics and controls.

Analyze Rubber and Resin Data for FT2:

Quantification of % rubber and resin for the FT2 plants was performed by Accelerated Solvent Extraction. The amount of rubber in young stem and root tissues was ~0.3-1%, comparable to previous experiments. Replicates FT2i-B1-5 and FT2i-B2-2 had significantly more rubber in the stembark extraction vs. controls (green).

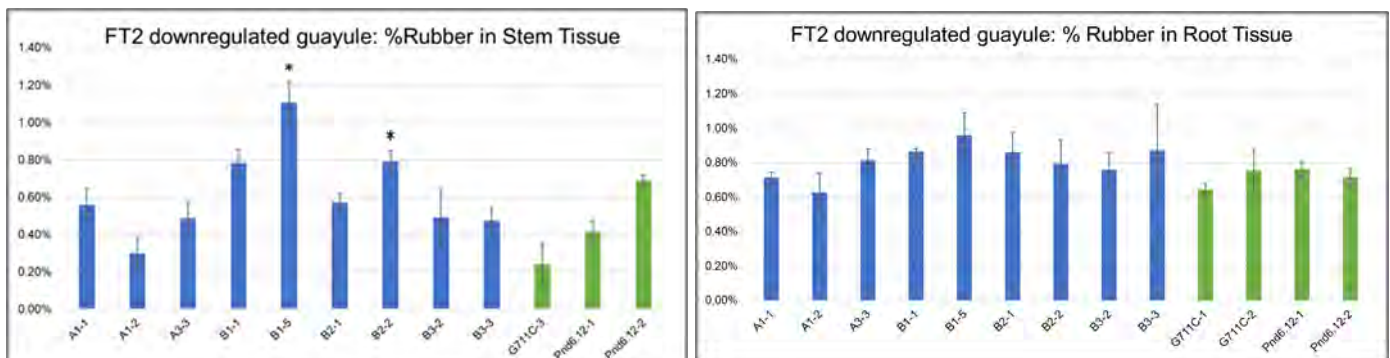


Figure 2. Rubber (wt%) phenotype for guayule plants with downregulated FT2.

Plants were transferred from tissue culture to soil, hardened in the greenhouse, then subjected to 30 days with 25C days/10C nights. Replicate testing for independent lines FT2iA and FT2iB and controls.

Resin concentration ranged from ~3-6% for the young guayule tissues, and extraction percentages consistently have smaller standard deviations compared to those for rubber. In some cases, there are significant differences in % resin between wild-type G711C/pND6 vector controls to the transgenics seen especially in the “B” series of extractions. Data analysis continues for this series.

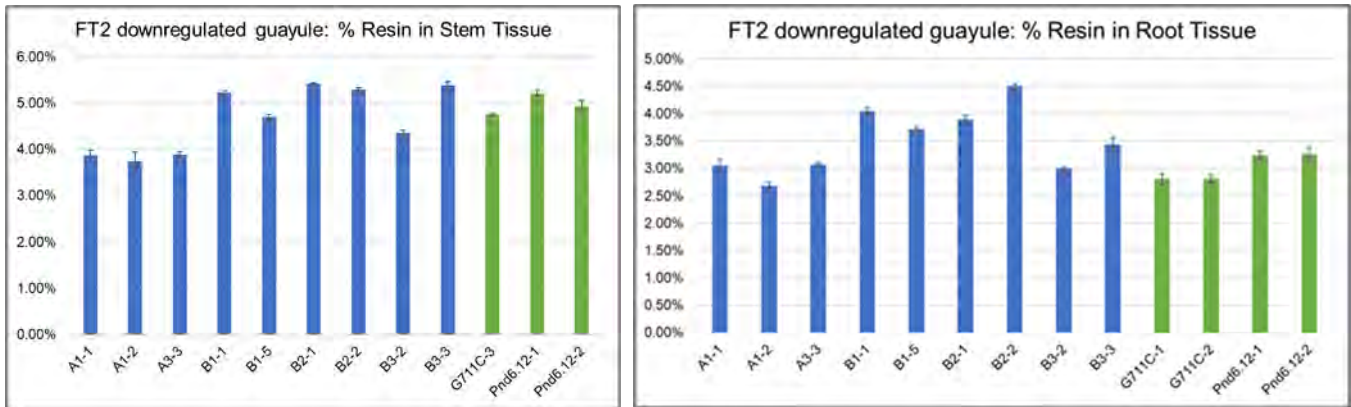


Figure 3. Resin (wt%) phenotype for guayule plants with downregulated FT2.

Plants were transferred from tissue culture to soil, hardened in the greenhouse, then subjected to 30 days with 25C days/10C nights. Replicate testing for independent lines FT2iA and FT2iB and controls.

Genotypes/phenotypes will continue to be characterized for SEP3i and FT2i lines in preparation for publication. Examination of gene expression may yield more insight as to why the flowering phenotype was observed for SEP3i but not FT2i lines.

LEAFY:

Subcultures of LFY putative transformants did not produce roots in selection media (K10). Thus, we have concluded that the plants are non-transformed escapes.

Publish Results:

Data needed to draft the SEP3 manuscript is likely delayed due to limited access to the laboratory (COVID response).



Photo 2. Developing guayule flowers.

Growth and Rubber/Resin Content in Guayule Germplasm Lines:

Resin and rubber analyses are completed; statistical analyses are ongoing.

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	Summary report completed: plant growth, rubber, resin	31 Aug 22
		Summary report completed: HTP collected parameters	31 Aug 22

Phenotypic characterization – Guayule:

An experiment with 60 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. The interactions of irrigation levels by genotypes are being recorded. Differential irrigation schedules were started at stress and no-stress treatments. At both trials, plots are maintained by hand weeding as needed. Plants are dormant, field and data collection will resume in spring.

Data is being summarized and organized for publication.

In general, drought stress conditions reduced 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.

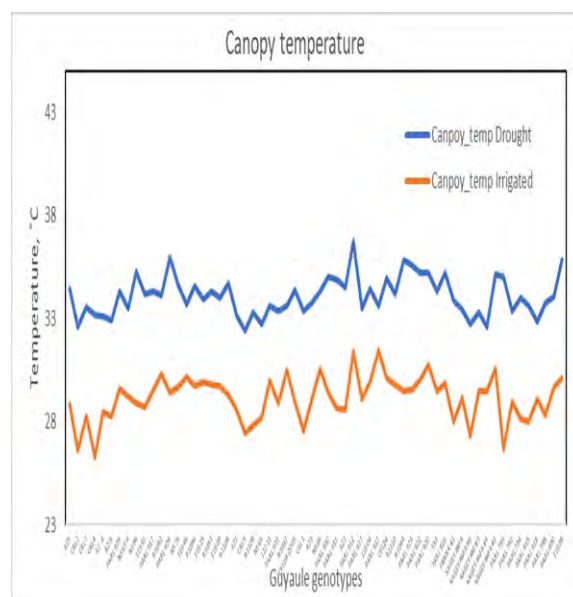


Figure 4. Differential response of guayule genotypes to drought stress at Maricopa, as determined by fresh weight of one-year old plants.

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	Report on guar germplasm germination temperature requirements/variability	31 May 22
2 Ray	Guayule salt tolerance trials	Screen new germplasm lines with most tolerance	31 Jul 22
		Surviving plants transplanted to field to increase seed	30 Apr 22
		Seed from surviving plants collected and planted for 2 nd round of selection	31 Aug 22

Guar Germplasm in New Mexico:

Research on next stage of assessing temperature requirements for germination and early growth to assess USDA germplasm as well as diverse breeding lines has been delayed. The loss of local market has affected interest in guar. We will complete all research work that was committed and will start the new work after that.

Guayule Salt Tolerance Trials:

Research is ongoing; nothing new to report.

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	30 Jun 22
		Present data at regional and national conferences	30 Nov 21
2 Angadi	Guar irrigation and fertility management trial	Report on optimum irrigation management and fertility management strategies	31 Aug 22
3 Dierig	Bi-monthly harvest from irrigation trials	Growth data over seasons from two locations	31 May 22
4 Dierig	Irrigation Timing Study	Plant replicated trial and begin treatments	31 Aug 21
5 Grover	Evaluate guar germplasm lines for field performance	Summarize results from Las Cruces location for manuscript.	31 Dec 21
		Coauthor manuscript "Performance of guar genotypes in multi-year and multi-location yield tests"	30 Jun 22
		Submit and revise manuscript	31 Aug 22
6 Grover	Evaluate guar response for salinity tolerance	Complete high-throughput illumine sequencing analysis on leaf and root tissues under control and salinity	31 Dec 21
		Validate RNA sequencing results using quantitative reverse transcription (PCR)	30 Jun 22
		Develop/submit manuscript	31 Aug 22
7 Grover	Evaluate guar response to planting density	Compile data/results from 2018-2020 study	31 Dec 21
		Generate manuscript from results obtained	31 Aug 22
8 McClos	Conduct guayule herbicide tolerance study, at Eloy and Maricopa, AZ (Fall)	Collect data to support 24c SLN herbicide registrations – study sequences of herbicide applications and tillage operations to control weeds until guayule canopy closure	31 Aug 22
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) herbicide application sequence for chemical weed control from	31 Aug 22

		seeding to 6mo old plants; (c) evaluate topical, postemergence broadleaf herbicide	
10 McClos	Generate manuscripts and Extension bulletins	Research reports and manuscripts complete	31 Dec 21
		Extension bulletin and 24c SLN ADA application complete	31 Aug 22
11 Ogden	Development and testing of AquaCrop model	Develop/Submit manuscript	31 Dec 20
12 Ray	Range of N and P application	Compare N and P utilization and effects of nutrients on biomass, rubber and resin production	31 May 22
13 Waller	Monitor TDR, infrared camera and flowmeter system	Develop tools for irrigation management	30 Nov 22
14 Waller	Integrate WINDS model with existing tools	Integrate new model with WINDS (winds.arizona.edu), and in-situ sensors	31 Aug 22
15 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	31 Aug 22
		Develop automated calibration system for WINDS	31 Aug 22

Guar Critical Stage-Based Deficit Irrigation Trial:

Overall, 2021 had good weather conditions during the season for guar research. Harvesting has been completed on time and processing field samples is near completion. We made good progress with manuscript writing from guar pre-irrigation and critical stage-based deficit irrigation trial.

The first manuscript written by former graduate student, J. Singh, was reviewed and he is now working on edits. It will be submitted to journal for review once co-authors approve. J. Singh is working on the second manuscript and is expected to submit in a week. We presented results from the trial in two separate conferences. A poster was presented in ASA-CSSA-SSSA annual meeting, while an invited talk summarizing irrigation responses of diverse crops in the region was presented in a Canadian webinar series



Photo 3. Part of a guar plot in the pre-irrigation and stage-based deficit irrigation trial, Clovis, New Mexico.

We have ground all forage samples and are working on yield components. The trial will be repeated in 2022. Dr. Idowu's new plant population demonstration study was harvested and yield samples from Clovis and Tucumcari were threshed at Clovis.



Photo 4. Dr. John Idowu's guar harvesting team, Clovis, New Mexico.

Guar Irrigation and Fertility Management Trial:

Currently, guar production is primarily located in parts of Texas in the US, but expanding the area north and west into cooler regions of the southern High Plains will reduce market volatility. Previous studies have shown that different cultivars of guar exhibit unique qualities that increase crop yield in different climatic situations. Studies have also looked at how guar performs in different water and irrigation stresses. Consequently, this study looks at how diverse guar cultivars improve nutrient use efficiency at higher fertility levels if water was applied during pre-season or in season irrigation applications.

Objectives:

- 1) To assess growth, biomass production and yield formation by diverse guar cultivars under different nutrient levels and different irrigation strategies.
- 2) To study water extraction patterns of guar cultivars under a range of nutrient and irrigation levels.

Preliminary analysis of first year are showing significant effect of irrigation, fertilization on seasonal biomass production and seed yield while cultivar differences were less significant.

Table 4. Preliminary results of above-ground biomass and seed yield of guar under two irrigation treatments, four fertility treatments, and three guar cultivars in 2021. Biomass was taken roughly every 3 weeks and shown as days after planting (DAP).

Treatments	Biomass 1 44 DAP (kg/ha)	Biomass 2 63 DAP (kg/ha)	Biomass 3 84 DAP (kg/ha)	Biomass 4 107 DAP (kg/ha)	Biomass 5 140 DAP (kg/ha)	Seed Yield Harvest (lbs/ac)
Irrigation						
Pre-irrigation (PI)	317 a	3601 a	4100 b	4670 b	4237 b	1632 b
In season irrigation (NPI)	371 a	3646 a	5522 a	6011 a	5687 a	2163 a
LSD	58	421	440	380	274	130
Fertilization						
0 NPK	358 a	3356 b	4478 a	4923 b	4524 b	1687 b
20 NPK	304 a	3302 b	4698 a	5238 ab	5076 a	1956 a

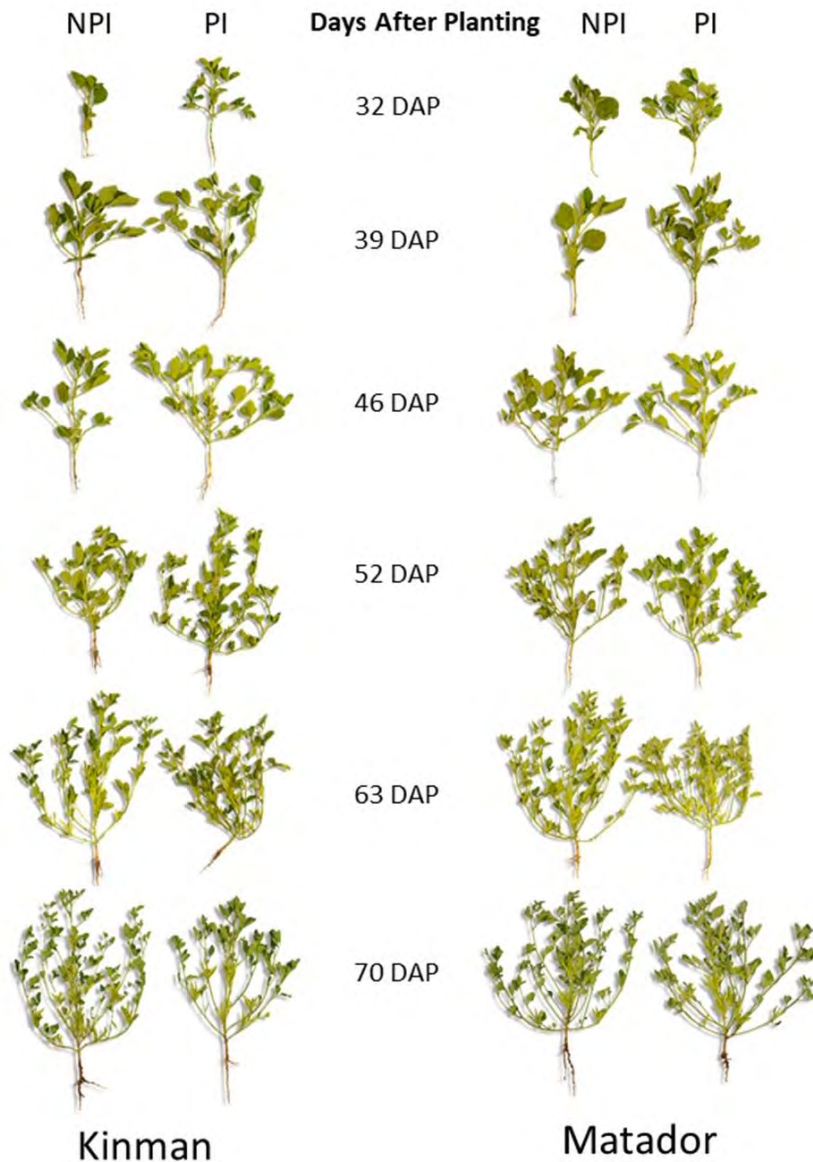
40 NPK	335 a	4115 a	5011 a	5598 a	5104 a	1957 a
60 NPK	378 a	3721 ab	5058 a	5602 a	5143 b	1989 a
LSD	82	595	622	536	388	184
Cultivar						
Kinman	346 ab	3923 a	4858 a	5347 ab	4934 ab	1829 a
Matador	301 b	3297 b	4961 a	5686 a	5157 a	1977 a
Judd 66	385 a	3650 ab	4615 a	4988 b	4794 b	1886 a
LSD	71	516	539	465	336	160

Above-ground biomass was affected by irrigation treatments. Early in the season, when guar plants were small, guar growth was similar whether it received water through in-season irrigation or by water extraction from the soil from pre-season irrigation. During two weeks of June and July, Clovis received a total of 7.10 inches of rain. Which made it difficult to compare irrigation treatments due to the fact that both treatments received a large amount of rainfall in a short amount of time. However, at later stages by 84 days after planting, soil water from pre-season irrigation was not sufficient and guar from in-season irrigation produced more biomass than the other treatments. Guar plants were larger, flowering was initiated and pod development was in progress at that time, which needed extra water resources to support that growth and development. Small pre-irrigation of 5 inches was not sufficient to support it. However, with significant differences in the later growth stages, it suggests that spaced out irrigation treatments increase the production of guar. Similarly, seed yield also showed significant differences among irrigation treatments. Pre-irrigation (PI) had considerably lower seed yield than NPI.

When looking at fertilization treatments, generally, as fertilization increased, biomass also increased but very slightly. Statistically speaking, we are seeing significant differences between no fertilizer (0 NPK) and with fertilizer during most biomass harvests. However, there is no significant difference in the above-ground biomass between the three treatments using fertilizer (20 NPK, 40 NPK, and 60 NPK). We see this in seed yield as well. No fertilizer treatment is significantly lower than other fertilizer treatments, regardless of how much was added. This again suggests that guar is a low input crop that rarely responds to higher inputs. This suggests that if the production is the same with 20 NPK and 60 NPK, in order to save money and

fertilizer, treatment can be held to 20 NPK. However, further replications and/or experiments need to be performed in order to fully understand this theory.

The three cultivars, Kinman, Matador, and Judd66, showed very little differences in both above-ground biomass and seed yield. Judd66 variety had the greatest biomass after 44 days while Kinman variety had the greatest biomass after 63 days, and Matador had the highest biomass after 84, 107, and 140 days. This may indicate different varieties grow more or less at different stages of their life cycle. For instance, Judd66 may be more successful during the early growth stages, while Kinman grows best during mid-growth phases, and Matador grows the most in the later stages. Such findings may suggest when is the best time of the growing season to irrigate or fertilize these three varieties. Matador had the highest seed yield but this was not significant among the other cultivars.



To assess seasonal biomass production under different treatments in guar irrigation and fertility management trial, we harvested biomass samples for five times. Three of those were at different pod filling stages, which will be used for forage analysis in collaboration with Dr. Miller. Her interest is to assess guar as a low input forage crop. Observations focused on biomass, yield formation and soil water use patterns in response to irrigation and fertility treatments.

Figure 5. Seasonal response of two cultivars of guar (Kinman and Matador) to pre-season irrigation (PI) and in-season irrigation (NPI) treatments during 2021 field season at Clovis, New Mexico.

Bi-Monthly Harvest from Irrigation Trials:

A new publication focused on the seasonal growth and yield response of guayule to irrigation has been released.



Photo 5. Stress irrigation trial, completed in 2020.

Irrigation Timing Study:

Field experiment was established in spring 2020 to study deficit irrigation timing on guayule. The field was prepared and was planted in April 2020. This study will help to determine if we are able to produce enough rubber yield with a low amount of irrigation. The different irrigation treatments started in late June.

Treatments:

1. Full Irrigation: Irrigate as determined by the model developed as part of this project. (75% ETo)
2. Stress before Harvest: Full irrigation for the first 16 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).

Data and Results:

In the first year, treatment 1, 4, and 6 received the same amount of irrigation. Treatments 3 and 5 are also the same in the first year.

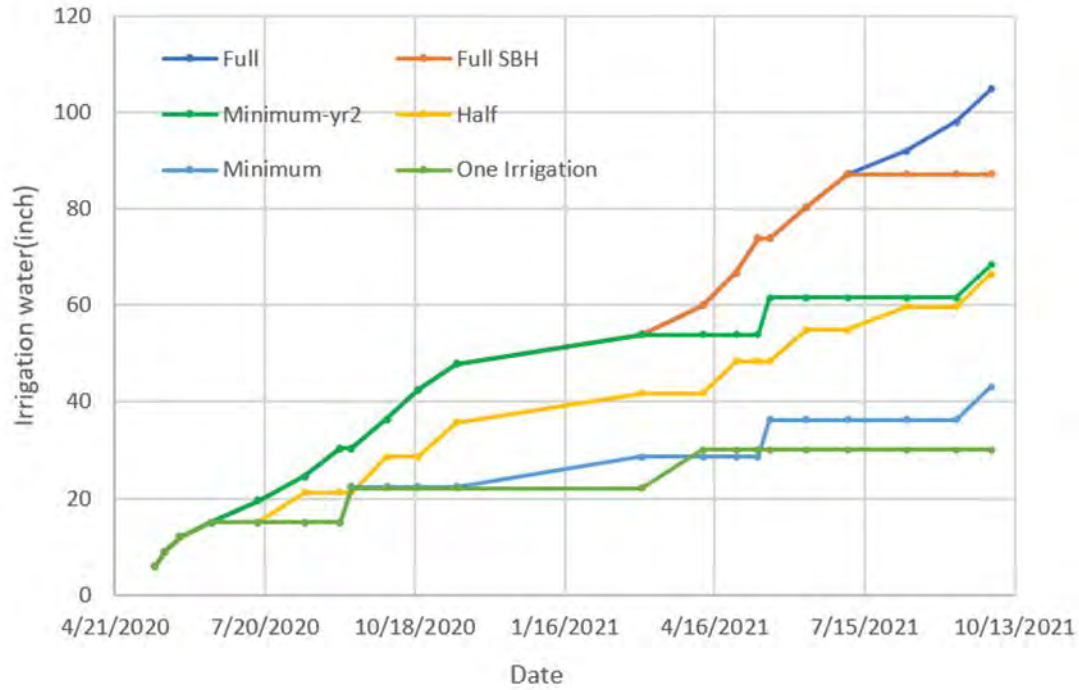


Figure 6. Irrigation amount (inches) by October 2021 for all six treatments (Full and Full SBH treatments received same amount of irrigation for the first 16 months).



Photo 6. Experimental plot of one irrigation per year (AZ-6 - left; AZ-2 - right).

By December 2021, the guayule crop in the irrigation study is 20 months old. Since winter is the dormant period for guayule, the irrigation part has been done for the first two years of the experiment. The plots will be harvested in March, 2022. The total irrigation amount applied to all

treatments ranged from 36 inches (One irrigation treatment) to 105 inches (Full irrigation treatment) in two years. The yield of these treatments will be reported along with the irrigation amount in the second quarter of 2022.

Table 5. Irrigation applied to guayule crop over two years.

	FDI	SBH	Min2	Half	Min	One
Acre-ft/2 years	8.7	6.7	5.6	5.6	4.0	3.0
Acre-ft/yr	4.3	3.3	2.8	2.8	2.0	1.5
% of Full	100	77	64	64	46	35
% of Full (rain included)	100	79	67	67	50	40

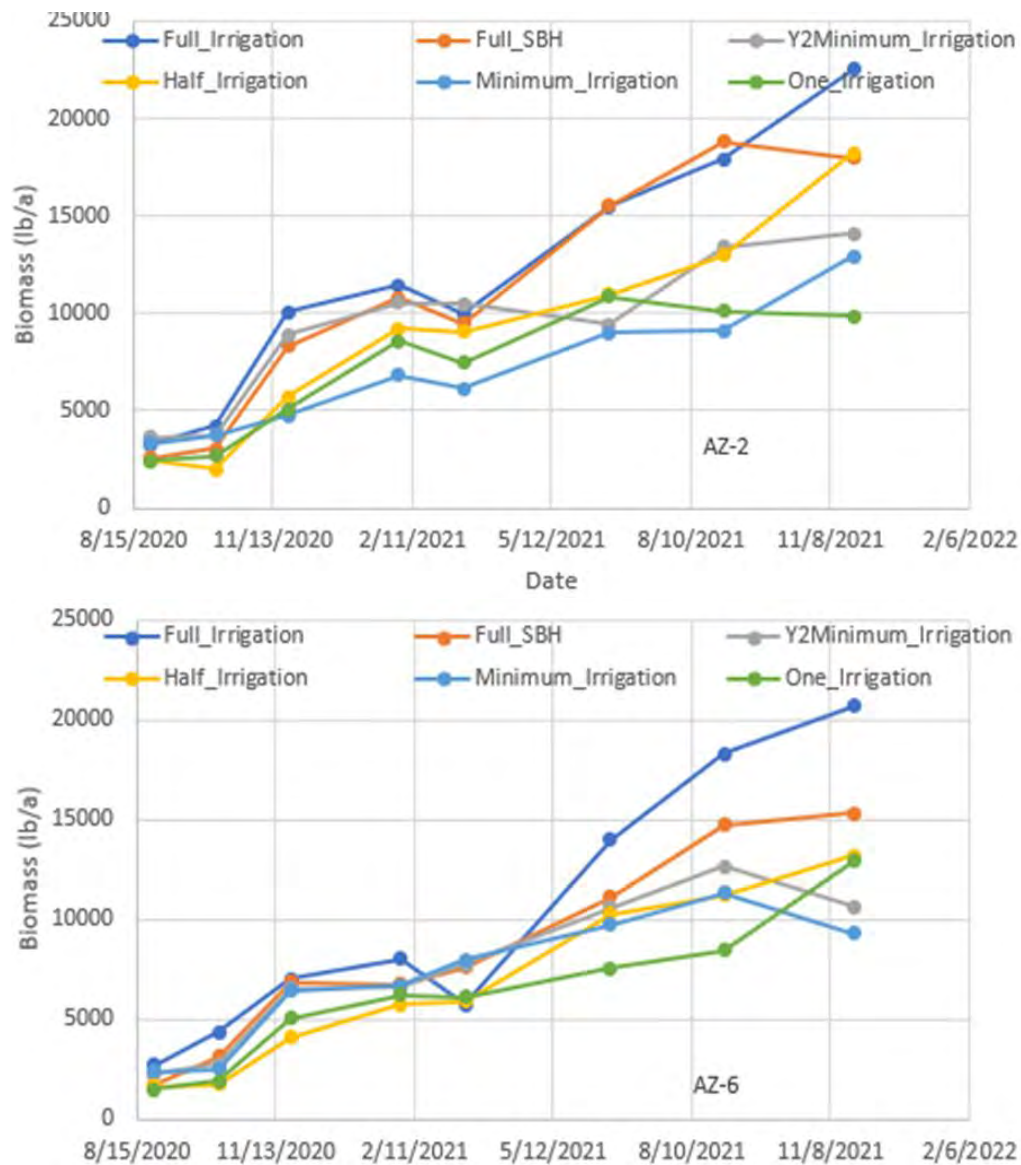


Figure 7. Biomass yield over time for AZ-2 (above) and AZ-6 (below).

In the first year, full irrigation, stress before harvest and minimum irrigation in year 2 received the same amount of irrigation. Although drought stress reduced biomass as expected, guayule biomass under stress still increased, but at lower rates. Short-statured AZ-6 was affected less by drought treatments. 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.

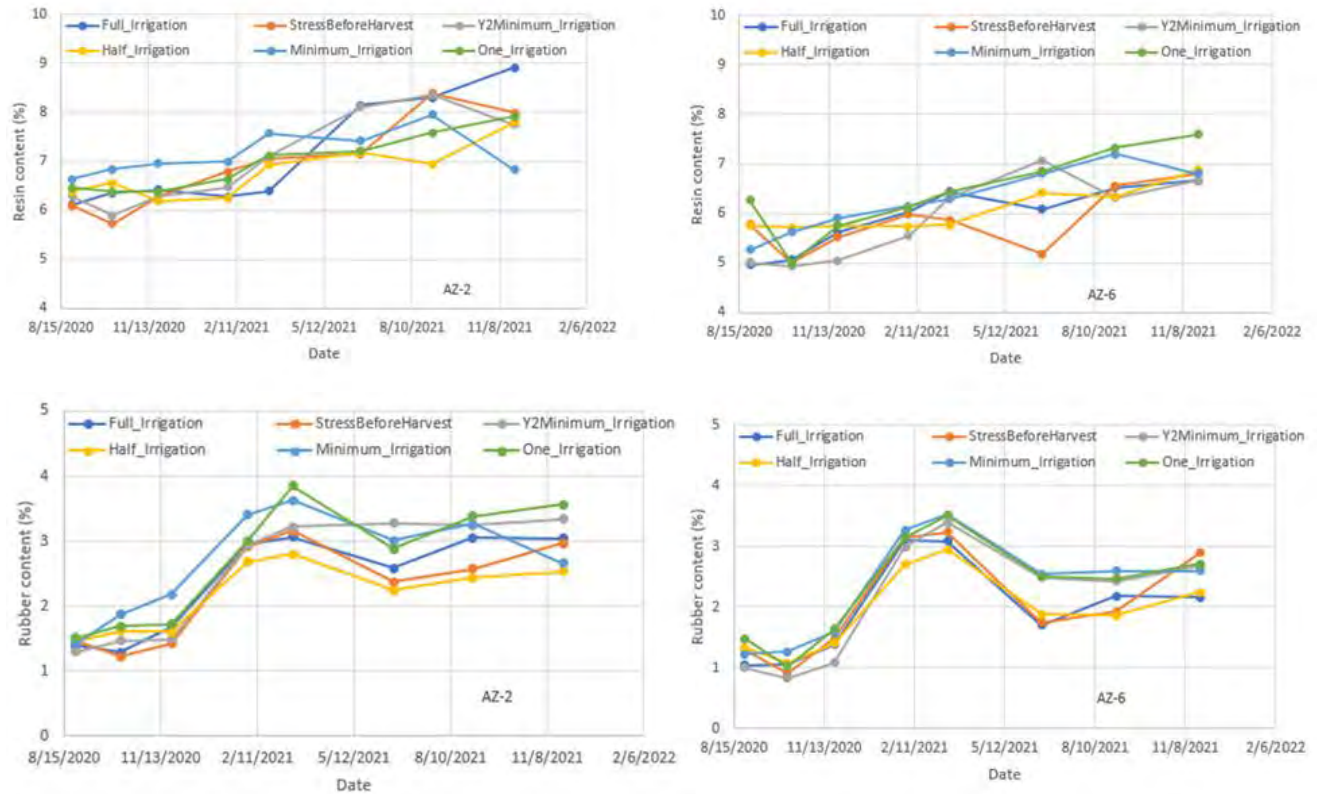


Figure 8. Resin and rubber content under different irrigation treatments for AZ-2 (above) and AZ-6 (below).

Resin content was high at early stages for both AZ-2 and AZ-6 and increased continuously over time. Rubber content increased significantly during the first winter. Rubber content in AZ-2 was flat in summer 2021, which rubber content in AZ-6 decreased during summer 2021. The differences among irrigation treatments on rubber content is not clear. In the spring 2021, biomass increased significantly. The decrease in rubber content was the effect of dilution. The dilution effect of resin was not as significant.

In 20 months, deficit irrigation treatments had respectable rubber yield compared to the Full irrigation treatment, showing guayule can be grown with low water input. 30-inches of irrigation water per year would be too low for all major crops in Arizona.

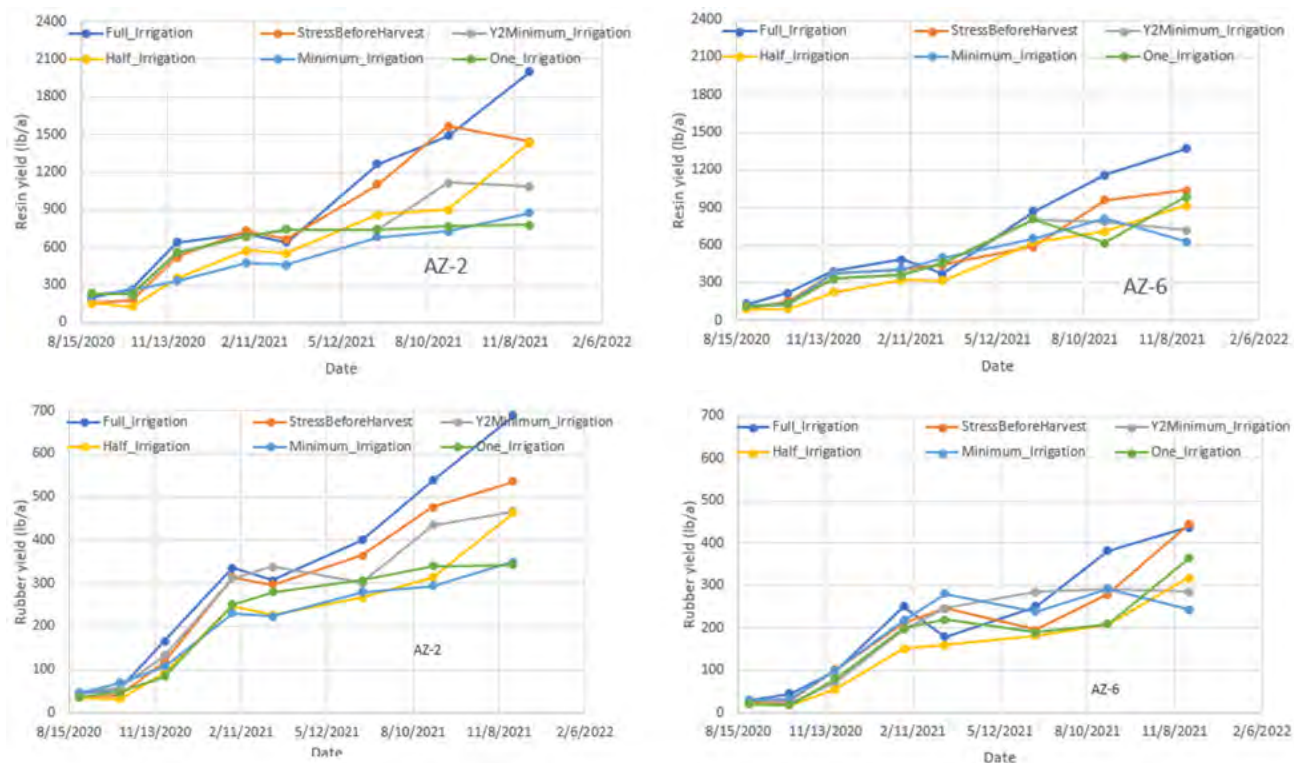


Figure 9. Resin and rubber yield under different irrigation treatments for AZ-2 (above) and AZ-6 (below).

Next Step: Work with SBAR scientists to manage the experiments, collect data, and prepare the final harvest in spring 2022.

Guar Response for Field Performance:

Nothing new reported.

Guar Response to Salinity Tolerance:

A manuscript focusing on molecular mechanisms of salinity tolerance in guar genotypes was completed and submitted. RNA sequencing (RNA-Seq) was employed to study the leaf and root transcriptomes of salt tolerant (Matador) and salt sensitive (PI 340261) guar genotypes under control and salinity. Our analyses identified 296,114 unigenes assembled from 527 million clean reads (158 Gbases), among which 44% were assigned to 51 Gene ontology annotations. Transcriptome analysis revealed that the gene expression differences were more pronounced between salinity treatments than between genotypes. Differentially expressed clusters associated with stress-signaling pathways, transporters, chromatin remodeling, microRNA biogenesis, and translational machinery play critical roles in providing salinity tolerance in guar. Furthermore, transcription factors belonging to several families, including bHLH, ERF, GRAS, zinc finger, were differentially expressed in response to salinity. In addition, differential expressions of genes like *CIPK26*, *E3 ubiquitin ligase PQT3*, *GIGANTEA*, and *KUP* may contribute to salinity tolerance. This study revealed the importance of various players during salinity stress and identified several candidate genes that may potentially be used for

developing salt-tolerant guar genotypes. Salt-tolerant guar varieties might be suitable for cultivation in marginal soils with high salinity or using degraded water for irrigation.

Guar Response to Planting Densities:

Nothing new reported.

Guayule Herbicide Tolerance Study, Fall 2021:

These field experiments were initiated in September 2021 at Bridgestone-Eloy April 2021. The data collection for the studies at MAC were completed. Data will be analyzed in early 2022. New plantings will be attempted at Eloy and MAC in spring 2022 to study over-the-top herbicides and sequences of herbicides in guayule as funding permits.



Photo 7. Post-directed herbicide application within a guayule field at the Maricopa Agriculture Center, Maricopa, Arizona.

Table 6. 2021 Preemergence and post-directed herbicide experiment details, Spring 2021.

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 Sanda Spartan Aim	Bridgestone B6	Hooded Sprayer Furrow irrigation	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 in sprayed canopy zone and an injury rating above the sprayed canopy zone. 4/19/2021 – Malva injury rating 5/13/2021 – applied application code B (second application of all chemicals) 5/26/2021 – Height Rating 5/26/2021 – Canopy Injury
4-12-2021	Appl. Code-B Prowl H2O Dual Magnum	MAC / F2 B 63, 64, 65	PPI-flat, field cultivator, lister, bed-top,	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

Spray Date	Chemicals Applied	Location/ Field	Method of Incorporation	ARM File Name / Data Tables?	Data Collected to Date
	Warrant Spartan Prefar Aim Activator 90 Appl. Code-C and D Goal Tender Caparol Sanda Liberty Chateau Aim Activator 90		incorporator, irrigation Hooded Sprayer		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 7/21/2021 – Applied application code C 8/2/2021 – Injury Rating 8/24/2021 – Injury Rating 8/26/2021 – Height data collected 10/21/2021 – Applied application code D 1/7/2022 – Height data collected
4-12-2021	Appl. Code-B Prowl H2O Dual Magnum Warrant Spartan Prefar Aim Activator 90 Appl. Code-C and D Dual Magnum Karmex Warrant Goal Tender Spartan Stringer HL Matrix Sanda Aim Activator 90	MAC / F3 B 66, 67, 68	PPI-flat, field cultivator, lister, bed-top, incorporator, irrigation Hooded Sprayer	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 7/21/2021 – Applied application code C 8/2/2021 – Injury Rating 8/24/2021 – Injury Rating 8/26/2021 – Height data collected 10/21/2021 – Applied application code D 1/7/2022 – Height data collected

Guayule Herbicide Tolerance Study, Spring 2022:

These studies were planted in fall 2021 at MAC. As discussed in previous reports, the MAC planting failed probably due to bird damage/feeding. The post-directed herbicide studies will be conducted in fall 2021 planting at Bridgestone's Eloy farm.



Photo 8. Significant injury on guayule plants caused by Sandea (halosulfuron) and Karmex (diuron).

Table 7. Postemergence herbicide study details, Spring 2021.

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	Hooded Sprayer Furrow irrigation	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 in sprayed canopy zone and an injury rating above the sprayed canopy zone. 4/19/2021 – Malva injury rating 5/13/2021 – applied application code B (second application of all chemicals) 5/26/2021 – Height Rating 5/26/2021 – Canopy Injury
5-20-2021 6-7-2021	Prowl H2O, Aim Activator 90 MSO Appl. Code B 1 st Aim treatments Appl. Code C 2 nd Aim treatments	MAC / F2 B61/62	PPI-flat, field cultivator, lister, bed-top, incorporvator, irrigation CAPS CAPS	F2 Aim Sequential Spring 2021 MAC F2	3/24/2021 – Farm applied application code A – 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 5/20/2021 – Pre-spray leaf counts/plant 5/20/2021 – Appl. Code B 5/25/2021 – Stand Counts 5/28/2021 – Nadir Pictures 6/5/2021 – Prespray Leaf Counts 6/7/2021 – Appl. Code C applied 6/10/2021 – Farm applied bulk Prowl H2O @ 4 pt/A 6/15/2021 – Stand Counts 6/18/2021 – Nadir Pictures 7/29/2021 – Height data collected

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 Sanda Spartan Aim	Bridgestone B6	Hooded Sprayer Furrow irrigation	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 in sprayed canopy zone and an injury rating above the sprayed canopy zone. 4/19/2021 – Malva injury rating 5/13/2021 – applied application code B (second application of all chemicals) 5/26/2021 – Height Rating 5/26/2021 – Canopy Injury
5-20-2021 6-7-2021	Prowl H2O, Aim Activator 90 MSO Appl. Code B 1 st Aim treatments Appl. Code C 2 nd Aim treatments	MAC / F3 / B65/66	PPI-flat, field cultivator, lister, bed-top, incorporator, irrigation CAPS CAPS	F3 Aim Sequential Spring 2021 MAC F3	3/24/2021 – Farm applied application code A – 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 5/20/2021 – Pre-spray leaf counts/plant 5/25/2021 – Stand Counts 5/28/2021 – Nadir Pictures 6/5/2021 – Prespray Leaf Counts 6/7/2021 – Appl. Code C applied 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 7/29/2021 – Height data collected

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

This work is ongoing. Data and summaries will be completed in early 2022 along with submission to herbicide manufacturers. Collaboration with the herbicide manufacturers will hopefully result in the submission of 24cSLN registration application. The data collected to date used to produce an Extension IPM Short on guayule weed control (“Guayule Weed Management During Establishment in Arizona”) The final editing changes are nearing completion.

Development and Testing of AquaCrop Model:

Huang continued working on AquaCrop model, changing the growing degree days in the program does not seem to change any of the output which is not expected. She will continue to change the equations to get a new model and continue to find the canopy coverage and biomass equations in python.

Range of N and P Utilization:

Samples harvested in August were analyzed for resin and rubber, completed on October 18. Phosphorus experiment initiated on October 22.

Monitor TDR, Infrared Cameras, and Flowmeter System:

Although the neutron probe and drone remote sensing work has gone well, there have been some difficulties with the in-situ sensors.

D. Hoare, M. Katterman, and Frank are continuing to maintain the sensors in the Eloy guayule experiment. In general, the sensors are working the majority of the week. There are some cloudy days where the sensors do not receive sufficient power. There are five sensor systems in the field. Three of the five soil sensors are working consistently. The other two only work occasionally, and the team could not figure out why they are not working. The cameras have not functioned satisfactorily. The probable causes of disfunction are the temperature in the field and the mounting technique. From an overall perspective, we demonstrated use of internet of things, but we did not have the expertise to deploy and manufacture sensors at a commercial level.

M. Katterman is taking weekly neutron probe measurements in Tucson, Eloy, and Maricopa. D. El-Shikha continues to successfully monitor experiments with drone readings.

Drone and satellite applications such as OpenET hold promise but the field sensors will be difficult to implement. However, we are installing some N-Drip soil moisture sensors in the next experiment and hope for better results.

WINDS Model Integration with Existing Tools:

The WINDS model is working in python and is autonomously running at Amazon web services. It is scheduled to run every morning at 2AM, which allows it to incorporate the most recent AZMET (weather) data. It currently runs three treatments each night without bombing. There is no reason to think the other treatments will bomb, but there will be obviously cases that will need special attention.

The WINDS model web page is online (privately accessible). The web page includes the capability to add treatments, irrigation data, select a weather station, a single soil type (we will add layer specification), crop, and interact with model outputs, which includes data from the WINDS model as well as the next irrigation date and depth.

As a first step in implementing the WINDS model with real time data, we are running all of the SBAR treatments. We have characterized the soils and other relevant data for every treatment at Eloy and Maricopa. Users can select any treatment at the web page at this time. There is still some adjustment needed in parameters, etc., but the main point is that the online Web app is capable of handling the 100+ treatments and replicates in the database.

All of the neutron probe data for all treatments and sample days is in a single table, and neutron probe. We are incorporating the neutron probe data. There is a button to upload the neutron probe data file and this data is converted to moisture content and added to the neutron probe table as moisture content. For calculation of status and next irrigation date for an individual treatment, the relevant neutron probe data is extracted from the neutron probe file (treatment and last date), which enables calculation of depletion in layers, moisture content in layers, overall depletion in the soil profile, and required depth of water to be added by irrigation. We will also add in the capability to plot moisture content over time for neutron probe data and the WINDS model.

We have incorporated current NOAA weather prediction into the database in order to estimate upcoming ET. We need to implement this data in an equation in order to estimate upcoming ET. We will also work with OpenET to estimate upcoming ET if possible.

D. Hoare's funding is limited, and it is likely that she will leave soon, but she has left us in a great place with a running online WINDS model. P.Waller will take over the programming and implementation of the website and database as needed.

We have been slow in submitting WINDS papers to journals.

Irrigation Experiments – Guayule and Guar:

Extensive repairs and maintenance were done for the drip system during the last quarter (for the guayule field in Maricopa). We stopped irrigating the fields for the deficit and regrowth irrigation experiments by mid-November. Soil moisture and plant data collection continued (biweekly and monthly, respectively). Also, multispectral and RGB images were collected by drones every four weeks for the two locations (Maricopa and Eloy). Remote sensing and crop coefficient data were analyzed, and a manuscript was written and submitted for publication at Ag Water management journal. We are editing the manuscript for resubmission by mid-January 2022.

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

Task #	Description of Task	Deliverable	Target Completion Date
1 Maier/ Neilson	DNA extraction of soil samples for microbiome analysis (Yr1 and Yr2)	MAC Yr1 complete MAC & Eloy Yr2 complete	1 Aug 21 1 Aug 21
2 Maier/ Neilson	Amplicon sequencing: bacteria, archaea, and fungi	MAC Yr1 and Yr2 complete Eloy Yr2 complete MAC and Eloy Yr3 samples complete	31 Aug 21 31 Aug 21 31 Aug 21
3 Maier/ Neilson	Putative guayule fungal pathogens	Identify associations between pathogen relative abundance and plant, irrigation, and microbial community diversity Manuscript preparation	31 Dec 21 31 Dec 21
4 Maier/ Neilson	Winter dormancy rubber production studies	Manuscript submitted for review and publication	31 Oct 21
5 Maier/ Neilson	Temporal microbiome network analysis of community interactions	DNA extraction for 240 samples Bioinformatics of soil samples collected monthly Manuscript preparation	31 Jul 21 31 Jul 21 31 Dec 21

6 Maier/ Neilson	Belowground associations with guayule 2020 harvest metrics	Chemical analysis of all soils sampled from MAC and Eloy, Spring 2020	31 Oct 21
		DNA extraction of field soils associated with guayule harvest of irrigation field trial	1 Feb 22
		Amplicon sequencing of bacteria, archaea, and fungi from root zone DNA extracts	1 Mar 22
		Multivariate statistical analysis of sequence data set to identify associations between guayule metrics measured at harvest	1 Jun 22
		Manuscript preparation	1 Sep 22

DNA Extraction for Microbiome Analysis:

DNA extractions for 2018 and 2019 soil samples are complete.

Amplicon Sequencing: Bacteria, Archaea, Fungi:

Amplicon sequencing of DNA soil extracts has been completed.

Putative Guayule Fungal Pathogens:

Amplicon sequences data sets have been processed. Bacterial/archaeal and fungal diversity analyses have been calculated for all samples. Multivariate statistical analysis to identify associations between relative pathogen abundance and soil, plant and irrigation variables is in progress.

The soil quality study is focused on soil properties and management practices that impact the relative abundance of putative fungal pathogens across all irrigation treatments at MAC and Eloy fields for the 2018 irrigation field trial. K. Brown has made significant progress on this project during Q4. The draft of the literature review for the introduction to his dissertation that summarizes current knowledge on guayule pathogens and the field conditions that influence their relative abundance and infectivity is almost complete. The chapter is entitled *Fungal pathogens and guayule (Parthenium argentatum): optimizing crop production in an arid environment*. A condensed version of this literature review will be used as the Introduction to his first manuscript

This research study evaluates the relative abundance of putative guayule pathogens in 216 soil samples from 18 plots in each of the fields. Samples were collected prior to guayule establishment in 2018 and following one year of growth (2019) to facilitate an analysis of the effect of plant establishment on putative fungal pathogen relative abundance. Chemical analysis was performed on the 2019 soil samples from all treatment plots. DNA has been extracted from all 2018 and 2019 soil samples and amplicon sequencing is complete on all soil extracts for characterization of bacterial, archaeal, and fungal communities. Initial bioinformatics processing of the sequence data sets is complete. A significant difference was observed between the

microbial communities of Eloy and MAC field soils. Bacterial/archaeal and fungal species richness has been calculated for all samples and associations with irrigation treatments are being evaluated.

Winter Dormancy Rubber Production Study:

The research for this study is complete and the figures are prepared for publication.

Temporal soil microbiome associated with guayule growth cycle:

Network analysis was optimized and is complete. Keystone species are identified in this report. Additional bioinformatics tools have showed association between plant-microbe and microbe-microbe interactions.

The manuscript for this project is in preparation with the title: *Identification of critical soil microbes in guayule-microbe and microbe-microbe associations during guayule growth stages.* The objective of this study is to combine the use of network analysis to identify critical microbe-microbe associations defining the guayule rhizosphere microbial community with an identification of critical guayule-microbe associations as defined by significant correlations between microbe relative abundance and the guayule NDVI values.

The NDVI-microbe analysis was used to identify critical microbes relevant to guayule-microbe associates as a function of growth stage from October 2019 through May 2020. In Q4, Y.Chen used a novel bioinformatics method to identify the overlap between critical microbes associated with plant-microbe interactions and those microbe-microbe interactions critical to the soil rhizosphere microbial community

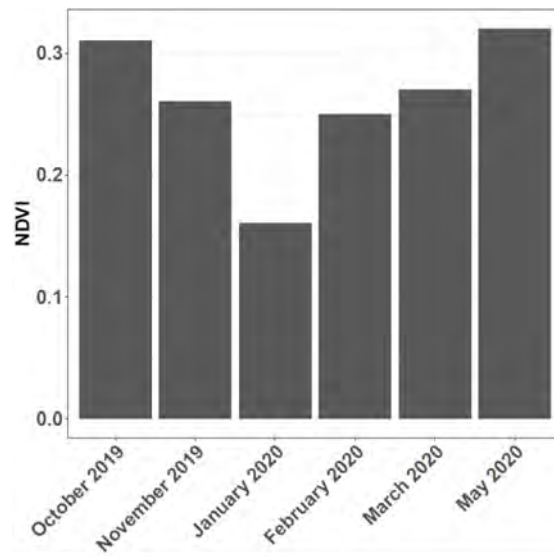


Figure 10. NDVI values associated with each sampling month. Data provided by D. El-Shikha and S. Wang.

The plant-microbe analysis identified 79 bacterial/archaeal taxa and 13 fungal taxa positively correlated with NDVI and 19 bacterial/archaeal taxa and 5 fungal taxa negatively correlated with NDVI as shown in the figure below's heatmap and associated phylogenetic tree. The analysis demonstrates that critical microbes defined by the guayule-microbe association vary with plant growth stage and that plants select a greater abundance of critical microbes during active growth months, than during the inactive growth/rubber production growth periods. Also, the taxonomic composition of the two growth stages is distinct with Proteobacteria and Gemmatimonadetes showing strong association with inactive growth stages and Actinobacteria, Planctomycetes and Chloroflexi dominating active growth stages.

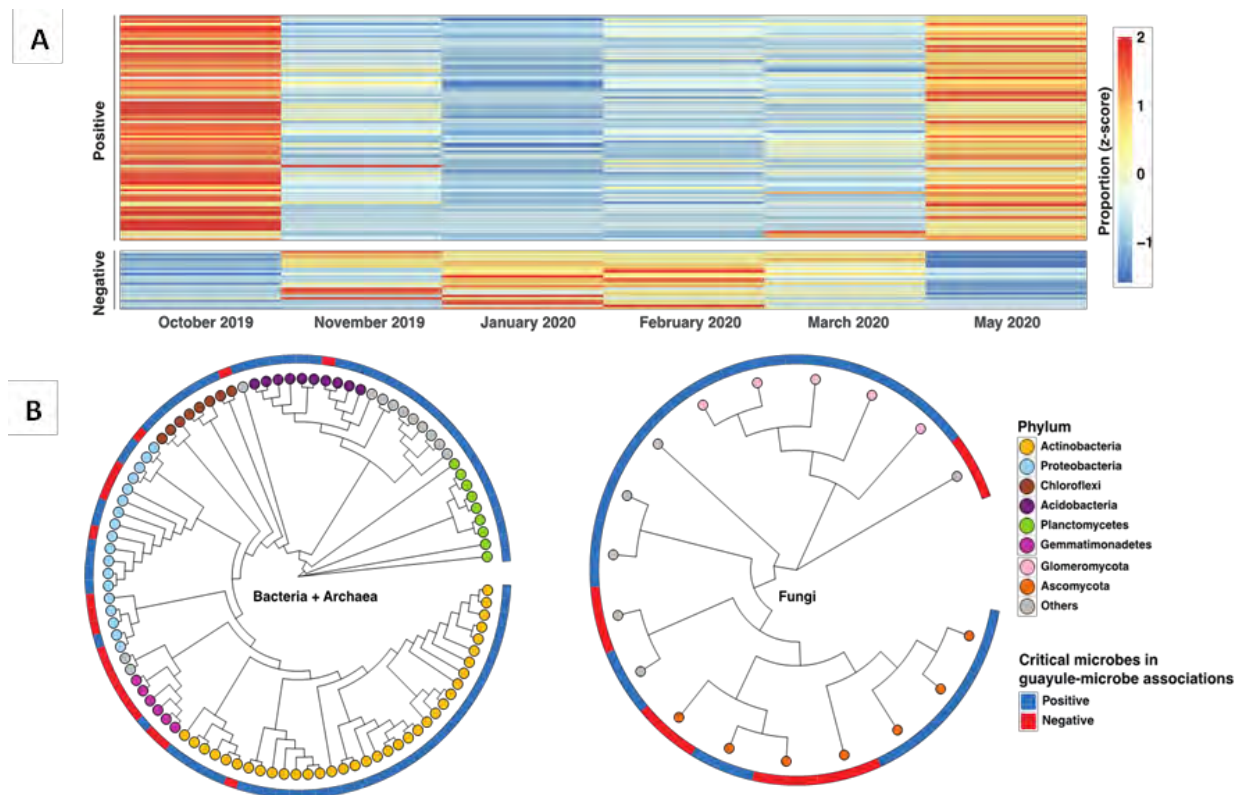


Figure 11. Critical microbes in guayule-microbe association.

A) Heatmap indicating microbial taxa positively (top) and negatively (bottom) associated with guayule NDVI. Red indicates high microbial relative abundance and blue indicates low relative abundance. B) Phylogenetic trees showing taxonomic associations of all taxa present in the heatmap.

One interesting example shown in the figure above is that the fungal Glomeromycota group which includes all of the arbuscular mycorrhizal fungi (AMF) are significantly associated with active guayule growth in October and May, but not with the inactive growth period when rubber production is high. AMF are known to assist plants in nutrient and water acquisition. We hypothesize that this fungal group is more critical to guayule during the growth stages associated with flowering and rapid growth and is less important during the period of non-growth and active rubber production. In summary, critical guayule-microbe interactions are significantly different during active growth periods and the non-active growth periods when rubber production is comparatively higher

During Q4, Y. Chen combined the results of the NDVI-microbe analysis and network analysis to identify the overlap of microbes critical to both plant-soil-microbe associations and soil microbe-microbe associations. The overlap was identified for each of the 6 sampling months using a novel bioinformatics tool called Zi/Pi plots as shown in the figure below.

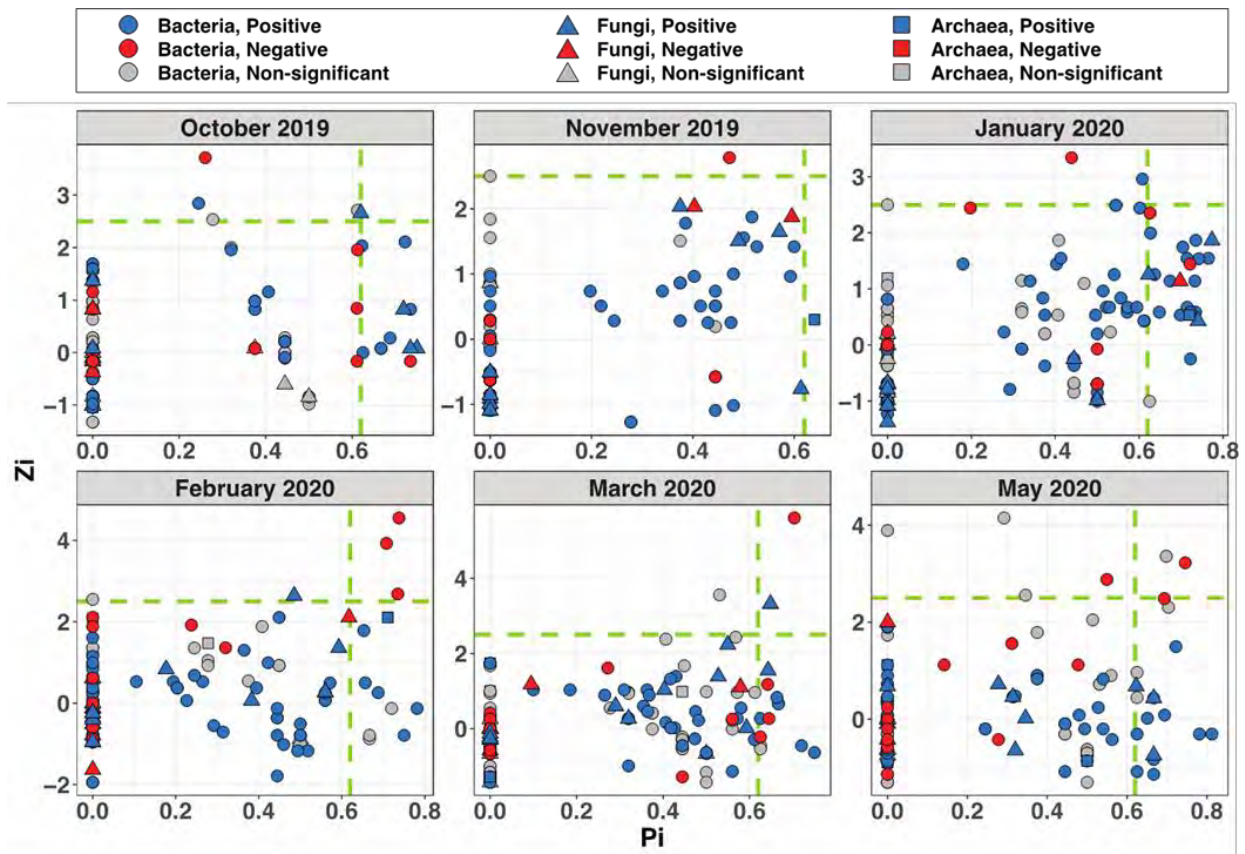


Figure 12. Analysis of overlap between critical microbes in guayule-microbe and microbe-microbe associations for each of the six months analyzed.

Red and blue circles and squares indicate microbial taxa significant to guayule-microbe associations. Position within the Zi/Pi plot indicates microbe-microbe significance within the microbial community networks. Green dotted lines indicate Zi and Pi threshold values. Taxa with Zi or Pi scores above the threshold values (those symbols spatially located above or to the right of the dotted green threshold lines) represent Module hubs (high Zi), Connectors (high Pi), or Network hubs (high Zi and Pi) within the microbial networks shown in the Q3 report.

Red and blue symbols represent bacteria/archaea (circles) or fungi (triangles) that are significantly associated with NDVI. Red symbols are positively associated, indicating an association with active growth stages (October and May) and blue symbols indicate significant negative NDVI correlation, or association with less active-growth and rubber producing stages (November to March). Colored symbols located above the Zi threshold (y-axis) or to the right of the Pi threshold (x-axis) represent the overlaps in critical microbes significant to plant-microbe and microbe-microbe associations. In conclusion, the majority of microbes critical to the guayule-microbe association for all growth stages are 'peripherals' or microbes that are not critical to the soil microbial community. However, there are from 2 to 18 microbial taxa in each month that were identified by this analysis as critical to both guayule-microbe and microbe-microbe associations. The greatest overlap was observed in January and the least in November, During the next quarter, the significance of the overlapping taxa identified by the Zi/Pi analysis will be evaluated.

Belowground Associations with Guayule 2020 Harvest Metrics:

Soils collected in Spring 2020 from the irrigations field trials in Eloy and MAC are being processed for chemical analysis. Undergraduate student, A. Soto, is grinding the Eloy soils in preparation for analysis. We estimate that the chemical data for these soils will be completed in February 2022.

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: Shakedown tests for the SFE are ongoing. To date, all components of the equipment are working. A leak in one of the extraction vessels required some troubleshooting before operation pressure could be reached.

Holguin: We are still working through our backlog of chemical analysis. There is delay in CO₂ extracted chemical analysis, which is behind schedule. We will begin routing meetings with the Brewer group to advance the task.

Molnár: Dr. M. Cascaes-Inacio resigned from her postdoc position early September. The search for a molecular biologist failed to the short timeline until the termination of the project and the part-time nature of the job, together with covid-related difficulties of relocating potential candidates from abroad. Dr. Zhong (a chemist) is currently learning molecular biology techniques to complete the molecular biology objectives of the project.

Repeated failures of the LC-MS equipment caused significant problems with our compound isolation work. Commercial synthesis of the synthetic genes was repeatedly delayed by the company citing pandemic supply chain disruptions and technical problems. One construct failed QC and needs to be re-synthesized by the company.

Ogden: We sent samples to Bridgestone in March 2021 and are still awaiting the results. We have subsequently sent additional samples to Dr. Hognin's group in New Mexico, and we are ordering GC columns of our own to complete the analysis.

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	Semi/full quantification of metabolic pools associated with cold adaptation	31 Aug 22
2 Holg	Metabolic analysis of temperature gradient	Manuscript drafted/submitted to Industrial Crops	31 Aug 22
3 Holg	Chemical analysis of molecules present in insect repellent fractions	Identify >50% of molecules present in fractions	31 Aug 22
4 Holg	Bulk chemical products in resin	Manuscript drafted/submitted	31 Aug 22

5 Holg	Guar gum extraction and analysis from field trials	Characterize gum composition from guar	28 Feb 22
6 Holg	Commissioning and testing supercritical fluid extraction equipment and analysis	Chemical analysis of SFE extracts; contribute to manuscript	31 Aug 22

Guayule Biochemical Composition Analysis:

Nothing new to report.

Metabolic analysis of temperature gradient:

Dr. Rodriguez-Uribe harvested 36 plant samples (18 leaves and 18 stems (12/month)) from the guayule germplasms: AZ6 and 593 grown at the Leyendecker Research Science Center from 10/13/2021, 11/12/2021, 12/13/2021. She isolated RNA from each of the 36 samples from 10/13/2021 and 11/12/2021, and then determined the integrity of each RNA sample by gel electrophoresis.

▪ RNA

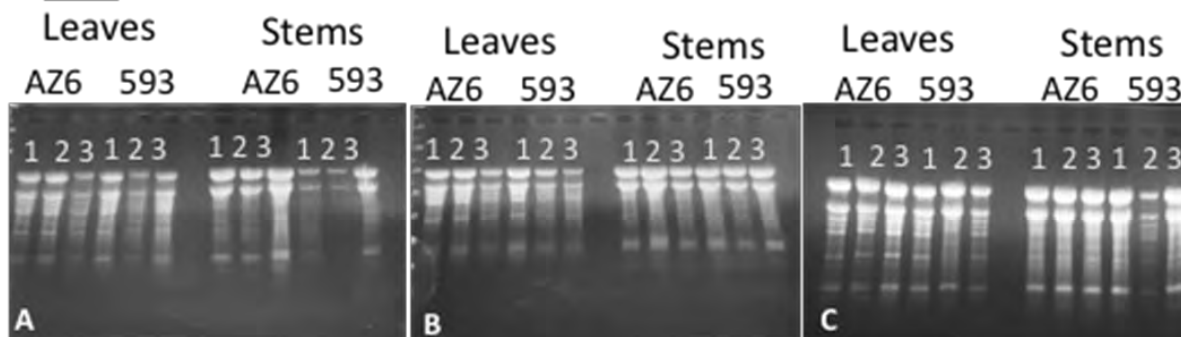


Figure 13. Isolated RNA from guayule samples collected at the Leyendecker Research Science Center. (A) 10/13/2021; (B) 11/12/2021; (C) 12/13/2021.

Dr. Rodriguez-Uribe freeze-dried 24 of the 36 samples from 10/13/2021, and 11/12/2021, for metabolome analyses. The last 12 samples harvested on 12/13/2021 were not freeze-dried due to a malfunctioning of the freeze-drier.

The transcriptome analyses of guayule leaves and stems from plants surviving the 2019-2020 winter were completed at LANL by Shawn Starkenburg. Dr. Rodriguez Uribe met virtually with Starkenburg on 10/22/2021 to discuss the analyses to carry out with the transcriptome data. These analyses will be carried out on the spring of 2022.

Chemical analysis of molecules present in insect repellent fractions:

In order to quantify various compounds from the complex resin mixture Multiple Reaction Monitoring (MRM) were implemented utilizing modern triple quad mass spectrometer Shimadzu LC-MS 8050. Separation of the target argentatins were obtained using liquid chromatography with the following conditions: Solvent A: H₂O + 5mM Ammonium acetate + 0.1% Formic acid; Solvent B: Acetonitrile + 5mM Ammonium acetate + 0.1 Formic Acid. Samples itself were diluted with MeOH and Water (50/50) with addition of 0.1% of Formic acid. As a result of LC-MS analyses MRM transitions were obtained however in two different mixtures.

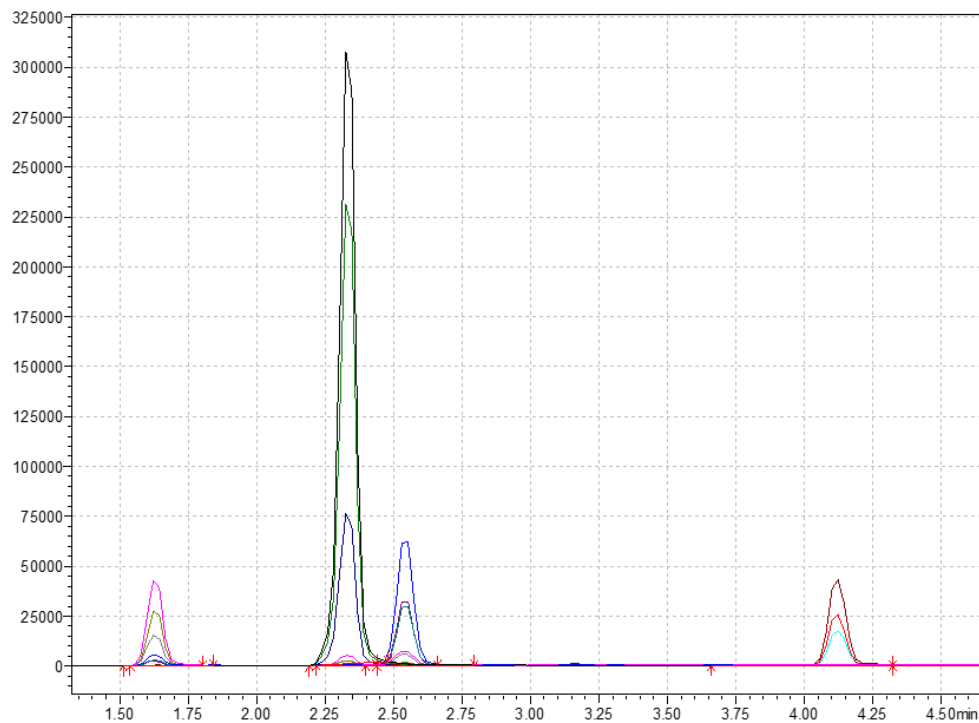


Figure 14. LC-MS analysis of Argentin C (RT:1.6), Argentin A (RT:2.3), Argentin H (RT:2.5), 3-Epi-Argentin D (RT:4.1) using MRM.

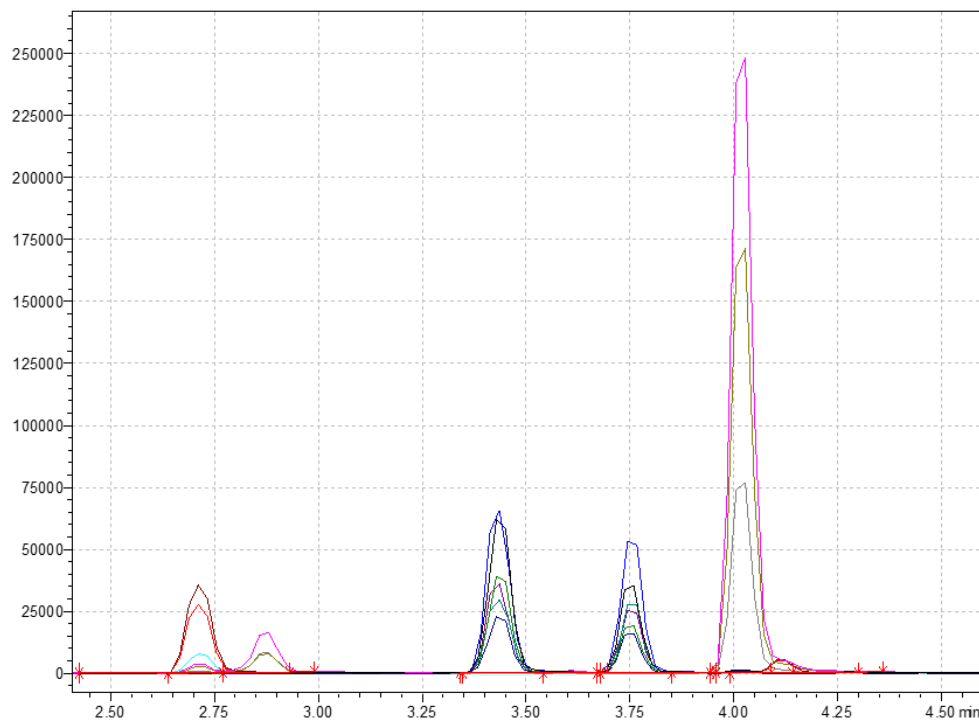


Figure 15. LC-MS analysis of 16,17(20)-didehydroargentin C (RT:2.7), Argentin B/Quisquagenin (3.4 and 3.7, they were not resolved), Isoargentin A (RT:4) using MRM.

Two separate mixtures were made in order to account for the isobaric isomers that could have been eluted in the same retention time. Additionally, following mass spectral parameters were obtained: Q1 Pre Bias (V), Q3 Pre Bias (V), collision energy, and prevalent form of target compounds that was one to several water losses (see table below). Next step of the analysis would be optimization of the MRM in one mixture with 8 argentatins together prior to quantification of tissue and resin samples

Table 8. MRM parameters for targeted argentatins.

Precursor m/z	Product m/z	Dwell Time (msec)	Q1 Pre Bias (V)	CE	Q3 Pre Bias (V)
Dehydroargentatin C - H ₂ O					
453.4	271.25	28	-17	-20	-18
453.4	121.25	28	-17	-26	-12
Argentatin B - H ₂ O					
439.4	127.1	28	-10	-22	-12
439.4	245.25	28	-24	-17	-26
Argentatin C-2H ₂ O					
439.45	127.1	28	-30	-20	-28
439.45	109.1	28	-16	-32	-24
Quisquagenin - 2H ₂ O					
439.4	175.3	28	-10	-24	-17
439.4	187.2	28	-30	-25	-19
Argentatin A					
473.4	143.2	28	-24	-15	-29
473.4	125.2	28	-25	-22	-25
Isoargentatin A - H ₂ O					
455.4	123.15	28	-17	-25	-12
455.4	271.3	28	-17	-21	-29
Argentatin H-2H ₂ O					
421.4	105.25	28	-30	-55	-25
421.4	121.2	28	-10	-35	-12
3-Epi Argentatin D-2H ₂ O					
423.3	187.1	28	-15	-21	-24
423.3	109	28	-22	-29	-19

Bulk chemical products in resin:

Research continues as planned; nothing new to report.

Guar gum extraction and analysis from field trials:

Dr. Rodriguez-Urbe carried out new isolations of guar gum (in triplicates) for each of the 27 USDA 2018 guar samples, and commercial guar gum (81 total isolations). She determined the D-galactose:D-mannose content with the Megazyme Kit for each of the 81 samples (see table below).

Table 9. Galactomannan concentration in guar.

Guar variety	D-galactose g/L	±	Galactomannan g/L	±	Galactomannan g/100g	±
P1-158126(1)	0.186	0.003	0.440	0.008	3.52	0.06
PI-180434(1)	0.188	0.015	0.444	0.036	3.56	0.29
PI-I217923 (1)	0.184	0.004	0.435	0.008	3.48	0.07
P1-186477(1)	0.194	0.007	0.460	0.017	3.68	0.14
PI-176377(1)	0.134	0.011	0.317	0.026	2.53	0.21
PI-179926 (1)	0.176	0.003	0.417	0.006	3.33	0.05
PI-1b4486 (1)	0.134	0.008	0.318	0.020	2.55	0.16
HES 1123(1)	0.178	0.003	0.422	0.008	3.37	0.06
PI-263698(1)	0.150	0.007	0.355	0.016	2.84	0.13
PI- 263406(1)	0.181	0.007	0.428	0.016	3.43	0.13
PI-338745(1)	0.161	0.025	0.381	0.060	3.05	0.48
PI-253187(1)	0.139	0.010	0.329	0.024	2.63	0.19
PI-671848 (1)	0.151	0.001	0.356	0.003	2.85	0.02
PI-593059 (1)	0.147	0.006	0.347	0.014	2.78	0.11
PI-593058 (1)	0.140	0.004	0.332	0.009	2.65	0.08
PI- 593049 (1)	0.148	0.007	0.350	0.016	2.80	0.13
PI-593048 (1)	0.164	0.002	0.389	0.004	3.11	0.03
PI-547070 (2)	0.184	0.009	0.435	0.021	3.48	0.17
PI-268229 (1)	0.194	0.020	0.460	0.048	3.68	0.38
PI-288377 (1)	0.186	0.005	0.439	0.011	3.52	0.09
PI-537281 (1)	0.185	0.009	0.439	0.021	3.51	0.17
PI-542608 (1)	0.187	0.001	0.442	0.003	3.54	0.02
PI-158125 (1)	0.176	0.012	0.417	0.027	3.34	0.22
PI-338796 (1)	0.166	0.003	0.393	0.008	3.15	0.06

PI-549164 (2)	0.182	0.000	0.430	0.001	3.44	0.01
PI-338811 (1)	0.180	0.001	0.426	0.003	3.41	0.02
PI-340261 (1)	0.164	0.002	0.388	0.005	3.10	0.04
D-galactose St	0.179	0.0008	0.423	0.002	3.39	0.017
Commercial guar	0.189	0.001	0.447	0.002	3.57	0.018

Dr. Rodriguez-Urbe contacted the Megazyme’s technical team to discuss the lower galactomannan concentrations (10X the values reported in the literature) observed in all the samples used including the positive D-galactose control observed with the Megazyme’s kits used in the last three years. The problem was not resolved.

Commissioning and Testing Supercritical Fluid Extraction Equipment and Analyses:

No chemical analysis activities occurred this quarter.

OTHER

Publications:

Dr. Rodriguez-Urbe assigned Metabolic Pathways to the metabolites identified in the multivariate analysis of pre- and post-acclimated AZ-2. She is currently waiting for the results of the multivariate analysis of pre- and post-acclimated of the W6-429 to assign Metabolic Pathways.

Dr. Rodriguez-Urbe and Dr. Holguin met virtually to discuss the reviewed peer review comments and edited the discussion section of the guayule metabolome manuscript.

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

ALL TASKS UNDER THIS OBJECTIVE WERE COMPLETED IN 2020

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	Evaluate supercritical fluid (CO ₂) extraction (SFE) and fractionation of guayule including impacts on residual biomass	Shakedown trials completed; parts/repairs needed have been identified	30 Sep 21
		Operation of continuous SFE of guayule resin demonstrated; experimental design completed for resin fractionation	31 Dec 21
		SFE experiments completed with samples sent for characterization	31 Mar 22
		Manuscript on methods of guayule biomass and resin SFE and fraction composition submitted	31 Aug 22
2 Brewer	Evaluate IP potential of guayule fractionation for insect repellent applications	Completion of IP disclosure and evaluation with NMSU business development	31 Dec 21
3 Brewer	Test insect repellency of guayule resin fractions on multiple urban/agricultural pests	Manuscript on insect repellency effects of guayule resin on second pest species submitted for peer review	31 Aug 22
4 Molnár	Identify and characterize key steps in guayule biosynthetic pathways that yield argentatin and guayulin as potential value-added coproducts	Cloned or custom-synthesized oxidosqualene cyclase and sesquiterpene synthase genes (8 genes)	31 Dec 21
		Completed functional characterization of oxidosqualene cyclases and sesquiterpene synthases in a yeast host	31 Mar 22
		Extracts generated from scaled-up synthetic biology reactions	31 Aug 22
		Preparation of draft manuscript or report	31 Aug 22
5 Molnár	Conduct microbial biotransformations of major metabolites in guayule resin	Completed screening of the fungal collections of NPC to biotransform guayule resin components	31 Dec 21
		Completed screening of the recombinant yeast collection of NPC to biotransform guayule resin components	31 Mar 22

		Extracts from scaled-up biotransformation reactions	31 Aug 22
6 Molnár	Isolate the structures and evaluate the potential anticancer and antimicrobial activities of novel compounds originating from microbial biotransformation or synthetic biology	Isolated novel compounds (2-10mg) Completed structure elucidation of novel compounds using 1D and 2D NMR techniques IC50 values (inhibitory concentration, 50%) determined against a panel of cancer cell lines and normal human cells MIC (min. inhibitory concentration) and MBC/MFC (min. bactericidal/fungicidal concentration) values determined against a panel of Gram-positive and Gram-negative bacteria and Candida Preparation of draft manuscript or report	31 Aug 22 31 Aug 22 31 Aug 22 31 Aug 22
7 Ogden	Characterization of pure resin and blended adhesives	1 papers submitted for review	30 Sep 21
8 Ogden	Distillation of resin into multiple fractions	Distilled fractions analyzed MS Thesis complete; separation strategy hypothesized	31 Dec 20 31 Aug 21
9 Ogden	Develop guayule resin-based adhesives	Results with possibility of patents and/or publications	31 Mar 22

Evaluate Supercritical Fluid (CO₂) Extractor (SFE) and Fractionation of Guayule Including Impacts on Residual Biomass:

Dehghanizadeh and the undergraduates fixed a leak on the supercritical fluid extraction (SFE) system and conducted pressurization tests. Whole guayule shrub extractions will start with the new samples from Bridgestone in 2022 Q1.

Armijo completed a series of hydrothermal liquefaction (HTL) temperature experiments and determined that for 270-350°C, 80-95 wt.% bio-crude oil yields could be obtained with little char and good energy contents. For the spring semester, Armijo will conduct more HTL experiments using new resin and bagasse samples from Bridgestone to determine if resin+bagasse can provide better opportunities for jet fuels than bagasse HTL alone. Characterization of the bio-crude oils will be done to provide data to the CSU group for the integrated guayule model.

Table 10. Results of hydrothermal liquefaction (HTL) temperature experiments on guayule resin.

Conditions	Resin Used (g)	Oil Phase (g)	Aqueous Phase (g)	Char phase (g)	Oil Yield (wt. %)	Char Yield (wt. %)	Centrifuge Needed	HHV Oil (MJ/kg)	HHV Char/Solids (MJ/kg)
Whole resin HHV (MJ/kg)	38.1, 39.1								
270 °C, 15 wt%	89.2	75.7		1.26	84.8%	1.4%	x	34.1, 33.2	
270 °C 10 wt%	40.4	38.2	389.5	0.87	94.4%	2.2%	x	41.6, 40.5	38.3, 37.1
310 °C 10 wt%	40.5	32.3	402.8	1.02	79.8%	2.5%		41.7, 41.4	
310 °C 10 wt%	40.4	37.7	398.8	1.03	93.3%	2.5%		41.0, 42.5	
310 °C 10 wt%	40.2	34.9	390.3		86.8%	0.0%		40.4, 41.6	
350 °C 10 wt%	42.1	39.5	412.0	0.84	93.8%	2.0%	x	40.4, 42.6, 41.9	30.6, 31.8
350 °C 10 wt%	42.6	37.5	415.1	0.39	88.1%	0.9%		40.2, 41.2	26.0, 28.5

Shalygin worked on the characterization/quantification of resin components using the LC-MS (as described in quarterly report from Holguin group).

The manuscript on guayule bagasse and algae HTL was accepted for publication in *Energies*, however, the manuscript was withdrawn after Bridgestone expressed concerns with publication of specific guayule bagasse composition data. Once the data from the guayule resin+bagasse HTL data is available, preparation of a manuscript will be reconsidered with sufficient review time for Bridgestone to address any potential IP issues before submission.

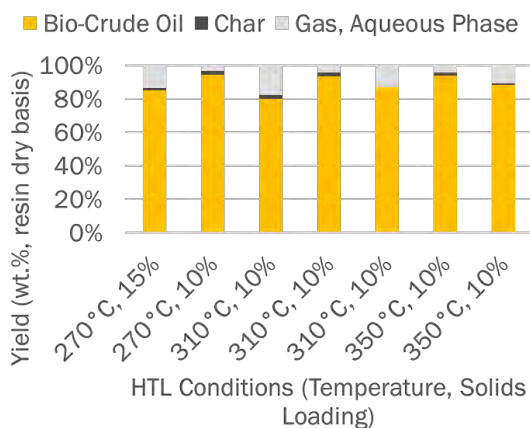


Figure 16. Guayule resin hydrothermal liquefaction results.

Evaluate IP Potential of Guayule Fractionation for Insect Repellent Applications:

Dehghanizadeh, Romero, and Brewer worked with NMSU's Arrowhead Center to file a provisional patent application for the guayule resin-based insect repellent.

Test Insect Repellency of Guayule Resin Fractions on Multiple Urban/Agricultural Pests:

Dehghanizadeh and Brewer met weekly with the Quinn group to provide data and feedback for development of the guayule resin distillation Aspen model. Plans were made for the resin fraction characterization for the cockroach repellency manuscript for *Bioresource Technology*.

Dehghanizadeh presented at the *Tech Connect* Conference and participated in the Natural Rubber Symposium.

Characterize Steps in Guayule Biosynthetic Pathways that Yield Argentatin and Guayulin as Potential Value-Added Coproducts:

Custom synthesis of bioinformatically selected oxidosqualene cyclase and sesquiterpene synthase genes was completed after repeated delays at the gene synthesis company, with delivery expected only in late October. After receipt of the genes, QC was completed (transformation into *E. coli*, plasmid isolation, restriction analysis) and the gene-containing plasmids were deposited into our collections. One of the genes did not pass QC as the corresponding plasmid afforded no *E. coli* transformants. We are still waiting for the company to re-synthesize this gene and deliver it as a plasmid. Subcloning of the genes into yeast expression plasmids was initiated, and will be followed up by functional characterization in 3 different yeast strains for the remaining objectives.

Conduct Microbial Biotransformations of Major Metabolites in Guayule Resin:

Small-scale biotransformations of argentatins A and B were repeated using *Cunninghamella elegans* and *Mucor mucedo*. Analysis of the extraction products confirmed that argentatins A and B were rapidly converted to a series of more polar compounds by *Cunninghamella elegans* in a couple of days, and the products were mostly observable in the fermentation broth. No biotransformation products of argentatins A and B by *Mucor mucedo* was detected in fermentation broth and the mycelia, and the starting materials, argentatins A and B, were completely consumed without biotransformation, probably as a result of its complete catabolism by *Mucor mucedo*.

Large-scale biotransformations of argentatins A and B by *Cunninghamella elegans* were completed. The crude biotransformation products of argentatins A and B were obtained as 147 mg and 91.5 mg, respectively, from 80 mg each of argentatins A and B. Analysis of the products confirmed that the composition of large-scale products are similar to those of small-scale products.

Isolate Structures and Evaluate Anticancer and Antimicrobial Activities of Novel Compounds from Microbial Biotransformation or Synthetic Biology:

Continuation of fractionation and purification of biotransformation products of argentatin C by *Chaetomium* sp. afforded two Baeyer-Villiger type oxidation products YX-MI1-3-1 and YX-MI1-3-2. The structures were completely confirmed by detailed analysis of their 1D and 2D NMR data.

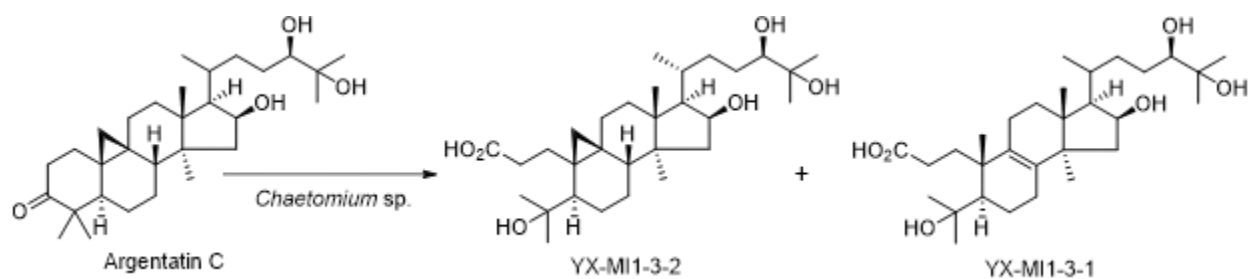


Figure 17. Chemical structures of transformed products of argentatin C.

Characterization of Pure Resin and Blended Adhesives:

One paper has been submitted for peer review. Nothing new to report.

Distillation of Resin into Multiple Fractions:

A. Smith, who mentors K. Burke, performed maintenance and testing on vacuum equipment. He did distillation experiments to obtain a guayulin rich fraction for Mostafa's bug repellency tests. Options for using a SEC to detect LMW rubber were explored and discussed with faculty. Equipment and settings to run a GC-FID for terpene testing at the university as an alternative to Bridgestone were researched.

Burke received a Scott Roberts Scholarship to work on guayule bagasse. He has an experimental plan for investigating vaporization of terpenes from bagasse.

Development of Guayule Resin-based Adhesives:

S. Pradyawong, A. Hinojosa, and T. Lane still researched replacement of urea-formaldehyde (UF) adhesive with guayule resin and enhanced the adhesion property of UF adhesive by using the guayule resin at the Advanced Ceramics Company. They focused more on tensile test and comparison of the test results of reference standards and resin-UF adhesives. The results were consistent to the previous quarter's report. We are still waiting for the results of insect repellency test from Dr. Brewer group (NM), and the composition/content analysis from Dr. Holguin's group and Bridgestone. We finished testing the adhesion property of Andrew's distilled guayule resin fractions. The unmodified resin fractions do not show any adhesion property.

Acid and base modifications could enhance adhesion property of the resin fractions. Most of the base modified resin fractions could be adhesives only under dry conditions ranging from 1.78 to 3.15 MPa and 1.47 to 2.43 MPa, respectively. We finished experimental works at the company at the end of the quarter.

Ogden and Pradyawong attended the 2021 TechConnect World Innovation Conference on October 18-20, in Washington DC. We presented SBAR work and explored collaboration opportunities.

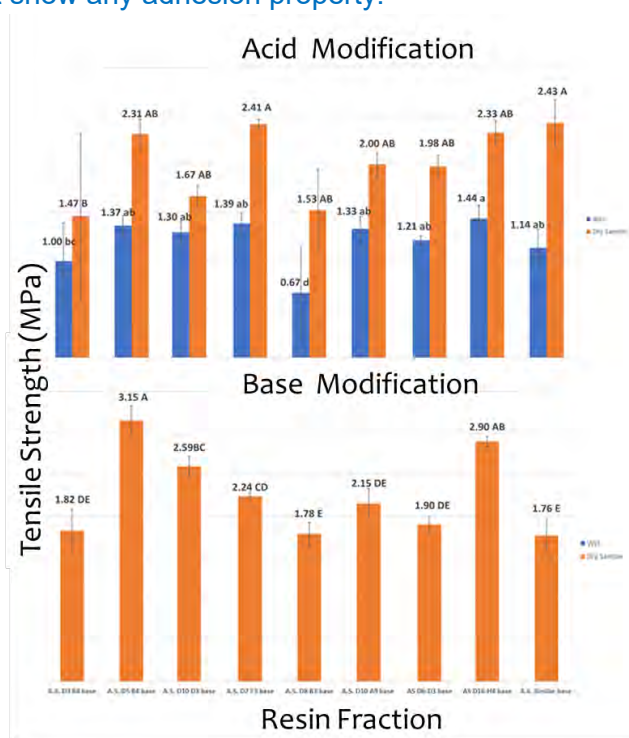


Figure 18. Adhesion properties of distilled resin fractions.

SYSTEM PERFORMANCE & SUSTAINABILITY

Project Coordination: Colorado State University (Dr. Jason Quinn) leads the fortnightly working group meetings. 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 has at least two meetings each month with presentations being done every other meeting and slide updates on the other. 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:

- Revision of bagasse to fuels manuscript
- Resign modeling
- Jet fuel from Fischer-Tropsch modeling
- Advancement of guayule integrated model
- Developed and moderated sustainability team meetings on a bi-monthly basis in support of research goals
- Hiring of additional personnel – J. Torres – to lead LCA of Hevea and guar

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

Issues/Risks:

Fan: Currently, a PhD student S. Yao is working on part of this project. (He is supported by a scholarship in Fall 2021 and Spring 2022 semesters, and will be funded via SBAR during summer 2022). Now we are also in the process to have a new student joining our group next fall semester.

Miller: The IMPLAN modelling is not complete because reevaluation of prior work identified some potential improvements that could be made to the approach. This puts the work behind schedule but is an improvement in quality. I have some concerns about the importance of this work now – with the lack of interest in growing guar, is improving the IMPLAN modelling of the economic impact worth the time investment? (Waiting on forage analysis to decide on guar analysis.) Have not made progress on the guayule IMPLAN data, lagging due to teaching load last semester.

The hemp project is on hold for now. Waiting on co-author to finish an unrelated project.

There are two projects that were not in the original 5-year plan, but were identified as important at the SBAR retreat. Work is progressing on these two projects, which will be part of graduate thesis projects. The delay in identifying the best method for forage analysis may necessitate a change from Omotayo completing his research as his thesis. He is beginning work on more policy-focused paper on risk management options for guayule growers.

Quinn: J. Torres has been identified to work on the project and will fill two gaps. The first is the development of a Hevea LCA and the second is guar data reduction and manuscript development. This is why the guar work has been slow.

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 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	30 Mar 22
2 Miller	Addition of NM Specialty Crops to BENCO model	Add chili, onions, and pecans to the model to allow farmers the option to compare conventional crops to guar and guayule	30 Sep 21
3 Miller	Evaluate the potential for using guar as water-saving forage for dairy rations in eastern NM	Manuscript submitted	31 Jan 22
4 Miller	Develop sensitivity analysis for water usage and labor costs of guar and guayule adoption	Presentation abstract and manuscript submitted	30 Jun 22
5 Miller	Feasibility research on having guayule custom-harvested instead of using farmer's own equipment (BENCO)	Presentation abstract and manuscript submitted	30 Apr 22
6 Quinn	Techno-economic and Life Cycle Assessment results	Update/finalize economic and environmental impact results (guar); final report generated	1 Sep 22
		Updated economic and environmental impacts (guayule); final report generated	31 Aug 22
7 Seav	Validated integrated model, including alternative crops	Updated integrated model to evaluate farm-level economics	31 Aug 22

Evaluate Economic Impacts in Rural Areas Using Whole Farm Budgets and Input Models:

Many of the projects use the BENCO model as the basis for analysis. Two new student research projects have begun, one uses BENCO to assess the feasibility of offering custom-harvesting of guayule to attract growers. This was presented at NMSU Research Week and is progressing as a manuscript. The USDA risk management program evaluation is just beginning.

The IMPLAN discussion is being re-evaluated to better capture the economic impacts of growing guar as opposed to conventional grains, with some concerns identified in the risk section below. No progress was made in the last quarter on modelling the impact of a guayule plant in Arizona. I still need to obtain information for the plant parameters, including the number of inputs, including labor, that a plant would use.

Addition of New Mexico Specialty Crops to the BENCO Model:

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 Seavert. We have not met with New Mexico pecan grower and harvester to meet and discuss.

Evaluate Potential for Using Guar as Water-Saving Forage for Dairy Rations in Eastern NM:

The evaluation of guar as a potential dairy forage is progressing. Omotayo met with researcher at Leyendecker ASC to learn how samples were dried for writing the methodology section of the manuscript. The type of forage analysis was decided. Currently, we are waiting on yield analysis to determine which variety of guar will be analyzed as the most promising forage variety.

Develop Sensitivity Analysis for Water Usage and Labor Costs of Guar and Guayule Adoption:

Omatayo is working on the water usage part. Submitted poster abstract for NMSU Research Week, and he received 3rd place award for his poster presentation. GAMS model for profit maximizing crop mix of guayule under different levels of water constraints.

Labor sensitivity analysis has begun for chili, will look at option for growing guayule as a crop substitute under different labor costs.

Feasibility Research for Guayule Custom-Harvest vs. Farmer Equipment (BENCO):

Nothing new to report.

Techno-economic and Life Cycle Assessment Results:

Process Modeling: The focus this quarter was continued updating of the model. Specifically, two areas have the focus: 1) bagasse to fuels and 2) resin distillation. Jet fuel represents a prioritized co-product from the bagasse. We have previously developed a pyrolysis model and integrated it. This quarter we developed a Fischer-Tropsch module and integrated it into the modeling framework. The work includes literature-based assumptions which need to be validated with experimental data. Additionally, work has been dedicated to the development of a distillation model. Two models have been developed at different fidelities. Both are constructed in ASPEN. We are now directly working with UA and NMSU to properly validate the performance of the models in terms of constituents.

Table 11. Results of High Temperature Fischer-Tropsch (HTFT) and Low Temperature Fischer-Tropsch (LTFT) on the minimum rubber selling price.

Baseline Min. Rubber Selling Price	\$3.05 /kg
HTFT Min. Rubber Selling Price	\$4.65 /kg
LTFT Min. Rubber Selling Price	\$4.53 /kg

Validated Integrated Model, including Alternative Crops:

Updated the integrated models as changes were needed for machinery calculations, budget modifications and guayule yields, as well as other minor modifications within the model.

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	28 Feb 22
		Submission of manuscript based on field trial data	30 Apr 22

Scenario Analysis:

The CSU team continues to work on the integrated models with a focus on guayule modeling efforts. This past quarter collaboration with CSM has been minimal.

Bagasse to Fuels:

A bagasse to fuels model and corresponding manuscript have been developed with the manuscript submitted and we have responded to one set of reviewer comments. The model includes pyrolysis and pelletization pathways. Results include economic and environmental assessments of both pathways. Additionally, an additional fuels pathway model has been developed.

Co-product Analysis:

The CSU team is working on resin co-product modeling and supporting NMSU as they lead the co-product analysis. The CSU team and NMSU team are meeting weekly to collaborate on furthering potential co-product pathways. A vacuum distillation model is being developed around a promising value-add pest repellent.

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

ALL TASKS UNDER THIS OBJECTIVE WERE COMPLETED IN 2020

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

Task #	Description of Task	Deliverable	Target Completion Date
1 Fan	Develop optimization approaches for general harvest scheduling	Collect data and information for guar and guayule harvest scheduling	30 Sep 21

		Preliminary optimization models and results for harvest scheduling	31 Dec 21
		Final version of results summarized into manuscript; submission	31 Mar 22
2 Fan	Identify the optimal strategies related to the harvesting process for guayule	Comprehensive tests and modifications for proposed models related to guayule harvest scheduling complete	30 Jun 22
3 Fan	Continue integration of developed optimization modules for both guar and guayule	Summary of input data/parameters complete	30 Sep 21
		Summary of optimization models, algorithms complete	31 Dec 21
4 Fan	Construct system-level for optimal strategies for guar and guayule supply chains	Preliminary version of the instructions manual draft complete	31 Mar 22
		Final version complete	31 Aug 22

Develop Optimization Approaches for General Harvest Scheduling:

With the collected data and information for harvesting scheduling through existing research results, collaborators and public information, and the literature review in previous quarter, we constructed the optimization model (after the discussions and feedbacks from UA research group and Sustainability group), designed the solution approaches, and realized them through computer coding in this quarter. The model for harvesting includes harvesting window, machinery scheduling, resource limitations, late penalties, etc., and our focus is the “demand-driven harvesting planning and equipment scheduling”. The Figure below shows the problems and challenges in guar and guayule harvesting process.



Figure 19. Problems, challenges, and basic requirements.

Identify the Optimal Strategies Related to the Harvesting Process for Guayule:

The plan for Quarter 1 of 2022 is to perform numerical analysis from our proposed models and algorithms, and then share with the group for feedback.

Continue Integration of Developed Optimization Modules for both Guar and Guayule:

In last year, two optimization modules (facility location and transportation, production planning and machinery scheduling) are integrated in this quarter for guar and guayule supply chains and transportation. In this quarter, with the third developed optimization module for harvesting planning and equipment scheduling, the integration is continued.

For example, some previous results as our harvesting model’s inputs. In the first numerical study for harvesting, 13 guayule parcels will be considered (see figure below). The data, input parameters, algorithm codes and other collected information were summarized and organized for further integration. Also, the harvesting model will be integrated directly through Gurobi using Python and we have started writing computer codes and programs.

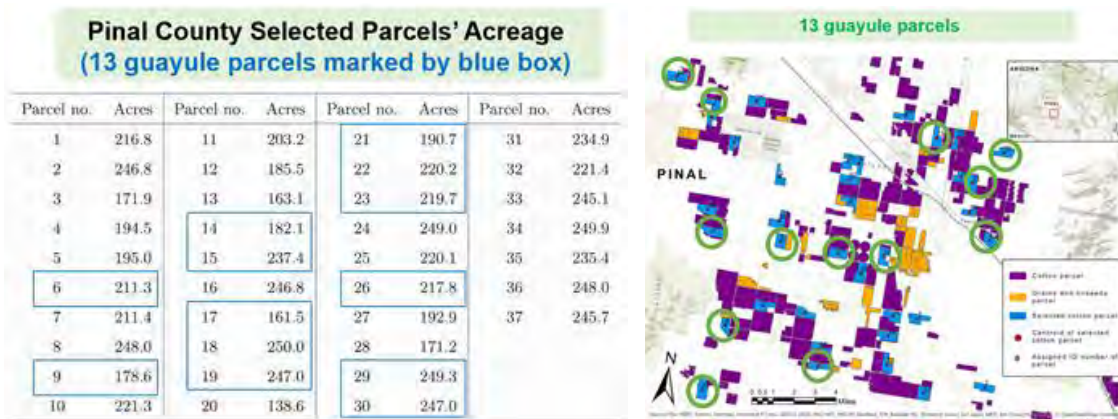


Figure 20. Data inputs - selected fields within Pinal County, Arizona.

Construct System-Level for Optimal Strategies for Guar and Guayule Supply Chains:

The 3rd version of the “Instructions Manual for Biomass Supply Chain and Transportation”, on how to use the developed optimization modules and to perform the analysis on economic benefits, social and environmental impacts, was updated in this quarter. With the development of module on harvesting optimization, the manual will continue to be updated in the following quarters.

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.

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: Hiring a new research assistant is helping me to continue working on all photographs and videos collected to develop educational videos, GIFs, and graphic arts. Field demonstration was delayed by COVID and prolonged drought.

Evancho: Some website materials are slightly behind schedule. All deliverables associated with website update are started except for Disease and Irrigation for Stand Establishment. They will all be delivered before March with the exception of Irrigation for Stand Establishment, which we are waiting for the experiment completion in years 5 and possibly 6.

Fields: I am still working to finalize the Year 4 Annual EEO Evaluation report. I had anticipated that it would be complete by the end of October, but my son broke both of his arms and was in casts (with both arms fully immobilized) and so I had to provide with so much additional care (feeding, bathing, dressing, helping with homework, etc.) that I fell further behind on writing that report. Most recently, COVID swept our family and caused additional time away from work. I have kept current with other tasks, and will have the annual report completed as soon as possible.

Idowu: Some of the challenges faced are related to the spread of the COVID-19 pandemic. For example, the NM Sustainable Agriculture Conference was moved from in-person to virtual. This prevented us from holding a tabling event during the December conference. Because of the spread of the COVID-19 Omicron variant, it is still unclear whether in-person extension events will be held in the winter months.

The guar end of project survey will most likely not take place in New Mexico. Farmers are unlikely to respond to our survey because guar is no longer a viable seed crop due to a lack of a processing facility. I met with the evaluator and we talked about the challenge. Under the current conditions in NM, the evaluator believes that such a survey may be impossible.

Miller: No progress on the *Guar*-dians of the Biosphere curriculum occurred during this quarter; no communication was received from participating teachers.

Shafer: Lesson adaptation is behind but in progress. Newly hired 4-H curriculum specialist has been tasked with completing curriculum work started by Morris; this should be completed by the end of Q1 2022. Guar-dians of the Biosphere work is also delayed due to lack of engagement from the active teachers. This task has moved to NM team under F. Miller.

Rock: Due to recent University developments, we believe that we are now able to begin recruiting students and the mentors for internship deployment for Spring and Summer 2022. We have worked with the project PI to initiate the final intern experiences in 2022. This has allowed our research and extension team to prepare interns for semesters when faculty, staff, and students have fully returned to campus, and allow the project team to fulfill remaining project objectives.

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	31 Aug 22
		Create videos of guar germination and growth	31 Aug 22
2 Angadi	Guar critical stage irrigation study	Produce report on guar crop growth based on irrigation management	30 Apr 22
3 Evan	Produce guayule newsletter articles	At least 2 guayule articles drafted and published – targeting AZ growers	31 Aug 22
4 Evan	Develop outreach documents for guayule	Background and introduction of guayule	31 Apr 21
		Guayule yield by variety	30 Jun 21
		Plant population management	30 Jun 21
		Guayule weed management	31 Aug 21
		Land preparation and planting	31 Dec 21
		Planting Dates and Timelines	31 Dec 21
		Fertilization	31 Dec 21
		Pest Control	31 Jan 22
Diseases	28 Feb 22		
Irrigation Water Management for Establishment	30 Apr 22		

5 Idowu	Travel to conferences	Present SBAR info/materials at 4-5 grower commodity conferences	31 Aug 22
6 Idowu	Continue 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) Peer-reviewed publication on N&P multilocational trials Generate trial summary (published on SBAR website)	31 Aug 22 28 Feb 22 31 Aug 22 31 Aug 22
7 Idowu	Newsletters to inform stakeholders	Distribute fall newsletter Distribute spring newsletter	31 Dec 21 31 Jul 22
8 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 21 31 May 22 31 Jul 22 31 Aug 22
9 Seav	Demonstrate breakeven price and yields of crips in cropping system	Updated BENCO models for AZ and NM Extension Extension publication Participate in Extension workshops	30 Sep 22 30 Sep 22 30 Sep 22
10 Seav	Validate flexible cash rent lease option for managing risks	Draft Extension publication regarding equitable lease arrangements	30 Mar 22
11 Seav	Assess financial benefits of crop insurance as risk management tool for guayule	Draft Extension publication re: financial impacts of crop insurance for guayule	30 Mar 22
12 Seav	Demonstrate trade-offs of machinery ownership to custom hiring operations	Draft industry article re: machine needs and options for guayule	31 Aug 22
13 Seav	Update cost/return budgets for all crops in Sensitivity Analysis model	Generate six Extension cost of production bulletins for AZ and NM	31 Mar 22

Guar Photographs and Videos:

With the help of new research assistant, Mallory Nielson, we have made good progress in guar extension and outreach projects, in spite of adverse weather and COVID.

We have developed needed animations and editing videos showing guar crop growth in response to different deficit irrigation management strategies. We will put captions and add

some commentary to it. We collected weekly photos and additional time lapse of guar plant growth focusing on inflorescence growth and development in irrigation and fertility management trial. We have put the video together. We will edit and put necessary captions, some info and voice over to finalize the video. We may repeat time-lapse video collection to improve quality.

Guar Critical Stage Irrigation Study:

First draft of factsheet on Guar Response to Temperature has been developed and is being reviewed and revised. We have made progress in analyzing deficit irrigation results and preliminary drafts are getting ready in two weeks. We will use the information from those manuscripts to develop fact sheet on Guar Deficit Irrigation.

Produce Guayule Newsletter Articles:

Winter newsletter was sent and will now be quarterly to increase dissemination of scientific materials.

Develop Outreach Documents for Guayule:

The variety trial document has been completed and submitted to FastTrack for review. The weed control rough draft is completed and ready for submission. Rough drafts of crop budgets for corn, cotton, wheat, barley, and alfalfa have been completed. After grower review and update, these will be submitted to FastTrack for review. These documents are being developed in collaboration with Seavert, Teegerstrom, Ollerton and Evancho.

Travel to Conferences:

Presentation of guar N and P trials was given at the ASA-CSSA-SSSA annual meeting in November.

Establish Guayule and Guar Trials in New Mexico:

The on-station guar spacing trials at 4 locations (Los Lunas, Clovis, Tucumcari, and Las Cruces) in New Mexico were harvested.

The guayule demonstration trial is progressing well in NM. We are monitoring the winter survivability of the plants to determine the variety adaptability to the southern New Mexico environment. The guayule cold tolerant trial in Las Cruces in partnership with Bridgestone is also progressing well.

Newsletter to Inform Stakeholders:

Nothing new to report.

Design and Implement Extension & Outreach Evaluation:

Nothing new to report.

Demonstrate Break-Even Price and Yields of Crops in Cropping System:

Miller and her graduate student of NMSU is continuing to develop BENCO instructional manual/videos for Extension educators in both English and Spanish languages. This feature will not only be very helpful for producers but also for student education sessions scheduled for this



Photo 9. Guayule field, Las Cruces, New Mexico.

summer. The extension/outreach efforts of the BENCO model are currently stalled waiting for invitation from extension educators.

Validate Flexible Cash Rent Lease Option for Managing Risks:

Continue to validate the methodology of estimating equitable annual cash rent, crop share, or flexible cash rent leases. On target to validate model but publishing results may be delayed to the following year.

Assess Financial Benefits of Crop Insurance as Risk Management Tool for Guayule:

Assisting Miller at NMSU with researching the financial benefits of crop insurance as a risk management tool for guayule.

Demonstrate Trade-Offs of Machinery Ownership to Custom Hiring Operations:

Assisting Miller and her graduate student at NMSU with the economic trade-offs of machine ownership to custom hiring when harvesting guayule.

Update Cost/Return Budgets for all Crops in Sensitivity Analysis Model:

Developing enterprise budgets for AZ is underway. Crop budgets include Durum wheat, spring barley, cotton, corn silage, and alfalfa hay. A broader grower/industry review is scheduled for mid-February 2022. The recently published guayule enterprise budget will need to be updated to reflect rapidly increasing input costs, this will allow for a more accurate projection of net returns on a whole farm basis for grower decision making. On target to publish budgets but when the industry can access this data will be dependent on UA Extension publications.

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	Educate local producers about guar	Arrange guar field day/field walk at Agricultural Science Center, NM	15 Aug 22
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 22
4 Evan	Present guayule production information to Native American farming communities	Presentation to Native American Farm Boards	31 Aug 22
5 Evan	Communicate with AZ growers and producers	Maintain relationships with local growers to share SBAR/guayule information	31 Aug 22
6 Fields	Track Grower Extension Team activities monthly	Compiled contact data totals submitted quarterly	31 Aug 21

Educate Local Producers about Guar:

We will continue working on developing guar web page for producers. Our efforts to further improve guar presentation materials will continue.



Photo 10. Exploring a guar field at the Guar Field Day, Clovis, New Mexico.

Establish Farm Demonstration Site in New Mexico:

Due to severe drought and COVID we could not conduct demonstration during the year. We will plan to conduct a field scale demonstration of guar in 2022 and make an effort to recruit farmers for the demonstration. Loss of Guar Resources as the only guar market for farmers in the US, will hurt this effort. However, we will make sincere effort to conduct the demonstration or plan for alternative outreach activities to educate wider audience.

Grower Workshops in Arizona:

Guayule Field Day was held on October 6th. 19 participants. Three additional crop producers in Maricopa and Pina counties were briefed on the field day the following week.



Photo 11. Sam Wang, Bridgestone Americas, discusses guayule production with growers at the Guayule Field Day, Eloy, Arizona.

Guayule and Native American Communities:

Bridgestone is scheduled to plant a guayule field with Tohono O’odham Native American Tribe next spring. Bridgestone is also scheduled to plant a guayule field with a family on the Gila River Indian Community in the spring. A private grower from the Gila River Indian Community attended the Guayule Field Day in October.

Communications with Arizona Growers:

Ethan Orr, ANR Associate Director and Dr. Ed Martin, interim director of Cooperative Extension, have been updated several times on guayule production. Information is used in meetings with policy makers to respond to questions about water availability in Central Arizona.

Two interviews were given this quarter. One to scientific journalist, Virginia Gewin, the other to the Desert Leaf reporter, John Smith. Both interviews were on water shortage impacts to agriculture in Central Arizona. Discussed guayule production with Todd Fichette, Western Farm Press Reporter for future story on guayule.

Community outreach event in Pinal County took place reaching 152 individuals in Pina County. My presentation covered how much water wheat, cotton, alfalfa, and guayule use and how these crops are used in our daily lives.

Track Grower Extension Team Activities Monthly:

The table below quantifies outreach by event during Q4 2021. Due to the ongoing impact of the COVID-19 pandemic, very limited outreach events are able to be scheduled in person. No significant personal contacts were noted. While late summer saw field days as reported in Q3, the team was able to host one school-focused event at the Clovis field site in October prior to the surge of the omicron variant. That event was attended by nearly 700 school children from 14 schools around the Northeastern region of NM. SBAR researchers and graduate students gave a general introduction to agriculture, including guar and participated in the guar bubbles activity, which continues to be extremely popular with groups.



Photo 12. Guar field day, Clovis, New Mexico.

Table 12. Outreach conducted during Q4, 2021.

	Event	Date	Number participating
AZ	None to report	N/A	N/A
NM	Student Field Day at Clovis	10/6/21	Approx. 700 students from 14 schools

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 21 31 May 22 30 Jun 22 31 Jul 21
2 Miller	Create video presentations under specific Agri-Business topics	10 videos (5-7min/ea) complete	31 Dec 21
3 Miller	Finalize SBAR Ag Science project development on bioeconomy	Recognition of SBAR-related science fair projects at NM State Fair Final manual (publication) for starting an Agri-Sci project Host workshop with FFA teachers and 4H Agents (coaches for Agri-Sci students) Host mentoring session for interested students to support FFA SAE project development	30 Sep 21 31 Dec 21 31 Mar 22 30 Jun 22
4 Miller	Co-lead development of <i>Guardians of the Biosphere</i> curricula and activities	Draft bioeconomy-related 4-H project curricula for grades 5-7; initiate curriculum review	30 Jun 22
5 Shafer	Adapt existing curriculum for 4H program	At least 3 curricula adapted Monitor curricula in action Evaluate SBAR curriculum experience	31 Mar 22 31 Mar 22 31 Mar 22
6 Shafer	Implementation of <i>Guardians of the Biosphere</i> curriculum	Evaluation summary	30 Jun 22
7 Shafer	Design STEM volunteer training program; recruit volunteers	Host 3 STEM volunteer trainings	31 Mar 22
8 Shafer	Develop STEM internship program plan, recruitment plan, evaluation plan	Develop list of partner companies/organizations Completed internship program plan, recruitment plan, and evaluation plan	1 Oct 21 1 Jan 22

		Evaluate 10 youth in intern experience	30 Jun 22
9 Rock	Update SBAR internal materials on <i>Project Puente</i>	Update resource documents and presentation for SBAR faculty	31 Dec 21
10 Rock	Recruit students for summer <i>Project Puente</i> internships	Recruit 7 students for internship	30 Apr 22
11 Rock	Recruit faculty mentors for summer <i>Project Puente</i> internships	Recruit 5 faculty mentors for <i>Project Puente</i> interns	30 Apr 22
12 Rock	<i>Project Puente</i> student project development and deployment	Facilitate SBAR internship projects; final poster presentations highlighting student work	31 Jul 22
13 Rock	<i>Project Puente</i> case study video	Design and develop short video highlighting student/mentor experiences for future training needs	31 Aug 22

Design and Implement Evaluation Tools:

During Q3 of 2021, the primary tasks related to the evaluation of the EEO components of the SBAR project included 1) continued participation in regular team and EEO all hands meetings; 2) ongoing analysis and review of evaluation data, meeting notes and other artifacts for the purpose of developing quarterly and annual reports and contributions towards publications in progress; 3) meetings with co-authors on graduate student publication in progress; 4) continued work on draft for a publication about the various formal and informal modalities that SBAR developed content and resources are being used in, adding additional as the YD efforts have moved forward; 5) met with extension leads to revise and discuss grower's assessment survey and plan to implement; 6) continued work on draft of graduate student summative project survey; 7) developing initial draft of overall project survey to go to all team members; 8) worked collaboratively with NM YD lead to develop a survey for MS workshop, waiting to receive data for analysis.

Grower-Focused Extension – The grower-focused extension team, work during this quarter included post-harvest processing and additional research, work on publications, and attendance at an agronomy society meeting where a poster was presented on guar irrigation. The team worked on a number of publications/extension fact sheets. A full publication was submitted in November for review by UA. They are currently writing up a Nitrogen fertilization publication on guayule.

The entire EEO team contributes content on an ongoing basis not only to the website, but also via a newsletter. The website continues to grow in educational content and resources that are available to and can be useful for a variety of educators. Similarly, the extension tools and briefs are useful in sharing both basic information about guar and guayule but also more grower-focused agronomic information.

Youth Development Extension – For the Youth Development team, efforts over Q4 included developing and implementing an adult training experience for adult volunteers, development of two levels of internship programs for summer 2022 in AZ, development

and implementation of a public speaking workshop to support science fair students in NM, and continued engagement of STEM Ambassadors in SBAR content. An initial adult training was held in Phoenix in November, although attendance was lower than hoped (only 7 attended, one of whom was a 4-H leader while the others were extension agents), likely due to COVID. Two more workshops are planned for this spring in Prescott and Pinetop-Lakeside where educators will take supply kits for distribution with training. While Phoenix is a large, diverse metropolitan city, Prescott and Pinetop-Lakeside are largely white communities, therefore an additional training is being explored in the Rio Rico/Nogales area South of Tucson. At the public speaking event, SBAR researcher Catie Brewer gave a talk on what a bioeconomy is prior to the workshop activities. An evaluation tool was developed for the public speaking workshop and I am waiting for the return of the surveys for analysis. I am working with David to develop an evaluation tool for the upcoming workshops.

Create Video Presentations on Specific Agri-Business Topics:

First four Spanish/English videos introducing Excel concepts using SBAR examples are recorded. Meetings scheduled for Ramos-Coronado to work with Anderson on any revisions that need to be made. Ramos-Coronado is also developing the supplemental curriculum/instructions that will accompany the videos. Depending on the feedback from Anderson about suggested changes and the level of detail needed in supplemental material, he should finish this project in the next quarter.

Finalize SBAR Ag Science Project Development re: Bioeconomy:

The 4H Agri-Science Project is moving forward. The contests were held, and the McKinley Extension Agent has agreed to help try to add an Agri-Science contest to the Navajo Nation Fair for 2022. A committee of New Mexico extension agents and teachers has been identified and is scheduling the first committee meeting for February 2022.

The Agricultural Public Speaking Workshop was attended by 60+ New Mexico kids.

- 22 High School, 17 Middle School, and 19 elementary + additional late registrations
- 46 students identified as white, 12 as American Indian, and 11 as Hispanic ethnicity
- Middle School and Elementary students attended workshops that featured SBAR curriculum
- All students received t-shirts that included SBAR logo

Students from San Fidel had to cancel live attendance because of Covid, but received a “box of swag” that included t-shirts and SBAR curriculum and materials



Photo 13. Students participating in the New Mexico Agricultural/Natural Resource Public Speaking workshop, focusing presentations on SBAR-related topics.

Co-Lead Development of *Guardians of the Biosphere* Curricula and Activities:

Nothing new to report.

Adapt Existing Curriculum for 4H Program:

No movement on curriculum adaptation in Q4. However, Matt Swanson, Associate in Extension, 4-H Curriculum Development has joined the team and will undertake this task in early Q1 2022. Matt will continue work started by Nick Morris.

Implementation of *Guardians of the Biosphere* Curriculum:

Adaptation of Guardians of Biosphere content adaptation is stalled, but the NMSU partners have reached out to active teachers regarding their participation in curriculum development. If they continue to be unresponsive, the youth development team will develop a curriculum with the available resources. This task has been taken over by NM team under Frannie Miller.

Design STEM Volunteer Training Program; Recruit Volunteers:

The first of multiple SBAR / AZ 4-H STEM Workshops took place November 13 at the Maricopa County Cooperative Extension office. Youth development professionals and current volunteers participated in the workshop. Based on evaluation feedback, some slight changes have been made for the next two workshops which are scheduled for Feb. 26 and Mar. 26, 2022, in Lakeside and Prescott, AZ, respectively. Updated plan is to model activity kits, then distribute materials to interested parties.



Photo 14. Participants engaging in hands-on curricula at the SBAR-STEM Workshop, Phoenix, Arizona.

Develop STEM Internship Program, Recruitment, and Evaluation Plans:

Brassill, Bruhn, and Shafer collaborated to reimagine the internship program for summer 2022. The program now has two aspects: SBAR Explorer Internship and SBAR Research Internship. Application and advertisement materials were developed and will be distributed in early Q1 2022. Several faculty and youth have already expressed interest in participating.

Update Internal Materials on *Project Puente* Internships:

Nothing new to report.

Project Puente Internship Student Recruitment:

Nothing new to report.

Project Puente Internship Faculty Recruitment:

As stated previously, our team switched gears to offer internships 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 of 6 student interns and associated SBAR faculty to participate in the final project year.

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 at the culmination of the project.

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: Daugherty has continued to be overloaded with COVID-related teaching disruptions and has not been available to work with Fernando on SBAR lesson/activity implementation. Likewise, Bradley and Mikesell were not available to being classroom/afterschool planning for fellows. Brewer and Fernando will focus on Theme 5 lesson plan revisions within the SBAR format while case numbers remain high.

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	Observe digital SBAR lesson deliveries by each Fellow	Fall observation	30 Nov 21
		Spring observation	30 Apr 22
2 Fields	Design/Schedule classroom evaluation tools, protocols and metrics for all Education activities	Fall tools developed/refined; evaluation data gathered	31 Dec 20
		Spring tools developed/refined; evaluation data gathered	31 May 21
		Summer tools developed/refined; evaluation data gathered	31 Jul 21
		Data synthesized; evaluation report generated	31 Aug 21

Observe Digital SBAR Lesson Deliveries:

Nothing new to report.

Design and Implement Classroom Evaluation Tools:

For the Education team, activity in AZ over Q4 continued to focus on engaging 2 fellows in the weekly seminar course, continuing to finalize curriculum lessons and related resources such as reviewing and editing videos (of researchers and other team members during the retreat), working on a publication to describe and share knowledge about the SBAR education graduate fellow experience and outcomes, and beginning to market SBAR materials to teachers. Team

members presented information about SBAR educational materials at the Arizona Science Teacher’s conference in Phoenix in November where again COVID impacted the numbers. Thoughts are that a table display might be a better option for future events. A number of tables had balloons and candy and other giveaways and seemed to attract attention and visitors who then generated conversations. As teachers are exhausted and many are leaving the profession, finding creative ways to distribute and encourage use of educational materials is challenging right now. The ‘Loteria’ game is proving to be a good giveaway that generates conversation about the idea of a sustainable bioeconomy. The group is still 10 cards short for a full game.

In NM, they have been able to successfully recruit graduate education fellows to pick up on the work in progress. This includes creating lessons for the fifth theme on Agricultural Economics to round out the curriculum. The goal is to finalize the curriculum lessons across both teams by the end of the spring semester. In addition, NM has identified that the ‘Guardians of the Biosphere’ after school program will continue, and the teacher located in NE NM near the Clovis field site will have a graduate student to support his work. Also planned for the Education team (AZ and NM) this spring are additional efforts to publicize the materials more broadly with educators via links on the website, through email list serves, conferences and leveraging 4-H teacher contacts. The omicron surge of COVID has yet to peak in AZ or NM, so while some in person activities had resumed in the late summer and early fall, those activities have again been put on pause.



Photo 15. Catherine Brewer and SBAR Teacher, Alan Daugherty, in his school classroom.

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

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Refine/Implement afterschool/4-H youth development curricula based on <i>Guardians of the Biosphere</i>	Two-semester curricula of SBAR-related activities and concepts suitable for middle school available on website	31 May 22
2 Brewer	Implement SBAR lessons in rural NM classroom, including in-person support	Feedback for refinement and dissemination of SBAR lesson plans in rural areas	31 May 22
3 Brewer	Dissemination of SBAR resources through conferences and online	Two conference presentations/workshops SBAR lessons for all 5 themes posted to website	31 Aug 22 31 Aug 22

4 Brewer	Collect education/outreach data to support program evaluation	Data associated info provided to program evaluator	31 Aug 22
5 Chav	Edit lessons and materials for online publication	Edit lessons Prep for digital posting	31 Mar 22 31 Aug 22
6 Chav	Support lesson plan design by teacher-Fellow partnerships for digital transition	Fall: Fellow lesson editing, recording, planning Spring: Fellow lesson editing recording, planning Advise and support NM teach as requested/needed	30 Nov 21 31 May 22 30 Jun 22
7 Chav	Present materials at conferences	Association for Science Education NARST NSTA-TBD	1 Jan 22 30 Apr 22 30 Jun 22
8 Chav	Design, scheduling and implementation of evaluation tools and metrics	Fall evaluation data gathered Spring evaluation data gathered	31 Dec 21 31 May 22

Refine/Implement 4H Youth Development Curricula Based on *Guardians of the Biosphere*:

Fernando revised the presentation and lesson plan for the pyrolysis/combustion (s'mores) activity for Theme 5 and submitted a draft to the Education Team for review.

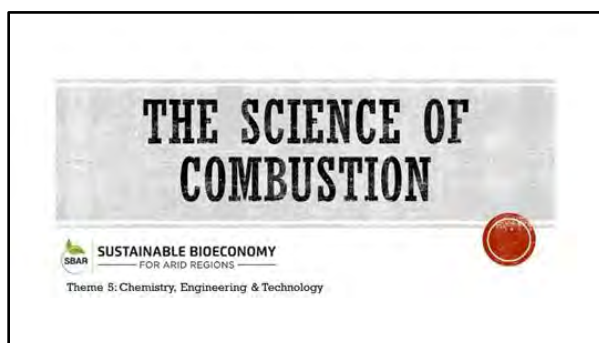


Figure 21. Cover slide for the revised pyrolysis/combustion lesson.

Implement SBAR Lessons in Rural NM Classroom:

Brewer and Fernando met weekly with Miller, Ramos-Coronado, and Omatayo to coordinate work on 4-H and science fair events, including a public speaking workshop for 4th-12th graders.

Dissemination of SBAR Resources through Conferences and Online:

Singh, 2020-2021 Fellow, presented on behalf of the SBAR Fellows at the Soil Science Society of America annual meeting.

Collect Education and Outreach Data in Support in Project Evaluation:

Nothing new to report.

Edit Lessons and Materials for Online Publication:

Weekly SBAR Fellow sessions were led by Chavarria, Knox, and Anderson. These in-depth working sessions led to a new version of the SBAR Lotería Game by SBAR Fellow Arisbeth Ibarra Nieblas. The lotería has cards in English, Spanish, and selected cards in the language of the Tohono O'odham to reflect the place-based nature of this version of the lotería. The lotería is inspired by the Sonoran Desert, agriculture in arid regions, bioeconomy in arid regions, and the SBAR project. Educators can use the cards to teach vocabulary and concepts about arid lands. The cards can also be used in story telling activities with students developing a concept, process or story to connect a set of cards.

Knox worked with SBAR Fellow, Ali Yaylali, on a research article and completed a draft. They used data from student (fellow) reflections over three years, seminar syllabi, and analysis of products/lessons produced by fellows. The article will be submitted to a journal in February 2022.



Figure 22. A game board of the SBAR Lotería Game created by Arisbeth Ibarra Nieblas.

Let's Play SBAR Lotería

SBAR Fellow, Tenzin Phakdon, worked on a lesson on environmental sustainability. The Education Team worked extensively on this lesson, providing edits, due dates, and step-by-step instruction on lesson development. Phakdon will not be returning as an SBAR Fellow in the Spring 2022 semester and the Education team will continue to work to revise the lesson that Phakdon was able to start.



Figure 23. Example lotería cards.

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

The Education Team worked with Tucson Media Studios to provide detailed feedback on rough video footage that was captured during the 2021 SBAR Annual Retreat. These edits included:

1. Adding in the video SBAR intro/exit slides
2. Adding in the interviewee's name, title/department, and university affiliation
3. Adding in the interview questions
4. Adding in key words/text

Tucson Media Studios will provide revised versions of the videos to the Education Team in January 2022.

In addition to working with SBAR Fellows, the Education Team has worked closely with two new members of the SBAR Team, Jacqueline Bruhn and David Shafer. The Education Team worked with Bruhn to feature the loteria game in the latest EEO Newsletter. Chavarria, Knox, and Anderson worked with the new team members to strategize for the SBAR Educational resources after the end of the SBAR project work. The Education Team met with David Shafer for an in-depth review of the SBAR materials and future 4-H connections with these materials. The discussion included:

- Big picture overview of translating SBAR into topics for lessons
- How the SBAR Seminar led to the lesson development
- CommunityShare as an opportunity to connect with schools
- How 4-H can carry on these lessons after the end of the SBAR project

Present Materials at Conferences:

The SBAR Education Team presented their work at the Arizona Science Teacher Association (AZSTA) conference on November 5, 2021. Knox presented an overview of the SBAR Education program. SBAR Fellow, Arisbeth Ibarra Nieblas, shared her process of working with an SBAR teacher and the SBAR Loteria Game that she developed. There were 30 people in person at the event and 200 on zoom due to COVID. The conference presentation raised important questions about how to get SBAR resources to the right people, utilizing clear branding, and serving schools that are facing severe teacher shortages.



Photo 16. SBAR Fellow, Arisbeth Ibarra Nieblas, presenting her work at the Arizona Science Teacher Association meeting, Phoenix, Arizona.

Design, Scheduling and Implementation of Evaluation

Tools and Metrics:

Nothing new to report.

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

ALL TASKS UNDER THIS OBJECTIVE WERE COMPLETED IN 2019

AWARDS

Items appearing in blue font are new in this quarter.

2021

Camero, J. *National STEM Scholar*. Selected as one of ten National STEM Scholars, who work to inspire the creativity and passion of middle school science teachers. National STEM Scholar Program Competition. September.

Omatayo, O. *3rd Place Poster Presentation, New Mexico Research & Creativity Week*. Awarded in the Graduate Student presentation section in the Agricultural Category of the NM Competition. November.

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 – December 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. **Acharya, B.R.; Sandhu, D.; Duenas, C.; Ferreira, J.F.S.; Grover, K.K. 2022.** *Deciphering molecular mechanisms involved in salinity tolerance in guar (*Cyamopsis tetragonoloba* (L.) Taub.) using transcriptome analyses*. *Plants (Basel)*. 2022 Jan 22; 11(3):291. DOI:10.3390/plants11030291.
3. **Bayat, H.; Cheng, F.; Dehghanizadeh, M.; Brewer, C.E. 2021.** Recovery of nitrogen from low-cost plant feedstocks used for bioenergy: a review of availability and process order. *Energy & Fuels*, 35(18), 14361-14381. DOI:10.1021/acs.energyfuels.1c02140
4. **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.
5. **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
6. **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.
7. **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
8. **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.
9. **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.
10. **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.
11. **Cruz, V.M.V.; Dierig, D.A.; Lynch, A.; Hunnicut, K.; Sullivan, T.R.; Wang, G. (S.); Zhu, J. 2021.** Assessment of phenotypic diversity in the USDA, National Plant

- Germplasm System (NPGS) guayule germplasm collection. *Industrial Crops and Products* (175) 2021.114303. DOI:10.1016/j.indcrop.2021.114303.
12. **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.
 13. **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.
 14. **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]
 15. **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]
 16. **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]
 17. **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.
 18. **Madasu, C.; Xu, Y-m.; Wijeratne, E.M.K.; Liu, M.X.; Molnár, I.; Gunatilaka, A.A.L. 2022.** Semi-synthesis and cytotoxicity evaluation of pyrimidine, thiazole, and indole analogues of argentatins A-C from guayule (*Parthenium argentatum*) resin. *Medical Chemistry Research*. DOI:10.1007/s00044-021-02835-1
 19. **Mealing, V.; Turek, J.; Smith, J.; Landis, A. 2021.** Social sustainability of new bio-based feedstocks in the Southwest. *The International Journal of Social Sustainability in Economic, Social, and Cultural Context*. 18(1): 23-42. DOI:10.18848/2325-1115/CGP/v18i01/23-42.
 20. **McCloskey, W.B.; Evancho, B.; Pier, N. 2021.** *Guayule weed management during establishment in Arizona*. Cooperative Extension Invasive Plant Management (IPM) Short. University of Arizona, Tucson, Arizona. 2p. September
 21. **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://bmcpantbiol.biomedcentral.com/articles/10.1186/s12870-019-2106-2>
 22. **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]
 23. **Rosalez, R.; Cheng, F.; Dehghanizadeh, M.; Bayat, H.; Cui, Z.; Jarvis, J.M.; Brewer, C.E. 2021.** Co-hydrothermal liquefaction of guayule bagasse and wastewater treatment algae. *Energies*. [Accepted; In Press]

24. **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.
25. **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.
26. **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.
27. **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
28. **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
29. **Summers, H.M.; Quinn, J.C. ND.** Improving water scarcity footprint capabilities in arid regions through expansion of characterization factor methods. *Science of the Total Environment* [In Press]
30. **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.
31. **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]
32. **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]
33. **Wang, G. (S.); El-Shikha, D.E.M.; Katterman, M.E.; Sullivan, T.R.; Dittmar, S.; Cruz, V.M.V.; Hunsaker, D.J.; Waller, P.M.; Ray, D.T.; Dierig, D.A. 2021.** Irrigation effects on seasonal growth and rubber production of direct-seeded guayule. *Industrial Crops and Products*. Volume 177, 2021, 114442. DOI:10.1016/j.indcrop.2021.114442.
34. **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.
35. **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.

36. **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	14	17	
Masters			11	11	1
PhD	1	2	3	2	

*Totals are through December 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*, 9/2021.

Scholarly Presentations

1. **Abdel-Haleem, H.; Mullen, C.; Luo, Z. 2021.** *Guayule – A promising biofuel and bioproducts crop*. Association for the Advancement of Industrial Crops 32nd Annual Meeting (hybrid). Bologna, Italy. 5-9 September.
2. **Angadi, S.V. 2021.** *Water management in stress prone environments: Lessons from New Mexico*. Managing Nature's Resources in Organic Cropping Systems under Water-Limited Conditions Webinar Series, Manitoba Organic Alliance, Canada. November [invited virtual speaker]
3. **Angadi, S.V. 2018.** *Sustainable Bio-economy for Arid Regions: Growing Guar*. Extension Field Day. Clovis, New Mexico. 9 August.
4. **Angadi, S.V.; Idowu O.J. 2021.** *Sustainable Bio-economy for Arid Regions: Guar Research*. Extension Field Day, Agricultural Science Center. Clovis, New Mexico. 3 August.
5. **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.
6. **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.
7. **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.
8. **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.

9. **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.
10. **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.
11. **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.
12. **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.
13. **Angadi, S.V.; Singh, J.; Singh, P.; Begna, S.; Gowda, P.; Guzman, I.; Idowu, O.J. 2021.** *Reducing irrigation water use by desert crop guar using deficit irrigation strategies.* American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America (ASA-CSSA-SSSA) Joint International Meeting. Salt Lake City, Utah. 8-11 November [poster]
14. **Armijo, J.; Bayat, H.; Dehghanizadeh, M.; Brewer, C.E. 2021.** *Hydrothermal liquefaction of hazardous biomass.* 2021 AIChE Student Annual Meeting. Boston, Massachusetts. 8 November.
15. **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.
16. **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]
17. **Brewer, C.E. 2018.** *Pairing biomass residues with conversion technologies.* Advanced Bioeconomy Leadership Conference, Washington, D.C. 28 February.
18. **Brewer, C.E. 2018.** *Polymerization and guar gum bubbles.* Outreach event activity. New Mexico 4-H State Conference. 11 July.
19. **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.
20. **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.
21. **Brown, K.S. 2020.** *Soil chemistry ... and other topics.* SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 25 March.
22. **Brown, K.S. 2020.** *Pathogens and Guayule (Parthenium argentatum): Literature Review.* SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. [virtual] 18 November.
23. **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]

24. **Brown, K.S.*; Neilson, J.W. 2018.** *Microbial contributions*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. April.
25. **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]
26. **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]
27. **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.
28. **Chen, Y.; Dierig, D.A.; Wang, S.; Ray, D.T.; Barberan, A.; Neilson, J.W. 2021.** *Using network analysis to identify critical soil microorganisms associated with guayule growth stages*. 2021 SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 August. [poster]
29. **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.
30. **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.
31. **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.
32. **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.
33. **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.
34. **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.
35. **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.
36. **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]
37. **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.
 38. **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.
 39. **Dehghanizadeh, M.; Brewer, C.E. 2021.** *Supercritical CO₂ extraction of resin and rubber from guayule (*Parthenium argentatum* Gray).* 2021 AIChE Annual Meeting, Boston, Massachusetts. 7-11 November.
 40. **Dehghanizadeh, M.; Knagg, A.; Romero, A.; Holguin, O.; Brewer, C.E. 2021.** *Testing of non-rubber extracts of guayule (*Parthenium argentatum*) as a bio-based urban insect repellent.* Tech Connect World Innovation Conference. National Harbor, Maryland. 18 October.
 41. **Dierig, D.A. 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.
 42. **Dierig, D.A. 2021.** *Update on Guayule Research and Development.* Guayule Field Day. Eloy, Arizona. 6 October.
 43. **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]
 44. **Ellsworth, P. 2021.** *Pale-striped flea beetle control at stand establishment.* Guayule Field Day, Eloy, Arizona. 6 October.
 45. **El-Shikha, D.E.M. 2018.** *Update – Guayule irrigation experiments at Maricopa Agricultural Center.* SBAR UA Research Team Seminar Series, Tucson, Arizona. 12 September.
 46. **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]
 47. **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]
 48. **Evancho, B.*; Schmalzel, C.; Lewis, M.; Teetor, V.H.; Ray, D.T. 2021.** *Response by guayule to nitrogen fertilizer in a semi-hydroponic system.* American Society for Horticulture Science Annual Conference, Denver, Colorado. 5-9 August. [poster]
 49. **Evancho, B.*; Teetor, V.H.; Willmon, J.; Bennett, M.C.; Montes, M.; Schmalzel, C.; Ray, D.T. 2018.** *Root structure differentiation between common guayule planting methods.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 2 August. [poster]
 50. **Evancho, B. 2018.** *Guayule Fuels the Future.* IES – Energy Talks Seminar, Sky Bar, Tucson, Arizona. 9 October.

51. **Evancho, B. 2019.** *Guayule: How Close Are We?* Marana Winter Field Crops Clinic. Marana, Arizona. 10 January.
52. **Evancho, B. 2019.** *Guayule: How Close Are We?* Casa Grande Winter Field Crops Clinic. Casa Grande, Arizona. 15 January.
53. **Evancho, B. 2019.** *Comparing direct-seeded and transplanted guayule roots.* SBAR UA Research Team Seminar, University of Arizona, Tucson, Arizona. 13 November.
54. **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.
55. **Evancho, B. 2021.** *Determining guayule minimum nitrogen requirements.* SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 5 May.
56. **Evancho, B. 2021.** *Guayule weed control strategies.* Guayule Field Day. Eloy, Arizona. 6 October
57. **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.
58. **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]
59. **Fan, N. 2018.** *Review on Optimization Methods for Biomass Supply Chain.* SBAR UA Research Team Seminar. University of Arizona, Tucson, Arizona. 28 November.
60. **Fan, N. 2021.** *Harvesting planning for guayule.* SBAR Research Team Seminar, University of Arizona, Tucson, Arizona. 29 September.
61. **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.
62. **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.
63. **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]
64. **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.
65. **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.
66. **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.
67. **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]
68. **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.
 69. **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]
 70. **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.
 71. **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.
 72. **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]
 73. **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.
 74. **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.
 75. **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]
 76. **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]
 77. **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.
 78. **Grover, K. 2018.** *Sustainable agriculture and guar production in New Mexico.* New Mexico State 4-H Conference, Las Cruces, New Mexico. 10 July.
 79. **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.
 80. **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.

81. **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.
82. **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.
83. **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.
84. **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.
85. **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]
86. **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.
87. **Grover, K. 2019.** *Guar: A potential alternative crop in New Mexico.* New Mexico Master Gardener's Meeting. Las Cruces, New Mexico. 8 May.
88. **Grover, K. 2019.** *Guar as an alternative crop in New Mexico.* New Mexico Sustainable Agriculture Field Day. Las Cruces, New Mexico. 26 June.
89. **Grover, K. 2019.** *Guar as an alternative crop in New Mexico.* SBAR Train-the-Trainer Workshop. Las Cruces, New Mexico. 2 July.
90. **Grover, K. 2019.** *Guar as an alternative crop in New Mexico.* SBAR Train-the-Trainer Workshop, Las Cruces, New Mexico. 2 July.
91. **Grover, K. 2019.** *Guar research and extension program in New Mexico.* Departmental External Review, Las Cruces, New Mexico. 10 October.
92. **Grover, K. 2020.** *Guar as an alternative crop in southwest USA.* 18th International Congress of Soil Science, Sindh Agriculture University, Tandojam, Pakistan. 11-13 February. [invited speaker]
93. **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]
94. **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]
95. **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]
96. **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]
97. **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]

98. **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.
99. **Grover, K. 2021.** *Guar as a potential crop in New Mexico*. Farm Field Day, Lyendecker Plant Science Center, New Mexico State University, Las Cruces, New Mexico. 25 August.
100. **Grover, K. 2021.** *Guar as a potential crop in New Mexico*. Farm Field Day, Fabian Garcia Plant Science Center, New Mexico State University, Las Cruces, New Mexico. 22 September.
101. **Grover, K. 2021.** *SBAR and guar in desert Southwest*. New Mexico State University Agriculture Day, Las Cruces, New Mexico. 25 September.
102. **Grover, K. 2021.** *Sustainable Bio-economy for Arid Region and Guar in New Mexico*. Farm Field Day, Fabian Garcia Plant Science Center, Las Cruces, New Mexico. 7 October.
103. **Grover, K. 2021.** *Guar as a potential crop in New Mexico*. Farm Field Day, Fabian Garcia Plant Science Center, New Mexico State University, Las Cruces, New Mexico. 23 December.
104. **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.
105. **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.
106. **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.
107. **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.
108. **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.
109. **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.
110. **Hoare, D.M. 2018.** *Irrigation Sensors and the WINDS Model*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 26 September.
111. **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]
112. **Hu, A. 2021.** *Management of guayule diseases*. Guayule Field Day, Eloy, Arizona. 6 October.

113. **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 WRRRC, Albany, California. 18 November.
114. **Ibarra Nieblas, A. 2021.** *Partnerships with Classroom Teachers and the SBAR Loteria Game.* Arizona Science Teacher Association Annual Meeting. Phoenix, Arizona. 5 November
115. **Idowu, O.J. 2018.** *Introduction to the SBAR Project.* Las Cruces, New Mexico. 6 Feb.
116. **Idowu, O.J. 2018.** *Sustainable Bio-economy for Arid Regions: Update.* Extension Field Day, Clovis, New Mexico. 9 August.
117. **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.
118. **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.
119. **Idowu O.J. 2021.** *Guar – A Low Input Alternative Crop.* Extension Field Day, Agricultural Science Center. Clovis, New Mexico. 3 August.
120. **Idowu O.J. 2021.** *Prospect of Guar, a High-Value Alternative Crop in Valencia County.* Los Lunas Extension Field Day, Los Lunas Agricultural Science Center. Los Lunas, New Mexico. 18 August.
121. **Idowu O.J. 2021.** *Alternative Crops for Sustainable Bioeconomy for Arid Regions.* Las Cruces Extension Field Day, Leyendecker Plant Science Center. Las Cruces, New Mexico. 25 August.
122. **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.
123. **Katterman, M. 2020.** *Guayule sensor and irrigation modeling + SBAR Education update.* SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 18 March.
124. **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.
125. **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]
126. **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.
127. **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]
128. **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]

129. **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.
130. **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]
131. **Knox, C. 2021.** *The SBAR Education Program.* Arizona Science Teacher Association Annual Meeting. Phoenix, Arizona. 5 November.
132. **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.
133. **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]
134. **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.
135. **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]
136. **Lewis, M. 2019.** *Salt stress tolerance in guayule.* SBAR UA Research Team Seminar, University of Arizona, Tucson, Arizona. 23 October.
137. **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]
138. **Lohr, P. 2020.** *AquaCrop modeling of guayule.* SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 5 February.
139. **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.
140. **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.
141. **Lopez, E.*; Fox, S.; Brewer, C.E. 2018.** *GK-12 Lesson Documentation Spreadsheet.* American Institute of Chemical Engineers Annual Meeting, Pittsburg, Pennsylvania. 29 October.
142. **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.

143. **Maqsood, H. 2018.** *Guar Crop Coefficient Development for New Mexico Environments*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 7 November.
144. **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.
145. **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]
146. **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.
147. **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]
148. **McCloskey, W. 2018.** *Weed Trial Results for Guayule*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 14 November.
149. **McCloskey, W. 2019.** *Guayule Weed Control Research*. The 9th Annual Central Arizona Farmer Field Day. Maricopa Agricultural Center (MAC), Maricopa, Arizona. 8 October.
150. **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.
151. **McMahan, C. 2018.** *Flowering Reduction in Guayule*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 19 September.
152. **McMahan, C. 2019.** *USDA-ARS Rubber Lab Update*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 27 March.
153. **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]
154. **McMahan, C.*; Placido, D.; Resendiz, M.; Ponciano, G. 2020.** Flowering downregulation in guayule. Update to SBAR Advisory Board. Online presentation. 12 February.
155. **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.
156. **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.
157. **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.

158. **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]
159. **Mealing, V. 2019.** *Field Data Collection and Integration.* SBAR System Performance and Sustainability Seminar, Colorado State University, Golden, Colorado. 13 November.
160. **Mealing, V. 2020.** *Field data collection update.* SBAR System Performance and Sustainability Seminar, Colorado State University, Golden, Colorado. 19 February.
161. **Mealing, V. 2020.** *Field data integration update.* SBAR System Performance and Sustainability Seminar, Colorado State University, Golden, Colorado. 25 June.
162. **Mealing, V. 2020.** *A framework for assessing the social sustainability of guar agriculture.* Congress on Sustainability and Engineering (ICOSSE) (virtual). Golden, Colorado. 3 August.
163. **Mealing, V. 2020.** *Towards a holistic sustainability assessment of guar and guayule.* SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
164. **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.
165. **Mealing, V. 2020.** *Sustainability assessment of guar and guayule cultivation: Utilizing unique field trial data.* USDA Rubber Lab Meeting (virtual). Golden, Colorado. 10 December.
166. **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.
167. **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.
168. **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]
169. **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]
170. **Mealing, V.S.*; Landis, A.E. 2019.** *SBAR Sustainability.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
171. **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.
172. **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.
173. **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]

174. **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.
175. **Morris, N.A. 2020.** *SBAR 4-H opportunities and future directions.* SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 19 February.
176. **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.
177. **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.
178. **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]
179. **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.
180. **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.
181. **Niu, D., 2018.** *Partial cloning of APETALA1 (AP1) gene from guayule.* cDNA Lab Seminar, USDA-ARS Western Regional Research Laboratory. 28 March.
182. **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]
183. **Ogden, K. 2017.** *Sustainable Bioeconomy for Arid Regions.* Biomass Research and Development Technical Advisory Board Meeting. 15 November. [invited speaker]
184. **Ogden, K. 2018.** *Sustainable Bio-economy for Arid Regions.* Southwest Indian Agricultural Association Annual Meeting. Laughlin, Nevada. 16-18 January.
185. **Ogden, K. 2018.** *Potential of the Bioproducts and Biofuels Economy.* AIChE Annual Meeting, Pittsburg, Pennsylvania. October [invited speaker]
186. **Ogden, K. 2020.** *Sustainable Bioeconomy for Arid Regions.* Grain Processing Lecture Series, Michigan Technological University, Houghton, Michigan. 17 January [invited speaker]
187. **Ogden, K. 2020.** *SBAR Project Update.* Southwest Indian Agriculture Association (SWIAA) 32nd Annual Conference, Laughlin, Nevada. 20-23 January [invited speaker]
188. **Ogden, K. 2020.** *Sustainable Bioeconomy for Arid Regions.* University of Utah, Salt Lake, Utah. 2 March. [invited distinguished lecturer]
189. **Ogden, K. 2021.** *Sustainable Bioeconomy for Arid Regions (SBAR): A coordinated approach to establishing bioeconomies.* TechConnect World Innovation Conference, Washington, D.C. 18-20 October.
190. **Ogden, K. 2021.** *Sustainable Bioeconomy for Arid Regions – How Kim Got Here.* Session to honor 2019 Warren K. Lewis Award for Robert Davis, American Institute of Chemical Engineers (AIChE) meeting. (virtual) 7-12 November. [invited speaker]

191. **Ogden, K. 2021.** *Guayule – Is this a viable crop for domestic rubber production?* Department of Chemical Engineering, Iowa State University, December [invited speaker]
192. **Ogden, K.*, White, R., Brewer, C.E. 2018.** *Public Private Partnerships.* ABLC Conference. Washington, D.C. 27-28 February.
193. **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.
194. **Omatayo, O. 2021.** *Guayule: A sustainable alternative in the arid region?* New Mexico Research and Creativity Week, New Mexico State University, Las Cruces, New Mexico. [poster]
195. **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]
196. **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.
197. **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.
198. **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]
199. **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.
200. **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.
201. **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.
202. **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.
203. **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.
204. **Quinn, J.C.; Summers, H.M.; Sproul, E.; Seavert, C.; Robbs, J.; Khanal, S.; Mealing, V.; Landis, A.E.; Fan, N.; Sun, O. 2021.** *Integrated economic and*

- environmental sustainability analysis of guar gum*. TechConnect World Innovation Conference & Expo. Washington, D.C. October. [virtual presentation]
205. **Ramos-Coronado, L. 2021.** *Harvesting Guayule: Own vs. custom hire analysis*. New Mexico Research and Creativity Week, New Mexico State University, Las Cruces, New Mexico. [poster]
 206. **Ray, D.T.; Dierig, D.A. 2021.** *Comprehensive evaluation of USDA guayule germplasm in Arizona*. SBAR UA Research Team Seminar, University of Arizona, Tucson, Arizona. 17 November.
 207. **Ray, D.T.; Teetor, V.H. 2021.** *Resin and rubber results from different irrigation types over two years*. SBAR UA Research Team Seminar, University of Arizona, Tucson, Arizona. 8 September.
 208. **Ray, D.T.; Teetor, V.H.; Schmalzel, C. 2021.** *Guar as an alternative crop in semi-arid areas of Arizona, New Mexico, and Texas*. American Society for Horticulture Science Annual Conference, Denver, Colorado. 5-9 August. [poster]
 209. **Resendiz, M. 2020.** *Flowering downregulation of Parthenium argentatum*. USDA-ARS Lab Meeting, Albany, California. 14 May.
 210. **Resendiz, M. 2020.** *Downregulation of floral identity genes in Parthenium argentatum*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
 211. **Rock, C.*; Brassill, N. 2018.** *Importance of Cooperative Extension in University Research*. University of Arizona, Tucson, Arizona. 14 March.
 212. **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]
 213. **Rogstad, A. 2019.** *SBAR Overview*. Association for the Advancement of Industrial Crops 31st Annual Meeting. Tucson, Arizona. 8 September. [invited speaker]
 214. **Rogstad, A. 2021.** *SBAR Overview*. Arizona Institutes for Resilience: Solutions for the Environment and Society Seminar. Tucson, Arizona. 10 February [invited speaker]
 215. **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.
 216. **Rodriguez-Uribe, L.*; Gutierrez, P. 2019.** *Implementing the Science of SBAR with Youth*. SBAR UA Research Team Seminar, University of Arizona, Tucson. 25 September.
 217. **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.
 218. **Rosalez, R.*; Brewer, C.E.; Jena, U. 2019.** *Co-Hydrothermal liquefaction (HTL) of guayule bagasse and wastewater treatment microalgae*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 11-13 September. [poster]
 219. **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.
 220. **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.
221. **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.
 222. **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]
 223. **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.
 224. **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.
 225. **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]
 226. **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.
 227. **Singh, J.*; Angadi, S.V.; Begna, S.H.; Idowu, O.J.; Guzman, I.; VanLeeuwen, D. 2019.** *Water extraction patterns 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.
 228. **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.
 229. **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.
 230. **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]
 231. **Singh, P.*; Angadi, S.V.; Idowu, O.J.; Brewer, C.E.; Knox, C.J.; Chavarria, S.P. 2021.** *Graduate Fellows as Conduits to Sustainability Education in Middle School and Youth Settings: Communication Science with Cultural and Community Relevancy*. Soil Science Society of American Annual Meeting, Salt Lake City, Utah. 7-10 November.
 232. **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]
 233. **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.

234. **Smith, A. 2020.** *Valorization of guayule resin*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 22 April.
235. **Smith, A.*; Ogden, K. 2020.** *Vacuum distillation of guayule resin*. SBAR Annual Retreat (virtual). University of Arizona, Tucson, Arizona. 27-29 July.
236. **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]
237. **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.
238. **Sproul, E. 2020.** *Integrated Economic & Environmental Analysis of Guayule and Guar Production*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 22 January.
239. **Sproul, E. 2020.** *Techno-economic analysis and life cycle assessment of guayule*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
240. **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.
241. **Sproul, E.; Summers, H.M.; Seavert, C.; Fan, N.; Zuniga Vazquez, D.A.; Landis, A.E.; Mealing, V.; Quinn, J.C. 2021.** *Sustainability assessment of producing guayule rubber with coproducts*. Association for the Advancement of Industrial Crops (AAIC) 32nd Annual Meeting. Bologna, Italy (virtual). 5-8 September.
242. **Sproul, E.; Summers, H.M.; Seavert, C.; Robbs, J.; Khanal, S.; Mealing, V.; Landis, A.E.; Fan, N.; Sun, O.; Quinn, J.C. 2021.** *Economic and environmental sustainability analysis of guayule rubber*. TechConnect World Innovation Conference & Expo. Washington, D.C. October. [virtual presentation]
243. **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]
244. **Summers, H.M. 2020.** *Techno-economic analysis and life cycle assessment of guar*. SBAR Annual Retreat (virtual), University of Arizona, Tucson, Arizona. 27-29 July.
245. **Summers, H.M.; Quinn, J.C. 2021.** *Advancing water scarcity footprint methods for arid regions*. International Symposium on Sustainable Systems and Technology (ISSST). (Virtual) 21-25 June.
246. **Summers, H.M.; Quinn, J.C. 2021.** *Advancing water scarcity footprint methods for arid regions*. American Center for Life Cycle Assessment (ACLCA) Virtual Conference. 21-24 September.
247. **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.
248. **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.

249. **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.
250. **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.
251. **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.
252. **Sun, O. 2018.** *GIS-Based Two-stage Stochastic Facility Location Considering Planting Plan Uncertainty.* INFORMS Annual Meeting, Phoenix, Arizona. 5 November.
253. **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.
254. **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.
255. **Sun, O. 2019.** *Biomass Supply Chain Configuration and Management.* SBAR UA Research Team Seminar. University of Arizona, Tucson, Arizona. 10 April.
256. **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.
257. **Sun, O.*; Fan, N. 2018.** *Harvest scheduling.* SBAR Logistics Team Group Meeting. (webinar) New Mexico State University. Las Cruces, New Mexico. 5 February.
258. **Sun, O.*; Fan, N. 2018.** *Optimization of feedstock logistics.* SBAR UA Research Seminar. University of Arizona. Tucson, Arizona. 14 February.
259. **Sun, O.*; Fan, N. 2018.** *Optimally locating biorefineries.* SBAR Sustainability Working Group Seminar. (webinar) Colorado State University. Lakewood, Colorado. 8 March.
260. **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 February.
261. **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.
262. **Thelander, W. 2021.** *Experience of growing guayule.* Guayule Field Day, Eloy, Arizona. 6 October.
263. **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]
264. **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.

265. **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.
266. **Waller, P. 2018.** *WINDS Model: A status report and connection to SBAR research.* SBAR UA Research Team Seminar Series, Tucson, Arizona. 10 October.
267. **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]
268. **Wang, G.S. 2021.** *Planting, irrigation, and crop management.* Guayule Field Day, Eloy, Arizona. 6 October.
269. **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.
270. **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]
271. **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]
272. **Zuniga-Vasquez, D.A. 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]
273. **Zuniga-Vasquez, D.A. 2019.** *Stochastic scenarios for guayule production.* SBAR System Performance and Sustainability Seminar, Colorado State University, Fort Collins, Colorado. 8 October.
274. **Zuniga-Vasquez, D.A. 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.
275. **Zuniga-Vasquez, D.A. 2020.** *Optimization for guayule and guar logistics and transportation.* SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 8 April.
276. **Zuniga-Vasquez, D.A. 2021.** *Optimal design of guayule and guar supply chains for the American Southwest.* SBAR Annual Retreat. University of Arizona, Tucson, Arizona. 11 August. [poster]
277. **Zuniga-Vasquez, D.A.*; Fan, N. 2020.** *Optimization for guayule and guar logistics and transportation.* SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 19 February.
278. **Zuniga-Vasquez, D.A.*; 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.
279. **Zuniga-Vasquez, D.A.*; 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.

280. **Zuniga-Vasquez, D.A.*; Fan, N. 2020.** *Smart farm production and scheduling design for guayule and guar.* SBAR Sustainability Team Meeting, University of Arizona, Tucson, Arizona. 30 September.
281. **Zuniga-Vasquez, D.A.*; Fan, N. 2020.** *Smart farm production and scheduling design for guayule and guar.* SBAR Research Team Meeting, University of Arizona, Tucson, Arizona. 30 September.
282. **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.* Association for the Advancement of Industrial Crops (AAIC) 32nd Annual Meeting. Bologna, Italy (virtual). 5-8 September.
283. **Zuniga-Vasquez, D.A.*; 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	2,152	300	0
Females	1,043	212	0
Race/Ethnicity			
Hispanic	502	96	598
Asian	253	38	291
Native American	370	47	417
African American	77	0	77
Anglo/White	1,807	303	2,110
Unknown	186	28	214

Audience Cumulative Total (when captured): 3,707 ppl

WEBSITE(S) OR INTERNET SITE(S)

SBAR Project Website

1. [.https://sbar.arizona.edu](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

Briefing Papers, Brochures, Factsheets, and Flyers

1. **Chavarria, S.P.; Knox, C.; Ogden, K.L. 2022.** *Building Education Capacity for Bioeconomies*. SBAR Briefing Paper. 2p. February.
2. **Dehghanizadeh, M.; Brewer, C.E.; Romero, A.; Holguin, O.F.; Ogden, K.L. 2021.** *Guayule Resin for Insect Repellents*. SBAR Briefing Paper. 2p. October
3. **Duncan, C.M. 2018.** *SBAR USDA-NIFA graduate student fellowship: UA Students*. One page promotional flyer. February and March.
4. **Duncan, C.M. 2018.** *SBAR USDA-NIFA graduate student fellowship: NMSU Students*. One page promotional flyer. February and March.
5. **Duncan, C.M. 2018.** *SBAR call for middle and high school science teachers*. One page promotional flyer. February and March.
6. **Duncan, C.M. 2018.** *SBAR 4-H summer camp: Biofuels powering your world*. One page promotional flyer. March.
7. **Duncan, C.M. 2019.** *SBAR Call for Middle & High School Science Teachers*. One page promotional flyer. March.
8. **Duncan, C.M. 2019.** *SBAR USDA-NIFA graduate student fellowship: UA Students*. One page promotional flyer. March.
9. **Duncan, C.M. 2019.** *SBAR USDA-NIFA graduate student fellowship: NMSU Students*. One page promotional flyer. March.
10. **Duncan, C.M. 2019.** *SBAR USDA-NIFA graduate science education fellowship*. One page general recruiting flyer. April.
11. **Evancho, B. 2019.** *Guayule Information & Feedback Session*. One page invitation to attend field day and tour. May.
12. **Grover, K. 2018.** *Guar – A potential alternative crop in New Mexico*. Two page informational handout. January.
13. **Idowu, O.J.; Ray, D.T.; Cruz, V.M.V.; Dierig, D.A. 2021.** *Guayule Growing Range Expansion in the Southwest*. SBAR Briefing Paper. 2p. October
14. **Kiela, C. 2018.** *Guayule*. SBAR Project two-page fact sheet. March.
15. **Kiela, C. 2018.** *Guar*. SBAR Project two-page fact sheet. April.
16. **Kiela, C. 2018.** *History of Guayule*. SBAR Project two-page fact sheet. April.
17. **Neilson, J.; McMahan, C.; Ponciano, G. 2022.** *Impacts of Soil Microbiome on Guayule Rubber Production*. SBAR Briefing Paper. 2p. January.
18. **Ogden, K.L.; Ray, D.T.; Chavarria, S.P.; Dierig, D.A. 2022.** *Guayule-Based Job Creation in the Arid Region's Bioeconomy*. SBAR Briefing Paper. 2p. January.
19. **Ogden, K.L.; Ray, D.T.; Quinn, J.C.; McMahan, C.; Brewer, C.E. 2021.** *Sustainable Bio-economy for Arid Regions*. SBAR Briefing Paper. 2p. October.
20. **Pradyawong, S.; Ogden, K.L. 2021.** *Guayule Resin for Adhesives*. SBAR Briefing Paper. 2p. October.
21. **Quinn, J.C.; Seavert, C.; Ogden, K.L.; Fan, N.; Miller, M.; Teegerstrom, T. 2021.** *Sustainability of Guayule-based Natural Rubber Production*. SBAR Briefing Paper. October 2021.
22. **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-quayule-work>
9. 12 Oct 2021. "Keeping growers up-to-date on guayule research may encourage more to plant the crop." Pinal Central. https://www.pinalcentral.com/elay_enterprise/news/keeping-growers-up-to-date-on-quayule-research-may-encourage-more-to-plant-the-crop/article_113af80f-e34e-53cb-afe8-07bdb3231ff5.html

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, Tatum, 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.
40. 3 Aug 2021. Clovis Field Day, Clovis Agricultural Science Center, Clovis New Mexico.
41. 13-14 Aug 2021. Cultivating Young Minds, Clovis Agricultural Science Center, Clovis, New Mexico.
42. 18 Aug 2021. Los Lunas Field Day, Los Lunas Agricultural Science Center, Los Lunas, New Mexico.
43. 25 Aug 2021. Las Cruces Field Day, Leyendecker Plant Science Center, Las Cruces, New Mexico.
44. 31 Aug 2021. Las Cruces School 3rd Grade Exploration Day, Las Cruces, New Mexico.

→Total Reach via Tabling Events and Workshops (when captured): **4,855 participants**

Note: Due to COVID-19 restrictions, in-person events have were restricted between March 2020 and August 2021.

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	487	0	487
Gender			
Males	862	0	862
Females	867	0	867
Race/Ethnicity			
Hispanic	904	0	904
Asian	33	0	33
Native American	184	0	184
African American	47	0	47
Anglo/White	545	0	545
Multiracial	17	0	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 – December 2021

PARTNER ORGANIZATIONS

Organization Person*	Project Role	Project Component
Bridgestone Americas,		
Von Mark Von 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
Brooke Silagy	Graduate Student	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	<i>Graduate Student</i>	<i>System Performance & Sustainability</i>
Logan Brammer	<i>Undergrad Student</i>	<i>Feedstock Development & Production</i>
Catherine E. Brewer	<i>Key Collaborator</i>	<i>Education Characterizations & Co-Products</i>
Nicolas Carrera-Little	<i>Undergrad Student</i>	<i>Characterizations & Co-Products</i>
Alyssa Castaneda	<i>Undergrad Student</i>	<i>Extension & Outreach</i>
Pedro Castillo	<i>Undergrad Student</i>	<i>Feedstock Development & Production</i>
Kenneth Cazarez	<i>Undergrad Student</i>	<i>Extension & Outreach</i>
Shivam Chawla	<i>Graduate Student</i>	<i>Feedstock Development & Production</i>
Feng Cheng	<i>Post-doc</i>	<i>Characterizations & Co-Products</i>
Murali Darapuneri	<i>Professional</i>	<i>Extension & Outreach</i>
Mostafa Dehghanizadeh	<i>Graduate Student Fellow</i>	<i>Education Characterizations & Co-Products</i>
Malachai Dehler-Egan	<i>Undergrad Student</i>	<i>Characterizations & Co-Products</i>
Barry Dungan	<i>Professional</i>	<i>Characterizations & Co-Products</i>
Shermal Fernando	<i>Graduate Student</i>	<i>Education</i>
Dominic Flores	<i>Undergrad Student</i>	<i>Feedstock Development & Production</i>
Miguel Flores	<i>Undergrad Student</i>	<i>Extension & Outreach</i>
Leonel Fournier	<i>Undergrad Student</i>	<i>Feedstock Development & Production</i>
Sarah Fox	<i>Undergrad Student</i>	<i>Characterizations & Co-Products</i>
Ryan Fullerton	<i>Undergrad Student</i>	<i>Feedstock Development & Production</i>
Claudia Galvan	<i>Professional</i>	<i>Characterizations & Co-Products</i>
Alonso Garcia	<i>Graduate Student</i>	<i>Feedstock Development & Production</i>
Adah Gellis	<i>Undergrad Student</i>	<i>Extension & Outreach</i>
Saba Gill	<i>Graduate Student</i>	<i>Characterizations & Co-Products</i>
Thomas Gloria	<i>Undergrad Student</i>	<i>Feedstock Development & Production</i>
Kulbhushan Grover	<i>Key Collaborator</i>	<i>Extension & Outreach Feedstock Development & Production</i>
Erin Gutierrez	<i>Undergrad Student</i>	<i>Characterizations & Co-Products</i>
Maria Gutierrez	<i>Undergrad Student</i>	<i>Extension & Outreach</i>
Paul H Gutierrez	<i>Key Collaborator</i>	<i>Extension & Outreach System Performance & Sustainability</i>
Befekadu Habteyes	<i>Professional</i>	<i>System Performance & Sustainability</i>
Jose Hackleen	<i>Undergrad Student</i>	<i>Feedstock Development & Production</i>
Mia Herrera	<i>Undergrad Student</i>	<i>Feedstock Development & Production</i>
F. Omar Holguin	<i>Key Collaborator</i>	<i>Characterizations & Co-Products</i>
John Idowu	<i>Key Collaborator</i>	<i>Extension & Outreach</i>
Moustapha Idrissa	<i>Undergrad Student</i>	<i>Feedstock Development & Production</i>
Jackie Jarvis	<i>Professional</i>	<i>Characterizations & Co-Products</i>
Umakanta Jena	<i>Professional</i>	<i>System Performance & Sustainability</i>
Sita Khanal	<i>Graduate Student</i>	<i>System Performance & Sustainability</i>
Alix Knagg	<i>Undergrad Student</i>	<i>Characterizations & Co-Products</i>
Kelly Laje	<i>Graduate Student</i>	<i>Characterizations & Co-Products</i>
Travis Le-Doux	<i>Undergrad Student</i>	<i>Characterizations & Co-Products</i>
Esai Lopez	<i>Undergrad Student</i>	<i>Education</i>
Alberto Lorenzo	<i>Undergrad Student</i>	<i>Feedstock Development & Production</i>
Andrea Loya Lujan	<i>Undergrad Student</i>	<i>Characterizations & Co-Products</i>
Sicilee Macklin	<i>Undergrad Student</i>	<i>Education Characterizations & Co-Products</i>
Michael Mares	<i>Undergrad Student</i>	<i>Extension & Outreach</i>
Cesar Martinez-Bejarano	<i>Undergrad Student</i>	<i>Characterizations & Co-Products</i>
Maryfrances Miller	<i>Key Collaborator</i>	<i>System Performance & Sustainability Extension & Outreach</i>
Julie Miller	<i>Undergrad Student</i>	<i>Extension & Outreach</i>

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
Luis Ramos-Coronado	Graduate 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
Jacqueline Bruhn	Professional	Education Extension & Outreach
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
Jeremy Elliott-Engel	Key Collaborator	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 & Sustainability
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
Sarocho 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
Matt Swanson	Professional	Extension & Outreach
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
Shunyu Yao	Graduate Student	System Performance & Sustainability
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
Alexis Carlson	Student	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: 23
Total Active Professional Staff: 28
Total Active Postdoctoral Researchers: 6
Total Active Graduate Students: 17
Total Active Undergraduate Students: 21
Total Active Fellows: 4
Total Active /Interns: 0

Total Active Participants:94
Total Past Participants (no longer active): 163
Total Individuals Involved Since SBAR Inception: 257

COLLABORATIONS AND OTHER CONTACTS

Collaborations:

<p><i>Academic Institutions:</i></p>	<p>CSM (Colorado School of Mines)</p> <ul style="list-style-type: none"> - Dept. of Civil and Environmental Engineering <p>CSU (Colorado State University)</p> <ul style="list-style-type: none"> - Dept. of Mechanical Engineering <p>FSU (Florida State University)</p> <ul style="list-style-type: none"> - National High Magnetic Field Laboratory <p>NMSU (New Mexico State University)</p> <ul style="list-style-type: none"> - 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 <p>UA (University of Arizona)</p> <ul style="list-style-type: none"> - 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 <p>UNM (University of New Mexico) – Gallup</p> <ul style="list-style-type: none"> - Dept. of Mathematics, Physical and Natural Science
<p><i>Nonprofits:</i></p>	<p>Environmental Defense Fund, Phoenix AZ</p> <p>Asombro Institute for Science Education, Las Cruces NM</p>

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

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

Other Contacts:

<i>Contacts with others within recipient's organization (interdepartmental or interdisciplinary collaborations):</i>	UA (University of Arizona) <ul style="list-style-type: none"> - 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
<i>Contacts with others outside the organization:</i>	Denver Museum of Nature and Science, Denver CO Central Arizona College, Coolidge AZ
<i>Contacts with others outside the United States or with an international organization:</i>	

APPENDICES

APPENDIX 1. SBAR WORKSHOPS

Documents Included

1. **Guayule Field Day** – Full agenda for the Guayule Field Day hosted at the Bridgestone Guayule Research Farm in Eloy, Arizona. 6 October 2021. (1p)
2. **Arizona 4-H STEM Adult Experience** – Full agenda for the STEM Workshop held in Phoenix, Arizona on 13 November 2021. SBAR-created lessons were demonstrated as examples to be used in 4-H programming. (1p)



THE UNIVERSITY OF ARIZONA
Cooperative Extension
 Pinal County

GUAYULE FIELD DAY

Presented by Bridgestone, UArizona—Cooperative Extension and SBAR

WEDNESDAY, OCTOBER 6, 2021 / 8:00-11:00AM

**BRIDGESTONE GUAYULE RESEARCH FARM
 4140 WEST HARMON ROAD, ELOY, ARIZONA 85131**

Registration at <https://forms.gle/6uFwM1uqa6cBXDt17>

Bridgestone requires the use of a facemask at all of their facilities.

8:00-8:20 am	Dave Dierig, Bridgestone—Update on Guayule Research & Development
8:25-8:45 am	Sam Wang, Bridgestone—Planting, Irrigation & Crop Management
8:50-9:00 am	Will Thelander—Experience on Growing Guayule
9:05-9:15 am	Alex Hu—Management of Guayule Diseases
9:15-9:30 am	Peter Ellsworth, UA Extension—Pale-Striped Flea Beetle Control at Stand Establishment
9:35-9:55 am	Blase Evancho, UA Extension/SBAR—Guayule Weed Control Strategies
10:00-11:00 am	Field Tour / Q&A



Question? Contact Blase Evancho
 University of Arizona, Cooperative Extension, Pinal
 820 East Cottonwood Lane, #C, Casa Grande, AZ 85122
 (520) 836-5221, phone / (520) 836-1750, fax
bee1@arizona.edu



SUSTAINABLE BIOECONOMY
 FOR ARID REGIONS



United States
 Department of
 Agriculture

National Institute
 of Food and
 Agriculture



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The University does not discriminate on the basis of race, color, religion, sex, national origin, age, disability, veteran status, or sexual orientation in its programs and activities.

Persons with a disability may request a reasonable accommodation, such as a sign language interpreter, by contacting UA, Cooperative Extension, Pinal County at 866.836.5221.

Requests should be made as early as possible to allow time to arrange the accommodation.

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



THE UNIVERSITY OF ARIZONA
Cooperative Extension



Agenda

Arizona 4-H STEM Adult Experience

November 13, 2021

9:00am – 2:00pm

9:00 – 9:15	Welcome	Dr. Nick Morris
9:15 – 10:00	4-H Overview and the 4-H THRIVE Model	Dr. Nick Morris
10:00 – 10:45	STEM in Agriculture	Dr. Betsy Greene
10:45 – 11:15	Augmented Reality (AR) / Virtual Reality (VR); Cross Reality (XR) Floating Farm	Andie Rodriguez
11:15 – 11:45	Greenhouse Sustainable Energy Engineering Design (SEED)	Rebecca Bhasme Dr. Jerry Lopez
11:45 – 12:15	Lunch	
12:15 – 12:45	LEGO Robotics and Underwater Robotics Remotely Operated Vehicles (ROVs)	Dr. Jerry Lopez
12:45 – 1:00	Tech Changemakers; 4-H STEM Challenge and Ag Innovators Experience	Dr. Jerry Lopez
1:00 – 1:15	Ag & STEM in the Classroom	Gigette Webb
1:15 – 1:45	Becoming a 4-H Volunteer	Gloria Blumanhourst
1:45 – 2:00	Closing	Dr. Jerry Lopez Dr. Nick Morris



**4-H STEM
YOUiversity**



SUSTAINABLE BIOECONOMY
FOR ARID REGIONS



Agnese Nelms Haury Program
in Environment and Social Justice

APPENDIX 2. SBAR PUBLICATIONS

Documents Included

Cooperative Extension Informational Sheets

1. **Guayule Weed Management During Establishment in Arizona. 2021.** A 2-page informational sheet produced by Arizona Cooperative Extension that describes guayule production concerns related to weed management during crop establishment. This summarizes results from SBAR research. December.

SBAR Briefing Papers

A library of SBAR-specific briefing papers covering a variety of topics have been developed to provide information and increase awareness. These papers are disseminated at events, conferences, and other meetings by project partners. They are also available for download on the SBAR website.

1. **Building Education Capacity for Bioeconomies** – A 2-page briefing paper generated in February 2022 to highlight the connections between education, workforce development and bioeconomies of the Southwest.
2. **Guayule Resin for Insect Repellents** – A 2-page briefing paper generated in October 2021 to describe the status of research into using guayule resin in insect repellents.
3. **Guayule Growing Range Expansion in the Southwest** – A 2-page briefing paper generated in October 2021 to describe the opportunities for expanding the growing range of guayule within Arizona, California, New Mexico and Texas.
4. **Impacts of Soil Microbiome on Guayule Rubber Production** – A 2-page briefing paper generated in January 2022 to describe the status of research into identifying the impacts of the soil microbiome on guayule rubber production.
5. **Guayule-Based Job Creation in the Arid Region's Bioeconomy** – A 2-page briefing paper generated in January 2022 to describe the potential for guayule-related jobs in arid regions.
6. **Sustainable Bio-economy for Arid Regions** – A 2-page briefing paper generated in October 2021 to provide an overview of the SBAR Project.
7. **Guayule Resin for Adhesives** – A 2-page briefing paper generated in October 2021 to explain the possibility of using guayule resin to generate natural adhesives.

8. **Sustainability of Guayule-Based Natural Rubber Production** – A 2-page briefing paper generated in October 2021 to describe the economic viability of natural rubber production using guayule as the feedstock.

Guayule Weed Management During Establishment in Arizona – September 2021

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Guayule is a desert-adapted crop that is grown using agronomic practices like those used to grow cotton. Guayule seed is planted shallow in dry soil on beds and then irrigated to germinate the seed. Guayule seedlings are small and grow slowly making them poor competitors with weeds. Weeds must be actively managed for several months after planting until the crop canopy closes and guayule becomes very competitive against weeds.

There are currently four herbicides registered (24c SLN labels) for use on guayule in Arizona: the preemergence herbicide Prowl H2O®, and the postemergence herbicides Aim®, Fusilade® DX, and Gramoxone® (Table 1; website: cdms.net checked 9/28/21). The use of these few herbicides must be supplemented with cultural practices to successfully control weeds in guayule. Guayule should be planted in fields that are as free of weeds as possible and rotated with other crops to manage difficult-to-control weeds. Fields can be preirrigated to germinate weed seeds which can then be destroyed prior to planting guayule. Tillage and chemical burn-down treatments (e.g., glyphosate and some herbicides in Table 1) can be used to produce weed free beds or rows for planting.

Prowl H2O and Preemergence Weed Control

Using Prowl H2O (pendimethalin) preplant-incorporated before bed formation is crucial for successful weed control in furrow irrigated guayule fields. In sprinkler irrigated fields, Prowl H2O can be applied after planting and incorporated with water. The amount of Prowl H2O applied prior to planting needs to be adjusted depending on soil type; 2 pints/acre in sandy loam soils or 3 pints/acre in soils with more clay content. Preplant-incorporated rates above 2 pints/acre in sandy loam soils may result in plant loss and poor stand establishment. Guayule requires several irrigations at short intervals (e.g., every other day in a sandy loam soil) to germinate seeds and keep the seedlings hydrated. This frequent irrigation during establishment increases the degradation or inactivation of Prowl in the soil. Additional Prowl H2O will need to be applied 6 to 8 weeks after planting to help maintain weed control. After guayule is established, greater rates of Prowl H2O can be applied over-the-top of guayule, as a directed spray to the soil between rows, or applied in irrigation water (see labels and Table 1). If guayule is transplanted, greater rates of Prowl H2O can be applied before or after transplanting, but do not spray exposed roots. Prowl must be incorporated mechanically or with water (rainfall or irrigation) soon after application. Prowl can be applied multiple times per year as long as no more than 6.3 quarts is applied per year (Table 1).

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 University of Arizona or the U.S. Department of Agriculture.

Aim 2 EC for Postemergence Broadleaf Weed Control

Guayule is not resistant to Aim (carfentrazone-ethyl), but it is tolerant to it after about the 4th true-leaf stage. **At this stage guayule will show damage from an Aim application (e.g., leaf necrosis), but will grow out of the damage while surrounding small weeds are completely killed.** Larger, more mature leaves of guayule are a gray-green color due the development of dense, silvery leaf hairs and a thick cuticle. This appears to be the basis of guayule tolerance to Aim at use rates of 1 to 2 fl. oz./acre (Table 1). Since Aim is a contact or “burn-down” herbicide, good scouting for weeds is essential so that weeds are sprayed when they are small. Aim herbicide requires the use of a surfactant to reduce the surface tension of water and improve spray droplet retention on leaf surfaces. Carrier volumes for Aim should be 20 gallons of water per acre or more depending on weed density. Appropriate nozzles (e.g., flat-fan nozzles) should be used to produce medium droplets to get good coverage of sprayed leaf surfaces. Sequential applications of Aim may be needed soon after planting to obtain adequate broadleaf weed control in newly planted guayule fields.

Leaf necrosis on 3.5 leaf guayule from Aim applied at a rate of 2fl.oz per acre.



Photo credit: William B. McCloskey, University of Arizona

Fusilade DX for Postemergence Grass Weed Control

Fusilade DX (fluazifop-P-butyl) is a systemic herbicide that can be applied to control weedy grasses in guayule fields and does not damage guayule seedlings at any growth stage. Fusilade DX should be applied to small weeds to ensure maximum efficacy like all postemergence herbicides. As with Aim, flat-fan nozzles and surfactants or methylated crop-oil-concentrates should be used to produce fine to medium spray droplets that will adhere to the more vertical leaf canopies of grass weeds. Repeat applications of Fusilade DX will be required to control perennial grass species (Table 1).

HERBICIDE APPLICATION STEWARDSHIP **Read and strictly adhere to all herbicide labels.**

Material based upon work supported in part by the Sustainable Bioeconomy for Arid Regions Center of Excellence Grant # 2017-68005-26867 and the U.S. Department of Agriculture National Institute of Food and Agriculture (USDA-NIFA) under the Crop Protection and Pest Management, Extension Implementation Program, grant # 2017-70006-27145.



Paraquat for Total Postemergence Weed Control

Gramoxone (paraquat dichloride) is a contact herbicide that is active on both grass and broadleaf weeds as well as guayule. If sprayed on guayule seedlings it will kill the seedlings. Paraquat can be used to control weeds between rows once guayule has grown to substantial size. Paraquat must be post-directed to the soil at the base of guayule plants and is best applied using a hooded sprayer to minimize spray contact with guayule foliage. A non-ionic surfactant should be added to paraquat to maximize foliar activity and weed control (Table 1).

Weed Control Tactics for Establishment

Guayule seeds and seedlings are very small, with low vigor and can easily be overwhelmed during seedling establishment. Planting in fields with few weed seeds in the soil will improve the survival of guayule seedlings. Other weed control tactics should include: Prowl H₂O applied preplant incorporated, Aim applied at the 4 true-leaf growth stage for broadleaf weed control, and Fusilade DX applications to control emerged grassy weeds. All foliar herbicides should be sprayed on actively growing weeds that are not stressed due to lack of water, temperature extremes, or mechanical or chemical injury. Depending on the size of the guayule, it may be possible and desirable to cultivate for weed control and then apply additional Prowl H₂O (followed by an irrigation for incorporation). Second applications of Aim or Fusilade may be needed to control to emerged weeds and it may be necessary to hand weed a field to remove large weeds not controlled by the previous tactics. After guayule canopies close in the seed-line, chemical sprays should be post-directed to the base of the guayule plants.

A hooded or shielded sprayer with gauge wheels for control of nozzle height and position will allow more accurate herbicide applications. In larger guayule, a single drop-tube between rows with a single nozzle or double swivel with two nozzles can be used to post-direct herbicides onto small weeds.

Where is the guayule!?! Hint, it is circled in red. Direct seeding presents with many weed control challenges.



Table 1. Herbicides registered for use in guayule. The user is responsible for understanding information on the section 3 and 24c SLN labels of these products. Treated guayule cannot be used for food or feed for human or animal consumption. Do not feed, forage or graze livestock in treated areas.

Trade name (common name)	Herbicide Group #	Foliar activity /movement	Rate Product (lb ai/acre)	Maximum amount per year	Spray vol. (GPA)	Spray Adjuvants	Pre-harvest interval (PHI)	Plant back restrictions	Weeds Controlled	Application notes
Prowl H₂O (pendimethalin)	3	No	Preplant: 2 to 3 pt. (0.95 to 1.4) Established: 2 to 4 qt. (1.9 to 2.8)	6.3 quarts (6 lb a.i.)	≥20	None	None listed	24 mo.	Preemergence herbicide. Grasses, certain small seeded broadleaves. Will not control emerged weeds.	-Apply preplant-incorporated in furrow or drip irrigated systems; if sprinkler irrigating, Prowl H ₂ O can be applied after seeding but before irrigation. -Direct spray to the ground beneath shrubs; contact with shoots may cause malformed plant tissues. -If transplanting, apply higher rates prior to or after transplanting; do not spray exposed roots; incorporate with rainfall or irrigation soon after application.
Aim EC (carfentrazone-ethyl)	14	Yes, contact	1 - 2 fl. oz (0.016 - 0.031 lb)	7.9 fl. oz. (0.124 lb a.i.)	≥20	NIS 0.25% v/v	3 days	None for registered crops; see label	Annual broadleaf weed < 4" in height or rosettes < 3" in diameter. Will not control grasses	-Scouting for weeds is critical – only small weeds will be controlled. -Thorough spray coverage is required for weed control. -Leaf speckling (necrosis) will occur, but no crop loss is expected in healthy stands. -Sequential applications must be at least 14 days apart.
Gramoxone 2.0 SL (paraquat dichloride)	22	Yes, contact	2 - 4 pts (0.5 - 1 lb)	Not specified on label, no more than 5 appl.	≥20	NIS 0.25% v/v	4 days	None	Annual broadleaf and grass weed, spray when weeds are 1" to 3" in size, do not spray weeds > 6" in size	-Can be used preemergence to guayule and postemergence as a directed spray in established plantings; do not allow spray to contact green stems or foliage as injury will result. -Thorough spray coverage is required for weed control. -Can also be used to desiccate guayule to facilitate harvest. Do not exceed 5 applications per year.
Fusilade DX (fluazifop-P-butyl)	1	Yes, systemic	16 - 24 fl oz (0.25 – 0.375 lb)	72 fl. oz. (1 lb)	10 – 40	COC 1% v/v; NIS 0.5% v/v	None listed	60 days for grass crops	Annual grasses (2"-8" tall) and perennial grass weeds (see label); perennials require repeat treatment	-Apply within 7 days of irrigating for best results. -Antagonism by some other herbicides can occur if they are applied 5 days before or after Fusilade application. -Apply to actively growing grasses not stressed by lack of water, temperature extremes or mechanical or chemical stress.



SUSTAINABLE BIOECONOMY
FOR ARID REGIONS

BUILDING EDUCATION CAPACITY FOR BIOECONOMIES

EXECUTIVE SUMMARY

> The SBAR Center of Excellence is a model for integrating innovative educational opportunities into all aspects of its research and development on sustainable bioeconomies. Educational components of the project engaged students from elementary, middle and high school, college, and graduate level through post-doctoral fellows.

> Five themes form the SBAR Educational framework, which are reflected in the educational resources available that enhance STEM learning:

1. Suitability for Arid Lands
2. Land Use and Culture
3. Building Bioeconomy
4. Plant Sciences and Sustainable Crops
5. Technology, Engineering, and Chemistry

SBAR ACCOMPLISHMENTS

> Reached over 1,700 youth through SBAR summer camps, after school programs, internships, and classroom-based activities.

> Developed a Sustainable Bioeconomy and Bioenergy (SBB) track within the Graduate Interdisciplinary Program at the University of Arizona.

> Implemented bioeconomy-based after school program, **"Guardians of the Biosphere."**

> Created real world STEM activities for in school and afterschool programs, 4-H, and other youth development opportunities.

> Downloadable materials include labs, detailed lesson plans and career videos.



KEY DETAILS

- > Created bioeconomy focused curriculum for middle and high school classrooms
- > Place-based curriculum grounded in real world STEM activities
- > Partnered with 8 school districts in Arizona and New Mexico

OPPORTUNITIES for EDUCATORS

- > Culturally inclusive STEM-based lesson and activity guides
- > Unique standards-based arid lands/ bioeconomy curriculum
- > Informal activity guides for hands-on exploration
- > Regionally focused interviews with local professionals
- > Connections to local and regional bioeconomy-focused professionals

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ADVANCING INNOVATIVE REAL WORLD STEM EDUCATION

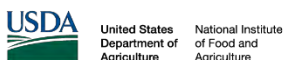
- > The SBAR education components create a framework for connecting students to concepts that build a more sustainable bioeconomy-based future for the arid Southwest. Curriculum engages students with real world STEM applications and builds connections to future job opportunities in the bioeconomy.
- > SBAR Education excelled at the creation of unique culturally relevant curriculum. SBAR Lotería is an innovative approach to teaching arid lands, sustainability, and bioeconomy concepts, and it can be adapted to a variety of formal and informal learning environments.
- > Educators have access to a broad range of curriculum to build a foundation for a sustainable bioeconomy in the Southwest.



WHAT IS STILL NEEDED

- > Integrated regional programs at community colleges in the Southwest for educating and training a workforce for bioeconomy opportunities.
- > Coordinate with industry partners to develop Certificate-based opportunities to meet workforce needs.
- > Expand career and technical education bioeconomy curriculum and apprenticeship programs.
- > Promote and support K-12 place-based STEM education related to arid lands and sustainability.

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



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SBAR Center of Excellence Briefing Paper (Building Education Capacity for Bioeconomies). February 2022.



SUSTAINABLE BIOECONOMY
FOR ARID REGIONS

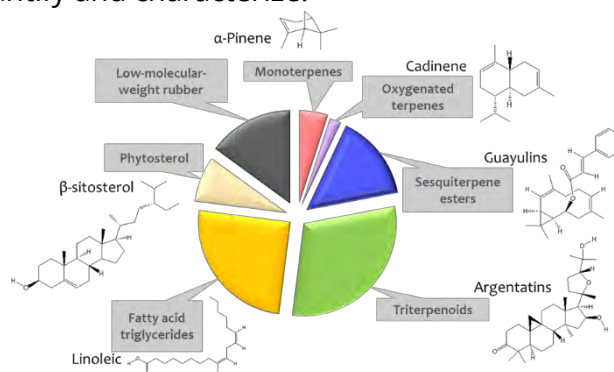
GUAYULE RESIN FOR INSECT REPELLENTS

EXECUTIVE SUMMARY

- > Guayule (*Parthenium argentatum*) is a desert-adapted shrub that produces natural rubber in its stems. To improve the economics of the cultivation and processing of guayule as a source of rubber, value-added uses are needed for the two rubber co-products, the resin and the bagasse.
- > The resin is a complex mixture of compounds, each with potential uses – as long as the mixture can be properly separated. One of those potential uses is as a bio-based insect repellent.
- > Guayule resin contains compounds that are already known to repel insects, or a similar to such compounds. SBAR researchers are separating and testing guayule resin fractions with the goal of identifying repellents for urban pests that are safer and easier to use.

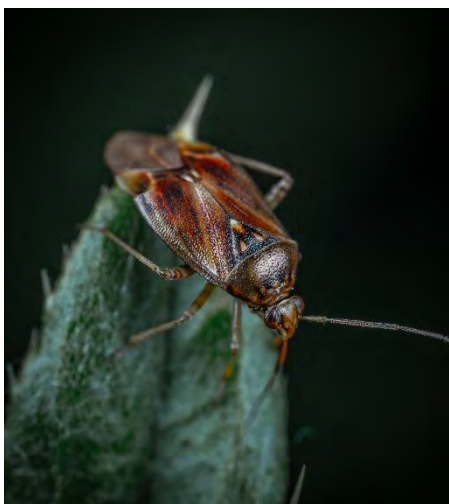
SBAR ACCOMPLISHMENTS

- > Since 2017, SBAR researchers have used physical and chemical separations and analytical techniques to more completely understand the composition of guayule resin, including compounds that are difficult to quantify and characterize.
- > Chemical engineers have worked with urban entomologists to design methods for testing guayule resin fractions as repellents for cockroaches. Test results have been promising for whole resin and many resin fractions. Application for a preliminary patent is underway.



RESIN DETAILS

- > For each kg of guayule rubber produced, there are 1-3 kg of guayule resin
- > Resin contains 100s of compounds, including essential oils and fatty acids
- > Guayulin and argentatin compounds are unique to guayule and may have anticancer, anti-fungal, and antimicrobial properties



QUEST FOR BETTER SEPARATION METHODS

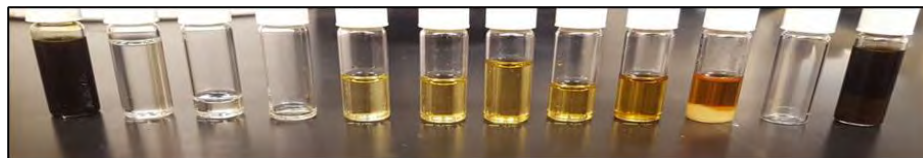
- > Vacuum distillation for large-scale, solvent-free separation
- > Accelerated solvent extraction for faster separation and purer fractions
- > Supercritical fluid extraction with carbon dioxide and other “green” solvents

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FUTURE WORK AND POSSIBILITIES

- > Future work will focus on testing guayule resin fractions against other urban pests, such as bed bugs and mosquitoes, as well as determining the level of toxicity to see if some guayule resin fractions can kill the insects. These fractions can then be tested in pesticide and repellent formulations to replace synthetic compounds or compounds that negatively impact humans, animals, plants, and other insects.

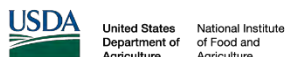


- > Once the target guayule resin compounds have been identified, the separation process will be optimized to get the highest combined product value for the least processing cost.

WHAT IS STILL NEEDED

- > Partnerships with chemical and bio-based product companies to test the efficacy and safety of guayule-driven compounds and fractions into pesticide formulations.
- > Pilot-scale studies of guayule resin extraction and separation methods to compare realistic yields and to evaluate impact on overall guayule processing costs.
- > Testing of guayule resin compounds for bio-activity related to human health (anticancer, anti-inflammatory, antioxidant, etc.).
- > Testing of guayule resin fractions for use in functional coatings (anti-termite).
- > Partnerships to explore the use of guayule resin compounds in fragrance applications.

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



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SBAR Center of Excellence Briefing Paper (Guayule Resin for Insect Repellents). October 2021.



SUSTAINABLE BIOECONOMY
FOR ARID REGIONS

GUAYULE GROWING RANGE EXPANSION IN THE SOUTHWEST

EXECUTIVE SUMMARY

> Guayule is a natural, low-water use, rubber-producing crop native to the southwestern US and central Mexico. It is currently grown in southern AZ (USDA Plant Hardiness Zone 9) characterized by a mild winter climate. The US imported \$1.4B worth of natural rubber in 2020 and Southwest producers can benefit from this market, reducing the US's reliance on imports.

> Expanding guayule production to include regions of higher altitudes and more northern latitudes in the southwest (Zones 6-8) will allow production in more geographical zones and will increase domestic rubber production, potentially allowing more farmers to benefit from the bioeconomy of a new industrial crop.

> To achieve this expansion, funding will be needed to breed guayule cultivars that are more cold-tolerant and adapted to regions with more severe winters compared to the current growing region.

SBAR ACCOMPLISHMENTS

> Multilocal studies of guayule in AZ to evaluate the yield potentials of different guayule accessions, and evaluation of 24 public germplasm accessions for cold tolerance in NM.

> Weed control studies in guayule to develop appropriate weed management strategies.

> Irrigation optimization to enhance rubber yield of guayule with minimal irrigation water applied.

> Fertility studies to enhance nutrient management of guayule production.

> Metabolic profiling of cold-tolerant plants completed, which showed similarities and differences in cold acclimation response between diploid and polyploid guayule plants.



GUAYULE DETAILS

- > Natural rubber-producing shrub
- > Native to the Chihuahuan Desert
- > Can be produced as a low-water use row crop
- > A perennial crop, provides harvests for several years
- > Researchers are working to improve guayule germplasm for domestic production

KEY TAKE-AWAYS

- > Potential \$1.4B market for guayule production in US
- > Market for natural rubber includes high performance tires (airplanes, buses, etc.), adhesives, rubber cement and roadways
- > Cold-tolerant cultivars will expand guayule growing range in AZ, NM, and TX

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FUTURE WORK AND NEEDS

- > A major constraint is the lack of cultivars that can survive and perform well in colder regions of the southwestern US. Expanding the growing range to cover USDA Plant Hardiness Zones 6-7 can increase the potential acreage of guayule, especially in AZ, NM, and TX.
- > Preliminary studies are ongoing to screen existing germplasm accessions for cold tolerance in Las Cruces, NM (Zone 8), which has colder winter temperatures than southern AZ. Resources and funding are needed to expand this work by breeding cultivars capable of withstanding lower winter temperatures characteristic of middle to northern AZ and NM.
- > A follow-up testing activity to evaluate the rest of the available guayule germplasm from the NPGS collections would be desirable, since differential response to freezing temperatures was observed on the limited set of polyploid germplasm.
- > More research is needed to determine the effect of irrigation frequency and soil moisture to cold tolerance, winter survival, and rubber yield of guayule germplasm in NM.
- > Testing the selections from Las Cruces and subsequent progenies in various locations in NM and TX is recommended to determine suitable germplasm as well as effect of cold damage to rubber content and biomass yield.



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



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SBAR Center of Excellence Briefing Paper (Guayule Growing Range Expansion in the Southwest). October 2021.



SUSTAINABLE BIOECONOMY
FOR ARID REGIONS

IMPACTS OF SOIL MICROBIOME ON GUAYULE RUBBER PRODUCTION

EXECUTIVE SUMMARY

> Guayule (*Parthenium argentatum* G.), a perennial shrub native to the US and Mexico, is under development as an industrial crop in the southwest, as a source of natural rubber, organic resins, and biofuel feedstock. Rubber production rates in guayule are elevated during winter as a stress response to cold temperatures; however, the specific physiological response is poorly understood. Elucidation of environmental factors influencing guayule rubber production is fundamental to enhancing rubber yield in guayule.

> Exploitation of the soil microbiome is an untapped frontier in production agriculture. Soil microbes play critical roles in plant physiology and responses to environmental stress. Plant soil microbe synergies are rarely managed in agriculture production; however, this exciting possibility is being explored in guayule for soil root-zone microbiome interactions. SBAR experiments to date have revealed strong correlations between guayule rubber production and the soil microbial biomass.

SBAR ACCOMPLISHMENTS

> Root-zone microbial community dynamics changed dramatically across guayule growth stages in field trials with distinct soil types.

> Guayule rubber content was positively correlated with soil DNA biomass (total soil microbiome) and negatively correlated with guayule Normalized Difference Vegetation Index (NDVI).

> Relative abundances of 10 bacterial families and 3 fungal classes were positively correlated with plant rubber content.



GUAYULE & THE SOIL MICROBIOME

- > Soil microbiome keystone taxa vary with guayule growth stage
- > Positive correlation: plant rubber content and soil DNA biomass
- > Positive correlation: plant rubber content and specific bacterial and fungal taxa

KEY POINTS OF INTEREST

- > Investigate soil microbiome management
- > Progress to controlled environmental conditions
- > Quantify associations between keystone soil microbes and guayule rubber production

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FUTURE WORK AND POSSIBILITIES

- > The next step is to systematically investigate the impact of growth-stage specific keystone microbes on guayule rubber production.
- > We hypothesize that soil enrichment with the keystone bacteria/archaeal and/or fungal species that have been identified in association with the winter period will cause significant changes to guayule rubber content.



- > Experiments are proposed in controlled greenhouse environments, to systematically vary the relative abundance of specific microbial taxa in the soil microbiome, and to determine microbiome profiles that significantly impact guayule rubber production.

WHAT IS NEEDED

- > Identification of key guayule-soil microbe associations correlated with increased rubber or resin production.
- > Determination of a profile of keystone soil microbes that associate with robust guayule plant establishment.
- > Development of agricultural management practices that enrich for these keystone soil microbes.

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



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SBAR Center of Excellence Briefing Paper (Impacts of Soil Microbiome on Guayule Rubber Production). January 2022.



SUSTAINABLE BIOECONOMY
FOR ARID REGIONS

GUAYULE-BASED JOB CREATION IN THE ARID REGIONS' BIOECONOMY

EXECUTIVE SUMMARY



> The SBAR Center of Excellence has identified opportunities for growing, harvesting and processing guayule (*Parthenium argentatum*) in the arid Southwest as part of a larger regional bioeconomy. The potential value of guayule coproducts (like resin adhesives, termite repellants, and insecticides) is even higher. Guayule production can be a sustainable driver for job creation in the Southwestern U.S.

> All parts of growing guayule present opportunities for job growth from planting and harvesting, to the extraction process that produces the rubber and other coproducts. Additional sectors for growth include **education** for training bioeconomy workers, **business entrepreneurs** for product promotion and marketing, and **transportation** specialists, among others.

> The significant job creation necessary to build a bioeconomy in the Southwest confirms the sustainability of guayule.

SBAR ACCOMPLISHMENTS

> Demonstrated guayule as a sustainable commercial crop for the arid southwest.

> Designed sustainable biomass supply chain optimization, including the location of processing facilities, transportation, and harvesting logistics.

> Completion of the BENCO model: a dynamic tool that supports evaluation of the economic, financial, and resource implications of crop adoption.

> Development of an SBAR internship program available for experiential learning to support jobs in guayule-based technology and production.

KEY DETAILS

- > Job creation is a key element of a sustainable bioeconomy
- > Guayule job opportunities range across multiple sectors
- > Non-formal learning (like 4-H) increases awareness of bioeconomy job opportunities

KEY TAKE-AWAYS

- > Potential \$1.4B market for guayule production in US
- > Thousands of future guayule-based jobs will cross multiple economic sectors
- > Job training opportunities abound via internships, community colleges, and universities

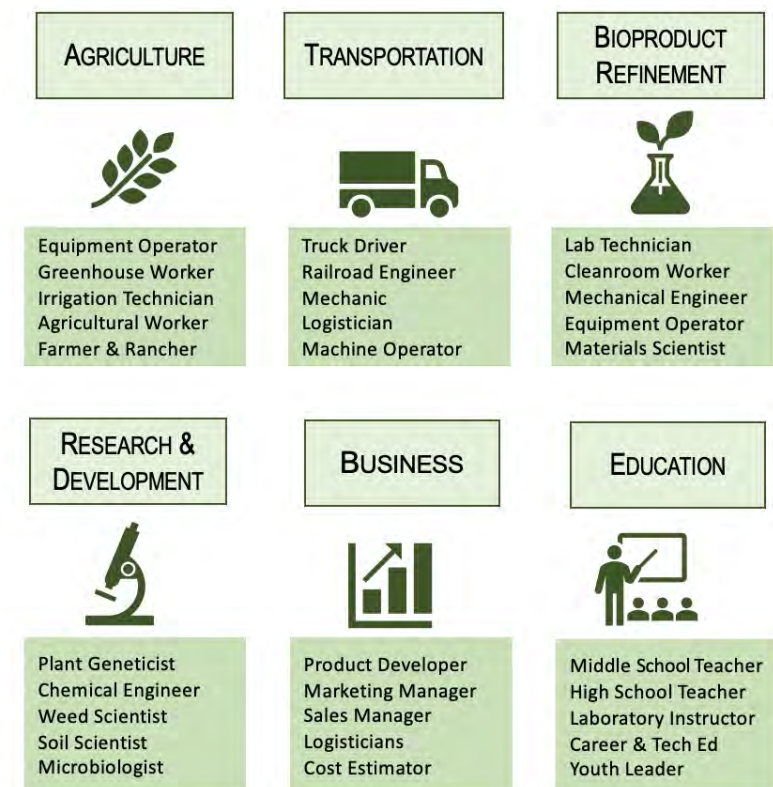
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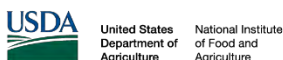
BIOECONOMY JOB CREATION

- > Increased guayule production in the arid Southwest will support an increase in jobs across different areas of the economy. Anticipated jobs cross six primary economic sectors: agriculture, transportation, bioproduct refinement, research and development, business, and education.
- > Job growth from bioeconomic innovation is a key part of a sustainable future for arid regions.

Job Creation in Guayule-Based Bioeconomy



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



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SUSTAINABLE BIOECONOMY
FOR ARID REGIONS

SUSTAINABLE BIO-ECONOMY FOR ARID REGIONS

EXECUTIVE SUMMARY

> The SBAR Center of Excellence brings together the University of Arizona, Colorado School of Mines, Colorado State University, New Mexico State University, USDA-ARS, and Bridgestone Americas to understand and improve all aspects of producing natural rubber and valuable co-products from guayule (*Parthenium argentatum*), a perennial shrub that is a domestic source of natural rubber.

> The team consists of agronomists, weed specialists, soil scientists, and biosystems engineers that work to improve feedstock production in a sustainable manner; chemical engineers that work to characterize guayule resins and bagasse while exploring new uses for these components of the plant; mechanical engineers and economists to ensure that new technologies are implemented in an economically viable and environmentally friendly way; and educators and extension agents to assure a steady supply of trained professionals to build a robust bio-economy in the arid southwest.

SBAR ACCOMPLISHMENTS

> Completed direct seeding germplasm trial of 45 diverse lines in 2 soil types that resulted in 10 lines with stable yields and high rubber content.

> Obtaining 24cSLN herbicide labels for guayule in Arizona.

> Studying relationships between nitrogen, irrigation, the soil microbiome, and rubber yield.

> Developed an integrated techno-economic and lifecycle assessment model from field to rubber production, resin and bagasse.

> Characterized guayule resin. Separated guayule resin into terpenes, terpenoids, and fatty acid components.

> Investigated high-value co-products from guayule resin.



KEY DETAILS

> Diverse team of researchers working on all facets of the guayule value chain

> Focus of research and development is on a clear path to commercialization

> Workforce development is a key element to building a sustainable bio-economy

QUEST FOR PARTNERSHIPS

- > Growers to establish test plots of guayule
- > Companies that market terpenes, adhesives, and/or insect repellents
- > Industry and commercial entities interested in biofuels from bagasse

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FUTURE WORK AND POSSIBILITIES

- > Communicate project results to a broad range of audiences.
- > Complete stress irrigation studies to understand the minimum amount of water needed to support a guayule crop.
- > Obtain herbicide labels that can facilitate guayule establishment.
- > Scale-up production of co-products from guayule resin and bagasse.
- > Identify industrial partners to commercialize co-products.
- > Partner with community colleges to strengthen workforce development training and activities.



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



United States Department of Agriculture National Institute of Food and Agriculture



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SBAR Center of Excellence Briefing Paper (Sustainable Bio-economy for Arid Regions). October 2021.



SUSTAINABLE BIOECONOMY
FOR ARID REGIONS

GUAYULE RESIN FOR ADHESIVES

EXECUTIVE SUMMARY

> Guayule (*Parthenium argentatum*) is a desert-adapted shrub that produces natural rubber in its stems. To establish a new industry for natural rubber production in Southwestern US, all components of the guayule plant must be valorized. Between 5 – 10% of the plant is resin, which is a complex mixture of guayulins, terpenes, terpenoids, fatty acids, and argentatins.

> Guayule resin without any modification is not a suitable adhesive. However, when the guayule resin is modified and blended with bio-based or petroleum-based resins, the wet and dry tensile strengths of the blended adhesives are better than the pure bio-based or petroleum adhesives. Potential applications include foundry sand adhesives, children's glue, packaging, and wood adhesives.

SBAR ACCOMPLISHMENTS

> Chemically modified guayule resin has been tested as a wood adhesive using ASTM standard methods. Initially it was blended with soy protein adhesives and shown to increase the water resistance of the plant adhesive by 60 to 70%, while no negative effects on dry adhesive strength were observed. The blended adhesives have been characterized using chemical, mechanical, and spectrometric techniques. The guayule resin/soy protein blends have been used as a binder for particle board.

> Guayule resin has been blended with commercially available formaldehyde-based adhesives and shown to increase both the wet and dry adhesion strengths. These blended adhesives can reduce our use of formaldehyde, which is an irritant.



RESIN ADHESIVE POTENTIAL

- > Guayule resin blended with either plant-based adhesives or urea-formaldehyde adhesives increases wet adhesion strength
- > Guayule resin is a source of sustainable bio-based adhesives

PATENTS SUBMITTED

- > Modified guayule resin/soy protein blends for bio-based adhesives
- > Particle boards including guayule resin/soy protein blends

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FUTURE WORK AND POSSIBILITIES

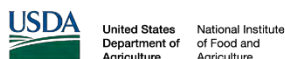
- > Future work will focus on further characterization of the guayule resin blends to understand the chemical and mechanical properties, as well as use of the blends in particle board formulations.
- > Guayule resin fractions will also be tested to evaluate the potential of generating multiple products from the resin.

WHAT IS STILL NEEDED

- > Partnerships with chemical and bio-based product companies.
- > Detailed adhesive market analysis.
- > Scale-up of guayule resin fractionation and separation.
- > Testing of guayule resin/soy protein particle boards for strength and water resistance.
- > Partnerships with particle board companies and other industries.



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SBAR Center of Excellence Briefing Paper (Guayule Resin for Adhesives). October 2021.



SUSTAINABLE BIOECONOMY
FOR ARID REGIONS

SUSTAINABILITY OF GUAYULE-BASED NATURAL RUBBER PRODUCTION



KEY POINTS OF INTEREST

- > Increased profitability with less water required
- > Minimum guayule rubber selling price required is \$3.04/kg for a net present value of zero over 30 yrs of production
- > Minimum rubber selling price assumes the co-product revenue is generated by selling bagasse at \$0.10/kg and resin at \$1.00/kg
- > Global warming of guayule rubber is 11 kg CO₂ eq per kg rubber, or 19,458 kg CO₂ eq per hectare

EXECUTIVE SUMMARY

> SBAR research has generated an integrated model that enables concurrent assessment techno-economics and life cycle impact assessment. The model includes all aspects of the guayule to rubber process with detailed agricultural and biorefining model. The biorefinery produces three products: natural rubber, bagasse, and resin.

> The current results show that the system can meet economic parity with reduced environmental impact than traditional natural rubber systems when the co-products (bagasse and resin) can be moderately valorized.

> The modeling work is being used to identify critical areas for further research and development to support commercialization of this drought-tolerant desert crop.

SBAR HIGH-IMPACT ACCOMPLISHMENTS

> Demonstrated guayule as a sustainable commercial crop for the American Southwest.

> Developed a unique integrated model that includes guayule agriculture from planting to processor, an integrated TEA/LCA model, and advanced water LCA methods for application in arid regions.

> Designed sustainable biomass supply chain optimization, including the location of processing facilities, transportation, and harvesting logistics.

> Increasing farm profitability with optimal crop rotations and machinery scheduling.

> Completion of the BENCO model: a dynamic tool that supports evaluation of the economic, financial, and resource implications of crop adoption.

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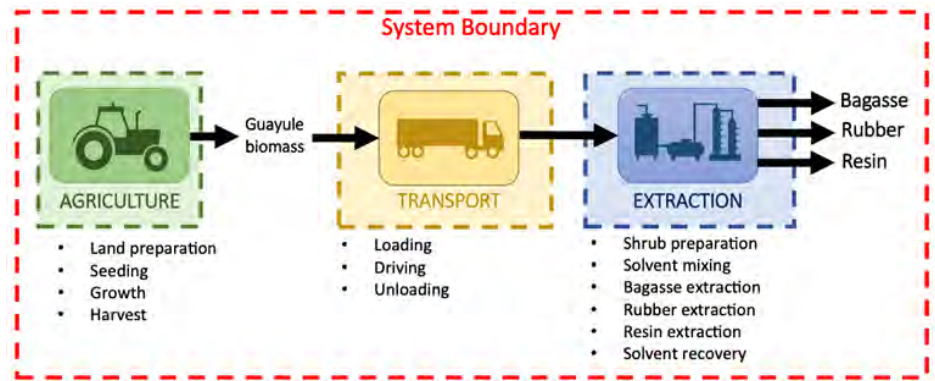


Fig. 1. Process model diagram of guayule rubber, resin, and bagasse production.

FUTURE WORK AND NEEDS

- > Drive the technology towards commercialization through results-based, focused research and development.
- > Evaluate co-product systems for trade-offs that can be used to enhance and direct future research.
- > Investigate water use intensity of the optimal cropping systems for guayule.
- > Optimize guayule harvest under extreme weather and disruptive events.
- > Update enterprise budgets to reflect current circumstances.
- > Estimate regional economic impact for crop adoption under different scenarios.
- > Partner with regional growers to establish break-even prices for guayule and existing crops using the BENCO model. (BENCO – break-even for new crop options)

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