SUSTAINABLE BIOECONOMY FOR ARID REGIONS (SBAR)

Summary Report – Quarter 2, 2019

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

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ACCOMPLISHMENTS
April 2019 – June 2019

INTRODUCTION AND PROJECT MANAGEMENT

General Overview: Project Organization

The Sustainable Bio-economy for Arid Regions (SBAR) Center of Excellence continues to receive project direction and oversight from Dr. Kimberly Ogden, who leads the overall research effort and ensures adequate progress toward meeting project goals. The SBAR Project Director (Alix Rogstad) continues to 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 be effective at capturing 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. The next scheduled thorough review and update will be in July 2019.

Advisory Board

Two individuals joined the Advisory Board this quarter, replacing those that have rolled off. The two new members are John Holladay (Pacific Northwest National Laboratory) and Paul "Paco" Ollerton (Tierra Verde Farms) (Table 1). Receiving the signed non-disclosure agreements (NDA) to ensure confidentiality of research data, information, and conclusions for the duration of the project is ongoing. To date 7 NDAs have been completed and returned, 4 other Advisory Board members are subject to existing project NDA and confidentiality agreements, and the remaining 4 NDAs are pending.

Table 1. *SBAR Advisory Board members.*

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

Budget and Financial Management

On-going budget management activities are working effectively, and all project expenditures are on track. Rogstad continued to develop sub-award agreements, non-disclosure agreements, and work with partners to ensure grant funds are spent according to the project plan and approved scopes of work.

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

Some project funds are not being spent down as anticipated, so Rogstad and Ogden developed and led the process to allow for all project principal investigators to suggest ways to utilize unspent funds. Suggestions submitted were evaluated and prioritized by the SBAR Leadership Team and the SBAR Advisory Board in June. Reallocation of funds will occur prior to the initiation of Year 3 implementation so that funds may be distributed through the sub-award modification process targeted for August.

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. During this reporting period, the virtual meeting space (via Zoom) was utilized 34 times for over 34.4 hours. An additional 30 meetings were hosted during the same timeframe that did not require the virtual meeting space.

LEADS Team Meetings

The component leaders and co-leaders (LEADS) continued to meet with Ogden and Rogstad during established twice-monthly meetings held via SBAR's dedicated Zoom online meeting space. The LEADS evaluated and prioritized the proposals submitted by other SBAR team members for funding reallocation in June.

2019 SBAR Annual Retreat

The 2019 SBAR Annual Retreat is under development. The meeting will be hosted at the University of Arizona in Tucson (12-13 September), in collaboration with the Association for the Advancement of Industrial Crops (AAIC). This year's Annual Retreat will host multiple opportunities for student engagement (poster and oral presentations) as well as integrated discussion opportunities for all SBAR team members to contribute to research design (through breakout sessions).

Communication and Reporting

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. 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 and Social Media

The SBAR-specific website (www.sbar.arizona.edu) continues to be regularly updated and maintained, serving as the digital "face" of the SBAR Center (Figure 1).

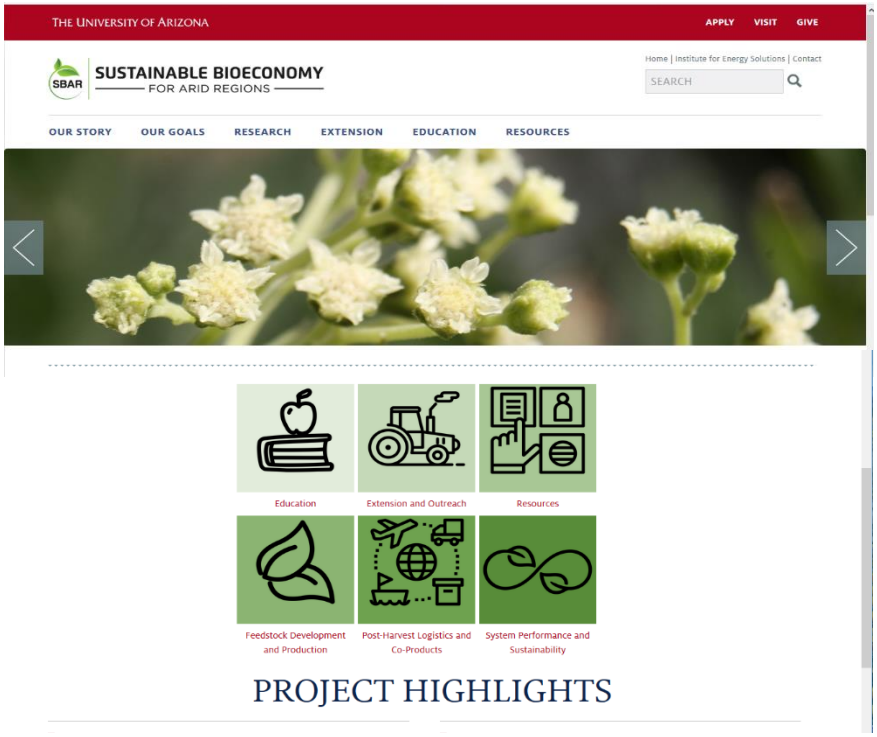


Figure 1. *Website landing page for the Sustainable Bioeconomy for Arid Regions Center.*

There were 1,261 unique sessions from April – June 2019, which was an increase of 685 unique visits as compared to the previous quarter (a 119% increase). Page views occurred in 31 different countries this quarter (top two: USA and India), including 13 countries that have not visited the website previously. The page was visited by people in 20 different states during this reporting period: Arizona, California, Colorado, Florida, Illinois, Iowa, Kansas, Massachusetts, Michigan, Minnesota, New Mexico, New York, Ohio, Oregon, South Carolina, Tennessee, Texas, Virginia, Washington, and Wyoming. Since activation, the website has had visitors from 6 continents and 43 different countries around the world (Table 2).

This quarter experienced an increase of 232 webpage visits from the USA as compared to last quarter, which demonstrates continued interest and an increase in awareness about the SBAR Center and its on-going activities. There have been 3,319 unique website sessions since July 2018. The highest visited website pages during this period included those that described youth activities (4-H Summer Biofuel Camp; youth art contest) and student fellowship opportunities offered in Arizona and New Mexico (Education). Other highly visited pages included those that provide the project overview/general description, and accomplishment reports. The website will continue to be updated regularly as the project unfolds.

Table 2. *Web traffic to the SBAR Center webpage since inception.*

Country	Time Period			
	Jul – Sep 2018	Oct – Dec 2018	Jan – Mar 2019	Apr – Jun 2019
Australia		X	X	X
Austria	X			
Brazil			X	
Canada	X	X	X	X
Chile				X
China		X	X	X
Egypt		X		
Estonia			X	
Ethiopia		X		
France			X	X
Germany	X	X		X
Ghana				X
Hong Kong	X	X		X
India	X	X	X	X
Iran	X		X	X
Ireland				X
Israel			X	
Italy	X	X	X	X
Japan	X	X	X	X
Kuwait		X	X	
Lebanon				X
Malaysia			X	X
Mexico		X	X	X
Morocco				X
Namibia				X
Nepal		X		X
New Zealand	X			
Pakistan		X		X
Philippines	X			X
Poland			X	
Russia				X
South Africa			X	
South Korea				X
Spain				X
Sri Lanka				X
Sweden				X
Thailand	X			X
Turkey		X	X	
Ukraine				X
United Arab Emirates				X
United Kingdom	X	X	X	X
United States	X	X	X	X
Zambia			X	

FEEDSTOCK DEVELOPMENT & PRODUCTION

Project Coordination: The two Feedstock Development (FD) working groups continue to meet monthly and on an as-needed basis in between monthly meetings. The UA continues to lead both monthly meetings, 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 both the UA and New Mexico State University. These weekly briefings provide an opportunity for open communication regarding on-going experiments and results.

Issues/Risks:
The USDA-ARS's main **issue** is personnel since transformations and plant culture maintenance requires a lot of hands-on time and skill. We were able to hire a more experienced technician, Mariano Resendiz, who started working on the project at the start of June 2019.

The second issue is the growth rate of the plants. Leaf discs that were transformed in December 2018/January 2019 are only now developing shoots. To try to accelerate growth we are testing changes in the media (higher sucrose concentration) and process (longer time before calli transfers). The shoots need to be 1.5 cm in size before they can be considered large enough to constitute a recovered plant. At that point they can be tested to confirm transformation (milestone above). We anticipate they will be large enough for the first 3 constructs by December 2019.

The spring 2019 guayule preemergence herbicide studies at MAC were initially planted on April 25, 2019 by direct seeding of pelleted AZ-2 seed into dry soil. The fields were then furrow irrigated every other row every day for 5 days to germinate the seed. This method of irrigation resulted in a large crack that generally ran down the center of the beds where the germinated guayule seedlings were growing. The cracking resulted in desiccation and the death of most guayule seedlings. Thus, the preplant incorporated on the flat preemergence herbicide studies in field 1, borders 42, 44, and 46 were retreated with 1/2x the initial rate of herbicide and replanted. The PPI bed-top preemergence herbicide experiments had less cracking due to the mechanical incorporation on the bed top and these experiments (field 1, borders 43, 45, and 47) were not replanted.

The lesson learned was that course-textured soils must be pre-irrigated following listing and prior to bed formation in order to successfully germinate guayule using alternate row furrow irrigation. This avoids the problem of cracks running down the center of the bed.

Because we are focusing on the plant growth models, especially the Aquacrop model, the drone data is slightly behind target. Secondly, the biggest risk in the development of the Phase 1 growth model is that the post-doc hired (Pradyawong) probably has to return to her country. The modeling work will be on track, but the work planned for Year 3 related to resin coproducts will be affected and delayed.

The soil quality and health team continues to experience delays in completing the analysis of the Year 1 soil samples. Both the analytical lab at NMSU and our research group decided that we were not satisfied with the quality control of our analytical methods for soil chemical, physical

and biological characterizations. We have refined protocols during Q1 and Q2 and believe that this work on protocol development will allow a more technical analysis of associations between soil health parameters and guayule production metrics.

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

Task #	Description of Task	Deliverable	Target Completion Date
1 Dierig	Evaluate USDA germplasm lines	Ploidy analysis completed	31 Aug 19
2 McMah	Prepare expression vectors for downregulation of SEPATALLA3 and FLOWERING LOCUS T genes in guayule	Complete construct for transformation work on SEPATALLA3 Complete construct for transformation work on FLOWERING LOCUS T	30 Nov 18 31 Mar 19
3 McMah	Perform plant transformations using all 3 constructs (AP1, SEP3, FT)	Confirmed transformation for invitro plants – 6 lines AP1 Confirmed transformation for invitro plants – 6 lines SEP3 Confirmed transformation for invitro plants – 6 lines FT	30 Jun 19 30 Jun 19 30 Jun 19
4 Ray	Evaluate Yr1 growth and rubber/resin content in guayule germplasm lines	Growth characteristics determined in 21 guayule germplasm lines Rubber/resin content determined in 21 guayule germplasm lines	15 Oct 18 15 Oct 18
5 Ray	Compare root growth/architecture and water use in direct-seeded and transplant-established guayule	Plantings established Compare root growth and top growth for direct-seeded and transplant-established plants	5 Nov 18 15 Jun 19
6 Ray	Develop protocols for collection/evaluation of guayule leaf cuticular wax	Preliminary information to finalize protocol both for leaf collection and GC Mass Spec evaluation Cuticular waxes described and compared	15 Dec 18 15 Aug 19

Evaluate Germplasm Lines (Variety Trials):
Plants from each replication of all varieties from the two trials with USDA germplasm lines at Bridgestone Eloy were harvested at 11 months-old this past March. Samples were analyzed for dry weight, rubber and resin content and estimated yield per acre. Table 3 lists data of the varieties tested and ranked from highest dry weight (biomass) to lowest.

Table 3. *One year-old shrubs harvested in March 2019 at Eloy from two variety trials of USDA public lines planted in April and June 2018. [DOP=Date of Planting]*

	Dry Weight (g/plant)		Rubber Yield (g/plant)		Rubber (%)	
	DOP **April** 2018 (B2E field)	DOP **June** 2018 (C1 field)	DOP **April** 2018 (B2E field)	DOP **June** 2018 (C1 field)	DOP **April** 2018 (B2E field)	DOP **June** 2018 (C1 field)
USDA Variety	Avg/4 reps ±std error		Avg/4 reps ±std error		Avg/4 reps ±std error	
CAL2	677 ±68	605 ±81	14.7 ±1.2	9.2 ±1.2	2.2 ±0.17	1.5 ±0.05
CAL1	600 ±64		12.0 ±1.4		2.0 ±0.07	
R1109	554 ±48	550 ±70	15.5 ±1.6	15.6 ±2.2	2.8 ±0.09	2.7 ±0.13
CAL5	518 ±104	576 ±53	11.1 ±2.4	10.5 ±1.4	2.1 ±0.19	1.8 ±0.16
PARL 934	509 ±77		13.0 ±2.1		2.5 ±0.06	
CAL7	474 ±70	416 ±37	13.9 ±2.1	11.8 ±1.2	2.9 ±0.07	2.8 ±0.13
AZ-2	464 ±41	454 ±59	13.7 ±1.1	13.1 ±1.8	3.0 ±0.12	2.9 ±0.08
CAL3	383 ±13		9.9 ±0.2		2.6 ±0.05	
PARL 930	352 ±32	290 ±28	9.3 ±0.7	8.0 ±1.0	2.7 ±0.08	2.7 ±0.08
R1110	348 ±72		12.0 ±2.0		3.5 ±0.21	
PARL 923	340 ±51		11.2 ±1.7		3.3 ±0.25	
R1096	336 ±34		6.9 ±0.7		2.1 ±0.09	
R1037	322 ±6	151 ±30	6.6 ±0.3	2.5 ±0.4	2.1 ±0.04	1.7 ±0.10
PARL 931	308 ±52	271 ±25	8.5 ±1.3	7.2 ±0.7	2.8 ±0.09	2.6 ±0.07
R1103	296 ±27		7.0 ±0.6		2.4 ±0.07	
CFS18-2005	293 ±51	209 ±28	8.1 ±1.2	5.2 ±1.1	2.8 ±0.14	2.5 ±0.26
11619	293 ±41	256 ±35	10.8 ±1.5	8.4 ±1.3	3.7 ±0.05	3.2 ±0.06
11646	291 ±41	339 ±41	9.2 ±1.3	9.2 ±1.2	3.1 ±0.09	2.7 ±0.09
PARL 917	284 ±26	220 ±26	7.0 ±0.5	4.6 ±0.5	2.5 ±0.09	2.1 ±0.06
11633	275 ±19	215 ±23	8.7 ±0.8	6.3 ±0.7	3.1 ±0.16	3.0 ±0.17
11609	264 ±19	212 ±8	8.1 ±0.6	6.7 ±0.4	3.2 ±0.25	3.1 ±0.13
N396	263 ±34		8.0 ±0.9		3.1 ±0.07	
12231	261 ±33	260 ±38	6.7 ±0.9	5.6 ±1.1	2.7 ±0.25	2.0 ±0.15
CFS24	258 ±38		7.4 ±0.7		3.0 ±0.28	
PARL 921	254 ±76	108 ±18	7.0 ±2.1	2.7 ±0.6	2.8 ±0.12	2.4 ±0.20
R1040	250 ±24		8.8 ±0.9		3.5 ±0.25	
PARL 929	250 ±26		8.2 ±0.9		3.3 ±0.18	
11604	241 ±42		7.6 ±1.0		3.3 ±0.18	
PARL 922	235 ±23		8.4 ±0.9		3.5 ±0.12	
PARL 916	235 ±27	210 ±27	6.0 ±0.8	4.6 ±0.8	2.6 ±0.05	2.2 ±0.06
4265-X	223 ±38		7.7 ±1.4		3.4 ±0.17	
593	222 ±34		6.1 ±1.0		2.7 ±0.08	
AZ6	221 ±29		9.0 ±1.2		4.1 ±0.15	
R1044	216 ±19		7.7 ±0.7		3.6 ±0.08	

11591	212 ±18		6.5 ±0.6		3.0 ±0.17	
PARL 915	212 ±19		7.3 ±0.7		3.4 ±0.04	
N565 II	208 ±22	190 ±31	6.5 ±0.7	5.3 ±0.8	3.1 ±0.05	2.8 ±0.12
R1108	204 ±16		5.0 ±0.4		2.5 ±0.07	
CFS21	200 ±16	149 ±21	5.6 ±0.5	3.7 ±0.5	2.8 ±0.09	2.5 ±0.13
11605	197 ±26		5.5 ±0.9		2.8 ±0.19	
PARL 914	195 ±30		7.1 ±0.9		3.7 ±0.21	
PARL 924	193 ±17		4.9 ±0.5		2.5 ±0.11	
N565	190 ±27		6.0 ±0.4		3.2 ±0.23	
AZ5	180 ±26	179 ±34	6.8 ±1.1	6.3 ±1.4	3.7 ±0.14	3.5 ±0.19
N576	174 ±22		5.4 ±0.6		3.1 ±0.06	
PARL 920	172 ±26	202 ±42	5.3 ±0.9	5.3 ±1.0	3.0 ±0.13	2.7 ±0.13
11693	162 ±16	231 ±24	6.1 ±0.7	8.6 ±0.9	3.8 ±0.24	3.7 ±0.15
PARL 935	158 ±33		3.2 ±0.0		2.1 ±0.44	
PARL 919	151 ±16	191 ±24	4.9 ±0.6	5.7 ±0.7	3.2 ±0.18	3.0 ±0.09
R1093	132 ±15		3.3 ±0.4		2.5 ±0.08	
PARL 932	119 ±9	103 ±8	4.0 ±0.0	2.4 ±0.2	3.4 ±0.25	2.3 ±0.09
R1092	106 ±8	107 ±12	3.1 ±0.3	2.4 ±0.3	2.8 ±0.17	2.2 ±0.13
11635	105 ±25	80 ±22	3.9 ±0.9	2.7 ±0.7	3.8 ±0.17	3.3 ±0.17

Expression Vectors for Downregulating SEP3 and FT Genes:

Our project seeks to enhance natural rubber content in guayule by downregulation of flowering. Previously, three target genes – all transcription factors related to flowering – were identified, and guayule transformation constructs were completed for all three target genes.

1. **Downregulation** of *APETALA1 (AP1),* which promoted flowering in citrus (Pena *et al.* 2001).
2. **Downregulation** of *SEPATTALA (SEP)* a class E protein that may have a role in all aspects of flower development (sepal identity, petal identity, ovule identity, stamen identity, and carpal identity), in combination with other transcription factors.
3. **Downregulation** of *FLOWERING LOCUS T (FT).* FT2 downregulation in sugar beet resulted in continued vegetative growth without flowering (Pin et al. 2017).

In 2Q19 a fourth construct, for **downregulation of the LEAFY gene**, was prepared. LEAFY is a plant-specific transcription factor involved in floral meristem identity. It causes groups of undifferentiated cells to develop into flowers instead of leaves (Weigel et al. 1992) and has been downregulated in poplar (Klocko et al. 2016).

Plant Transformations using AP1, SEP3, and FT Genes:

As of mid-June 2019 we have:

~350 calli/shoots growing in culture for the APETALA1 gene (Figure 2A)

~306 calli growing in culture for the FLOWERING LOCUS T gene (Figure 2B)

~1890 calli/shoots growing in culture SEPATTALA3 gene (Figure 3).

Some numbers are lower than the 1Q report because escapes (false positives) have been eliminated through selection rounds.

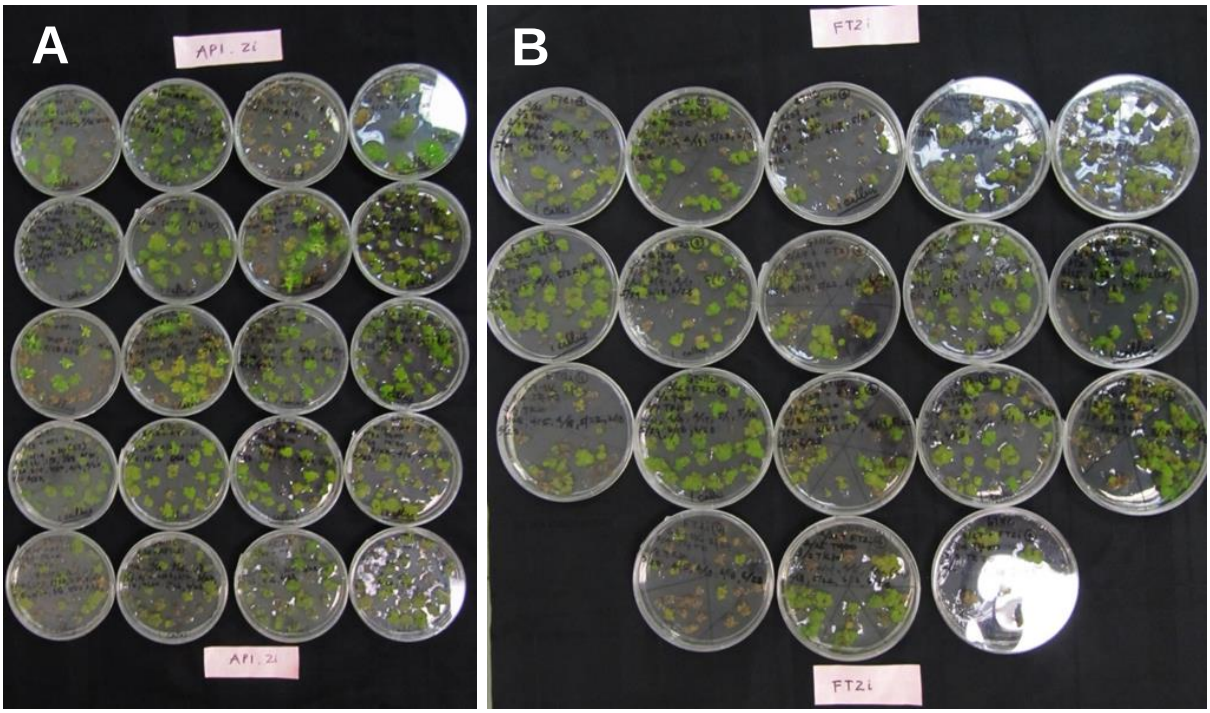


Figure 2. *Calli and shoots growing under selection in tissue culture for transformations of guayule AZ-2 with (A) AP1-2, and (B) FT2 genes.*

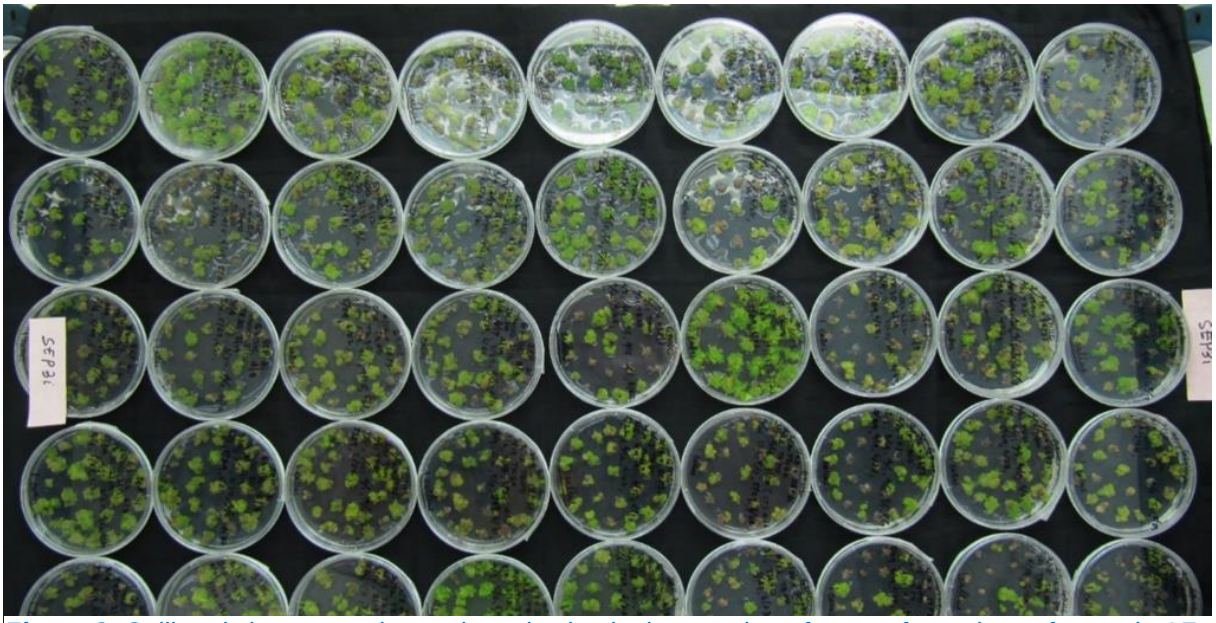


Figure 3. *Calli and shoots growing under selection in tissue culture for transformations of guayule AZ-2 with SEP3 genes.*

Transformations are currently being performed on the LEAFY RNAi construct (Figure 4); our team has completed about 2074 attempts so far this summer.

Photo 1. *Milagro Adom (L) and Mariano Resendiz (R) performing leaf disc transformations for LEAFY gene in the lab.*

Figure 4. *Leaf disc transformations for LEAFY gene.*

Yr1 Growth and Rubber/Resin Content in Guayule Germplasm Lines:
Research associated with this task has been completed; no new data to report.

Root Growth/Architecture Compared to Water Use in Direct Seed and Transplant-Established:
Research is continuing as planned; measurements were not taken this quarter and there are no new data to report.

Cuticular Wax Collection/Evaluation Protocols:
Due to the 2018-2019 United States government shutdown, the collaborators necessary for completing this task were unavailable. Thus, this task was not completed and, after further discussion with the team, has been abandoned.

Other Tasks:
Dormancy in guayule: Separately, a Dormancy collaborative study (with Colleen McMahan, Julie Neilson, Omar Holgrien, and Diaa El-Shikha/Pete Waller) took the third (and final) field sampling on April 22, 2019 in Maricopa, Arizona.

Soil rhizosphere microbiome and chemistry studies in response to field irrigation levels were planned as part of the original SBAR research. But ARS was also interested in these parameters as the plant experienced different metabolic states. Additional field samplings were agreed to. So, for selected data points, we have added → guayule plant carbon fixation rate,

gene expression, rubber biosynthesis rate, rubber particle and molecule characteristics, to evaluate associations between rhizosphere microbiome/chemistry and guayule plant physiology before, during, and after winter dormancy (3 sample points).

- First sampling: Nov 13, 2018; time of cold-induced increase in rubber synthesis
- Second sampling: February 12, 2019; time of winter dormancy and active rubber synthesis
- Third sampling: April 22, 2019; time of rapid plant biomass accumulation, low rubber synthesis

Plants harvested in April were larger than those harvested in February, as expected. Overall growth was most noted in # branches, which increased with each harvest, especially in April. The rubber transferase activity was highest in November by 7-fold compared to the other harvest dates. Rubber molecular weight, when measured from latex particles, was highest in April at 2.4M g/mol. Plant tissue and soil characterization continues.

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

Task #	Description of Task	Deliverable	Target Completion Date
1 Abdel-H	Phenotypic characterization - Guayule	Collect and analyze available phenotypic data; plant stand and establishment, plant height and width, and flowering time Collect and analyze first set of available high-throughput phenotyping (HTP) parameters: vegetation indices and reflectance	15 Jul 19 15 Jul 19
2 Dierig	Remote sensing evaluation of USDA germplasm lines	Rate of growth comparison between lines completed	31 Aug 19
3 Dierig	Thermogradient table analysis	Germination data completed	31 Oct 18
4 Dierig	Leaf characterization	Trichome and color analysis of leaves from plants of 10 lines in variety trials	30 Sep 18

Phenotypic characterization – Guayule:

A field trial containing 48 USDA guayule accessions were planted at MAC farm, Maricopa, AZ in randomized completed block Design (RCBD) with four replicates each. Each replicate consists of four rows spaced at 40 inches each and 10 -long plots, within each row plants are spaced at 12 inches. Plots are maintained by hand weeding as needed and surface irrigation at bi-weekly interval based on the weather and plant growth stage.

Collect and analyze available field phenotypic data of one-year old plants.
To estimate the rubber and resin contents of one-year guayule genotypes, two plants from each plot were harvested individually, dried, chipped and ground using hummer then Wiley mills. The final ground samples were sent to Eloy station to estimate rubber and resin contents using NIRS modules.

Analysis of variance (ANOVA) showed significant differences among guayule genotypes for the plant height over three measurements during August 2018, October 2018, and July 2019 (Figure 5). Guayule genotypes at July 2019 ranged from 32 to 91 cm. As indicated in the first two measurements, tetraploid genotypes such as AZ2 were taller than the diploid (CAL3). It is known that ploidy level could affect plant performance including height and growth. There were significant variations among genotypes in relative plant growth as function of plant heights.

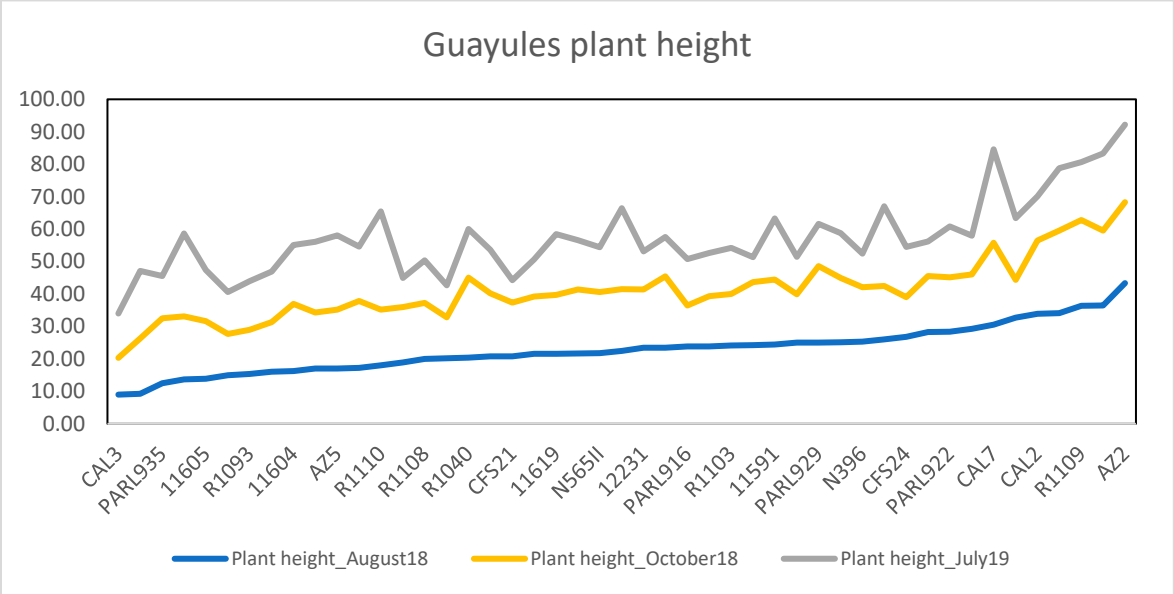


Figure 5. *Measured heights of guayule plants at three different times.*

Collect and analyze high-throughput phenotyping (HTP) parameters for one-year old plants.
A high-clearance tractor equipped with proximal sensors mounted on modified LeeAgra AvengerPro spray rig to collect FB-HT data for guayule and other crops. The HTP platform uses proximal data captured from electronic sensors to measure canopy multi-spectral reflectances to estimate different vegetation and chlorophyll content indexes and canopy temperature. Canopy reflectance is recorded at six wavelengths using Holland Scientific ACS-470 CropCircle sensors, which utilize an active pulse-modulated polychromatic light source. Canopy temperature is measured by Apogee SI-131 infrared thermometers. The reflectance data were used to construct vegetation indices (VI)

including; Normalized difference vegetation index-red (NDVIR), Normalized difference vegetation index-amber (NDVIA), Physiological reflectance index (PRI), Normalized difference vegetation index-red-red edge (NDRRE), Normalized difference vegetation index-amber-red edge (NDARE), Normalized difference red edge index (NDRE), DATT index, and Meris terrestrial chlorophyll index (MTCI). Beside these indexes, we also collected data for canopy temperature. Sixteen runs were collected at regular base weekly, the whole data set is being analyzed and will be reported in full coming report. analyzed during the growing season.

Preliminary ANOVA indicated significant variations among guayule genotypes for studied HTP-related traits. For example, the NDVI and ADRE indexes ranges from 0.15 to 0.45 and 0.15 to 0.22, respectively for studied genotypes (Figure 6). The higher NDVI and ADRE value indicates the healthier the plant is. Among guayules, highest vegetation indexes were observed in improved germplasm, as general role, as well some wild genotypes showed high in NDVI and NDRE values as well biomass such as R1109 (Figure 7). The tetraploid genotypes such as AZ2 were higher in vegetation indexes estimates than the diploid (CAL3).

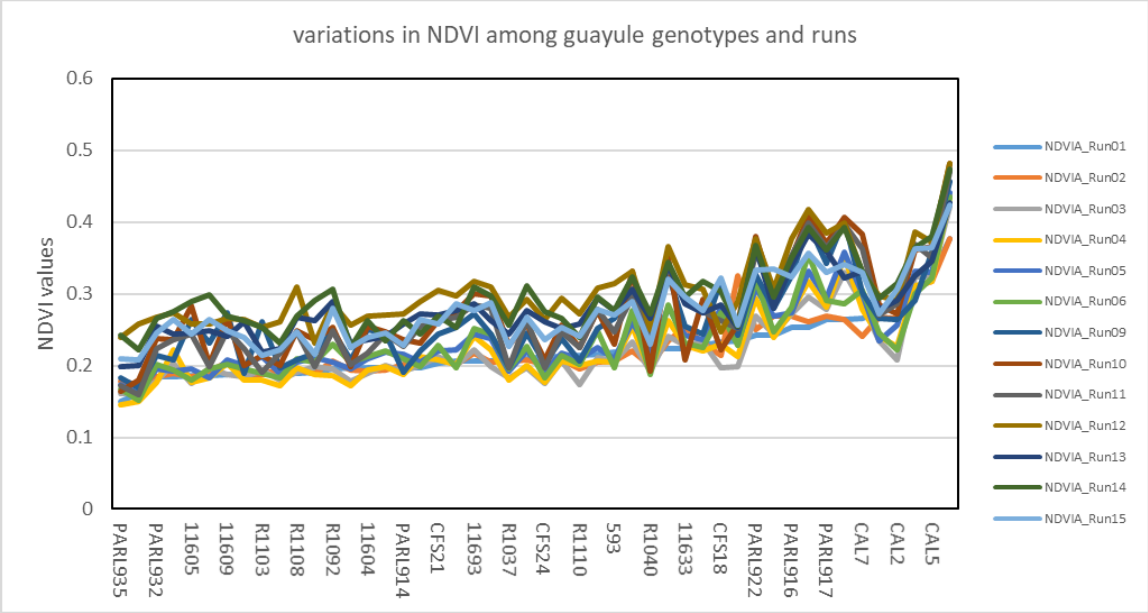


Figure 6. *Variations in NDVI among guayule genotypes and runs.*

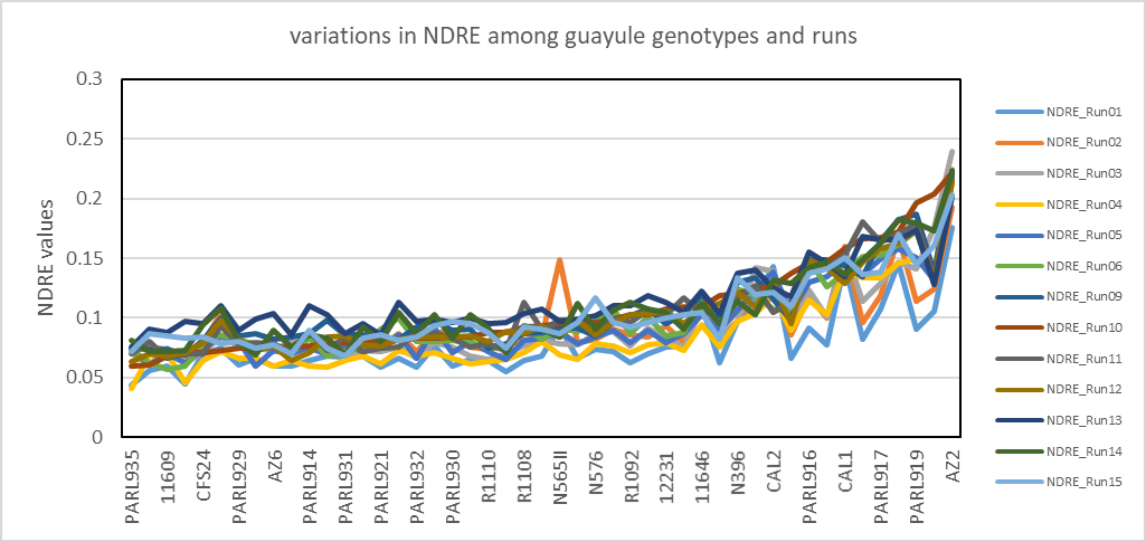


Figure 7. *Variations in NDRE among guayule genotypes and runs.*

Remote Sensing Evaluation:
Research is continuing as planned; no measurements were taken this quarter and there are no new data to report.

Thermogradient Table Analysis:
Research is continuing as planned; no new data to report.

Leaf Characterization:
Research is continuing as planned; no new data to report.

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	Identify guar germplasm suitable for cooler and northern latitudes Summarize data after harvest; present at field day in Clovis, NM	31 Aug 19 31 Aug 19
2 Grover	Multiply guar germplasm lines (increase # of seeds)	Obtain seeds from ~30 guar lines for evaluation Generate report on seed yield and related information learned from multiplication	31 Aug 19 31 Aug 19
3 Ray	Evaluate seed from plants surviving root rot inoculation	Screen seed progeny for increased root rot tolerance	15 Jan 19

4 Ray	Determine root rot tolerance per guayule germplasm	Screen 42 guayule germplasm lines for root rot fungus tolerance Identify survival rate (%) for each germplasm line Complete cuttings from surviving plants to increase seed	15 Jul 19 15 Jul 19 15 Aug 19
5 Ray	Guar yield trials in Tucson, AZ; Las Cruces, NM; and Clovis, NM	Increase guar seed for yield tests Guar seed harvested and cleaned Yield trial protocols established (3 different for comparison) Yield trials planted	15 Nov 18 15 Nov 18 15 Nov 18 15 Jun 19
6 Ray	Guar genetic combination trials	Guar seed from partial male-sterile plants collected and cleaned Guar seed from crosses of partial male-sterile plants with 2 elite lines planted Genetic diversity evaluated//flowering time, branching, leaf pubescence, and disease/insect tolerance	15 Nov 18 15 Jun 19 15 Oct 19

Guar Germplasm in New Mexico:
Dr. Dennis Ray sent seeds of USDA guar germplasm lines and we have planted the trial for him at Clovis, NM. This work which was planned for last summer, was postponed to 2019 summer season due to lack of sufficient seeds.

Guar Germplasm Line Multiplication:
No new activity to report.

Root Inoculation per Guayule Germplasm:
The first group of plants was inoculated and are being observed for symptoms. Research for this task is proceeding as planned; no new data to report.

Guar Yield Trials in Tucson, AZ; Las Cruces, NM; and Clovis, NM:
Guar seed from each line was weighed (Table 4) and divided into thirds. One sent to Clovis, NM, one to Las Cruces, NM, and one kept in Tucson.

Guar field was planted on June 17, 2019. Four replications of 30 varieties along with selections and crosses made in 2018.

Table 4. *Guar seed weighed on May 3, 2019, before being divided into thirds.*

PLOT	VARIETY	SEED WEIGHT (kg)
G1	SIRSA 56	2.8
G2	NO 10521	5.3
G3	NO 10949	4.1
G4	PI 186477	1.9
G5	EC 248A	5.2
G6	COL NO K619	2.0
G7	B-49819	2.9
G8	B-49823	3.8
G9	B-49824	4.8
G10	IC-83 NO 3	3.8
G11	COL NO 36 PUNJAB	3.4
G13	WKP-88-43	2.1
G14	PI 542608	2.0
G15	MULKHANIA	2.4
G16	SURTI	2.3
G17	GAWAR	2.0
G18	PI 263406	2.5
G19	PI 263698	1.9
G20	PLG 86	1.9
G22	PLG 241	1.8
G23	PLG 482	1.8
G26	TX73-2731	2.4
G27	TX71-3292	1.7
G28	G-05	0.3
G29	TX 78-3726	5.2
G31	Matador	4.7

Guar Genetic Combination Trials:
Research is continuing as planned; no new data 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	Identify critical growth stage of guar to reduce irrigation water use	31 Aug 19
		Contribute data for developing guar crop coefficients (Kc) for irrigation management	31 Aug 19

		Present data at regional and national conferences	31 Aug 19
2 Angadi	Conduct incubator study to understand temperature and germination relationships	Identify optimum soil temperature for guar planting for available guar cultivars Present data/findings at national conference	31 Aug 19 31 Aug 19
3 Dierig	Density trials in Tucson and Eloy, AZ	Establish trial with different densities in Tucson, AZ Summarize plant growth, yield performance, and traits for density trial with 2 varieties and 5 densities in Eloy, AZ	31 Oct 18 30 Apr 22
4 Dierig	Bi-monthly harvest from irrigation trials	Growth data over seasons from two locations	31 Dec 20
5 Grover	Evaluate guar response to moisture stress	Track and collect research data on moisture stress experiment Generate report/publication from results obtained Present research results at regional/national conferences	31 Aug 19 31 Aug 19 31 Aug 19
6 Grover	Evaluate guar response to planting density	Track and collect research data on guar density experiment Generate report/publication from results obtained	31 Aug 19 31 Aug 19
7 McClos	Collaborate with herbicide manufacturers on experiment design and data collection to support 24c SLN registration	Identify herbicide rates, application methods, and application timing for experiments Prowl H2O (pendimethalin) and Aim (carfentazone) labels expire in 2018; work with BASF and FMC on renewals	31 Aug 19 31 Jan 19
8 McClos	Conduct guayule herbicide tolerance study, Fall 2018 at Eloy and Maricopa, AZ	Track and collect research data to support 24c SLN preemergence herbicide registrations for metolachlor, bensulide, ethalfluralin, sulfentrazone, and acetochlor Track and collect research data to support 24c SLN postemergence herbicide registrations for clethodim and carfentrazone Generate report/publication from results obtained	31 Jan 19 31 Jan 19 31 Jan 19

9 McClos	Conduct guayule herbicide tolerance studies, Spring 2019 at Eloy and Maricopa, AZ	Track and collect research data to support 24c SLN preemergence herbicide registrations for metolachlor, bensulide, ethalfluralin, sulfentrazone, and acetochlor Track and collect research data to support 24c SLN postemergence herbicide registrations for clethodim and carfentrazone Generate report/publication from results obtained	31 Aug 19 31 Aug 19 31 Aug 19
10 Ogden	Literature review of field/plant level growth models	Complete literature review	31 Dec 18
11 Ogden	Phase 1 growth models developed	Preliminary models developed and shared with project team	1 Aug 19
12 Ray	Plant density trial	Fall trial established for comparison with spring-established trial	15 Sep 18
13 Ray	Biomass drying experiment	Biomass, resin, and rubber content analyzed	30 Sep 18
14 Ray	Guayule trials (direct-seeded and transplant-established)	Compare for root growth/water use Compare a range of N and P application rates Compare N and P utilization and effects of nutrients on biomass, rubber and resin production	15 May 19 31 Dec 18 15 May 19
15 Waller	Install TDR, infrared camera and flowmeter system	Provide data on guayule irrigation experiments Provide data set that can be used to refine the use of sensors for WINDS crop irrigation mgmt. Generate a publication on integration of sensors and WINDS model; present a conference	15 Jan 19 15 Jan 19 15 Jan 19
16 Waller	Integrate python MySQL WINDS model with existing tools	Integrate new python model with WINDS (winds.arizona.edu), and in-situ sensors Add crop coefficient method to WINDS	15 Apr 19 15 Apr 19 15 Apr 19

		Develop educational videos and documents on use of WINDS	
17 Waller	Irrigation experiments: Guayule and Guar	Collect data; image collection, neutron probe readings, in-situ sensors, crop coefficient development and destructive plant samples for chemical analysis	15 Jul 19
		Document effects of irrigation treatment on plant growth, soil moisture, plant stress, plant chemical response, plant vegetative indices, and crop coefficient	15 Jul 19
		Generate a publication on guayule irrigation experiments	15 Jul 19

Guar Critical Stage-Based Deficit Irrigation Trial:
All 2019 field trials are planted, and the crop is well established. Pre-irrigation treatments were given before planting deficit irrigation trial. The fall and spring season was extremely dry and planting triticale has dried 'no-preseason irrigation' blocks quite well. Frequent small rainfall events delayed planting by about 10 days. Graduate students have started their seasonal observations. Since Hadiqa Maqsood could not come to Clovis for observations, we are trying to help her by collecting some of her observations. We bought soil moisture sensors and installed them in select, important treatment plots for her. The data will help Maqsood in her research.

Dr. Diaa El-Shikha is collecting remote sensing images for Hadiqa. I am supporting his travel to Clovis for three times this season. Some of the essential ground data will be collected by my crew along with remote sensed data.

Incubator Study to Understand Temperature and Germination Relationships:
Temperature and germination study, which was started last quarter in incubators, was completed and data is being entered and analyzed.

Density Trials in Tucson and Eloy, AZ:
The densities are 30, 18, 12, 6, 3-inch in-row spacing for density 1, 2, 3, 4, and 5 respectively and the plants were harvested in March. Table 5 show treatments and actual populations. Five in-row spacings (30, 18, 12, 6, and 3-inch) correspond with five targeted plant populations: 5227, 8712, 13068, 26136, and 52272 plants/ac. The actual plant population after thinning were included in Table 2.

Table 5. *Plant population treatment with targeted and actual plant number for AZ-2 and Sel-1.*

Density # in the figure	Targeted in-row spacing (inch)	Targeted plant/m for sampling	Actual plant/m in sampling for AZ-2	Actual plant/m in sampling for Sel-1	Targeted plant population (plant/a)	Actual plant population for AZ-2 (plant/a)	Actual plant population for Sel-1 (plant/a)
1	30	1	1	1	5227	5699	5082
2	18	2	2	2	8712	8748	7877
3	12	3	3	3	13068	13068	10560
4	6	6	5.75	6	26136	26245	16843
5	3	12	9	6	52272	34521	22070

Figures 8 and 9 indicate that rubber and resin content did not respond to plant population treatment. However, AZ-2 genotype had lower rubber content and higher resin content according to NIR measurements. As a result, the trend for rubber and resin yield was similar to biomass yield.

In March, 2019, second sampling from the field were conducted. One meter of plant samples was taken from each plot (each treatment has four replications). The actual stand (plant/a) and the number of plant in one meter sampling are shown in the first two figures. AZ-2 had significantly higher biomass compared to Sel-1, and biomass increased with higher plant population. At the same time, plant size decreased as plant population increased, and AZ-2 plant size was much larger than Sel-1 plant size.

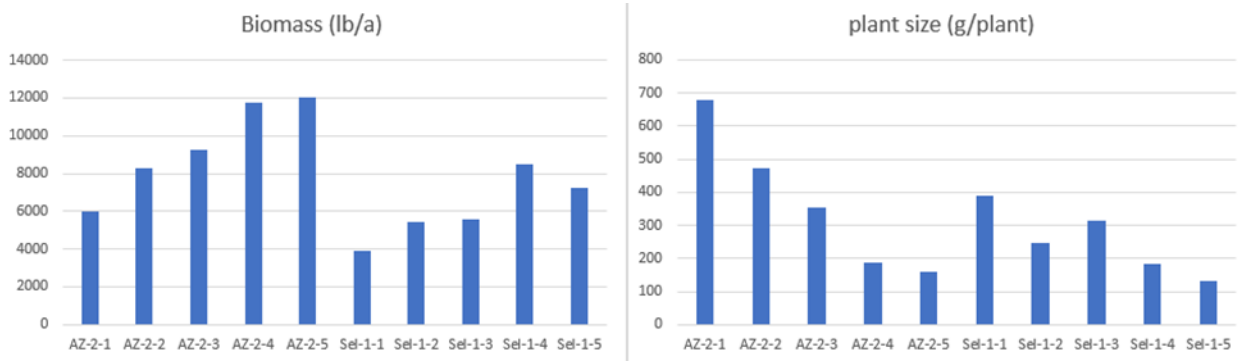


Figure 8. *Biomass and plant size response to plant population for AZ-2 and Sel-1. The crop was planted in mid-April 2018 and sampled in March 2019.*

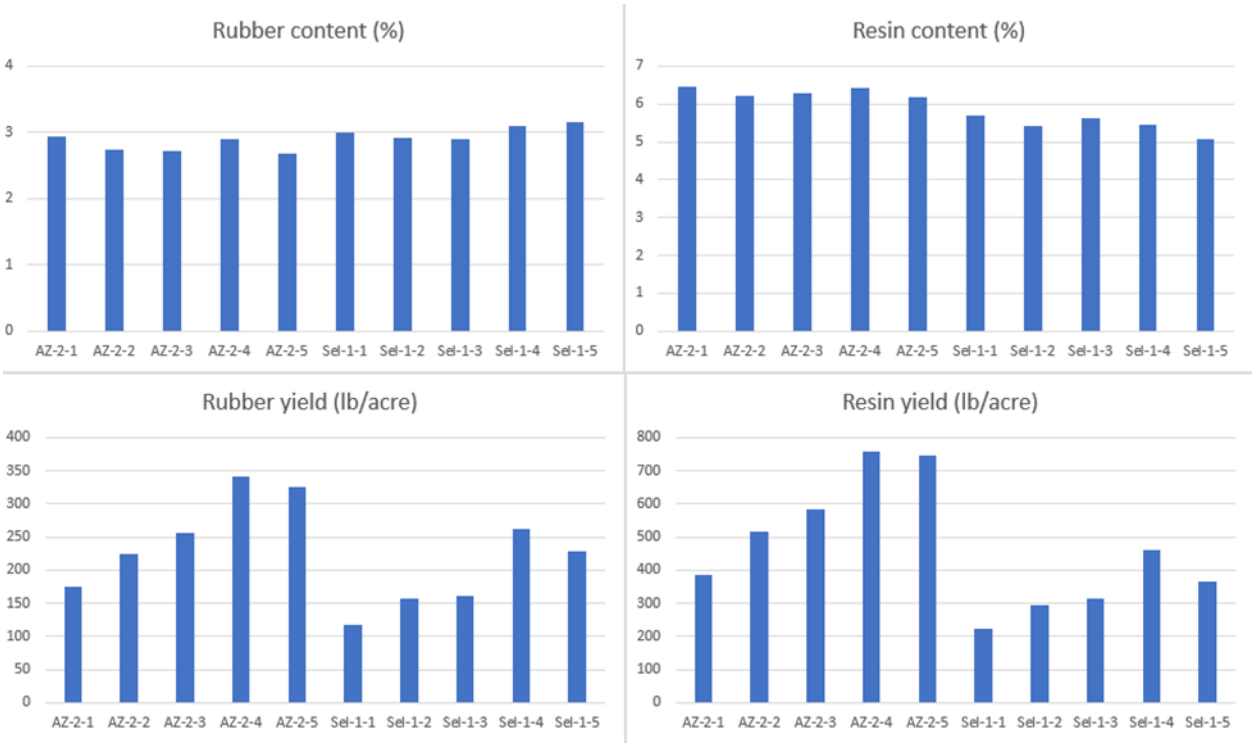


Figure 9. *Rubber and resin content and yield response to plant population for AZ-2 and Sel-1. The crop was planted in mid-April 2018, and sampled in March 2019.*

Bi-Monthly Harvest from Irrigation Trials:

Tables 6-15 compare the growth of plants from drip and flood irrigation treatments at 2 locations. Eloy is a clay soil and MAC is a sandy loam. Plants were harvested at 4, 6, 8, 10, 12 and 14 months of age. Differences based on treatments become evident by 14 mo. Plant dry biomass began higher at Eloy compared to Maricopa until the first winter. Likely due to warmer soil temperatures at Maricopa in the spring of 2019, biomass dry weigh became similar between the two locations until June 2019 when Eloy shrubs were higher weights than Maricopa. In the June harvest the 100% irrigation treatments had higher biomass compared to the 50% treatments at both locations. Differences in root weight are seen in Maricopa between the 50 and 100% drip treatments compared to only modest differences seen at Eloy treatments.

Table 6. *Shrub dry weight (g/m) (no root) harvested at 4, 6, 8, 10, 12, and 14 months from a replicated irrigation experiment at the Bridgestone Guayule Research Farm, Eloy, Arizona. Each value is the average of 3 1-m replications.*

Irrigation Treatment	**Bridgestone -Eloy Farm (Clay soil)** **Shrub Dry Wt. (g/m)**					
	August (4 mo)	October (6 mo)	December (8 mo)	February (10 mo)	April (12 mo)	June (14 mo)
Drip 50%	572.3	891.8	1472.7	1309.5	1501.2	1890.3
Drip 100 %	618.4	1258.8	1652.6	1498.6	1748.9	3141.0
Flood 50 %	610.3	909.6	2042.1	1375.5	1680.3	1794.4
Flood 100 %	762.0	973.5	1816.4	1628.5	1425.9	2392.5

Table 7. *Shrub dry weight (g/m) (no root) harvested at 4, 6, 8, 10, 12, and 14 months from a replicated irrigation experiment at the Maricopa Agricultural Center, Maricopa, Arizona. Each value is the average of 3 1-m replications.*

Irrigation Treatment	**Maricopa- U of A Farm (Sandy loam soil)** **Shrub Dry Wt. (g/m)**					
	August (4 mo)	October (6 mo)	December (8 mo)	February (10 mo)	April (12 mo)	June (14 mo)
Drip 50%	335.8	557.5	1368.6	1279.8	1396	1440
Drip 100 %	310.1	661.6	1225.1	1521.1	1940	2797
Flood 50 %						
Flood 100 %	329.5	638.7	1350.1	1448.6	1703	1555

Table 8. *Root dry weight (g/m) and root length (cm) harvested at 4, 6, 8, 10, 12, and 14 months from a replicated irrigation experiment at the Bridgestone Guayule Research Farm, Eloy, Arizona. Each value is the average of 3 1-m replications.*

Irrigation Treatment	**Bridgestone -Eloy Farm (Clay soil)** **Root dry weight (g/m) and Length (cm)**											
	August (4 mo)		October (6 mo)		December (8 mo)		February (10 mo)		April (12 mo)		June (14 mo)	
	Wt(g)	L (cm)	Wt(g)	L (cm)	Wt (g)	L (cm)	Wt (g)	L (cm)	Wt (g)	L (cm)	Wt (g)	L (cm)
Drip 50%	148	30	214	36	250	32	328	31	314	29	300	29
Drip 100%	140	29	214	30	238	37	350	28	325	29	378	33
Flood 50%	128	25	179	34	292	37	317	31	290	33	287	31
Flood 100%	141	27	169	31	251	31	338	31	217	27	307	32

Table 9. *Root dry weight (g/m) and root length (cm) harvested at 4, 6, 8, 10, 12, and 14 months from a replicated irrigation experiment at the Maricopa Agricultural Center, Maricopa, Arizona. Each value is the average of 3 1-m replications.*

Irrigation Treatment	**Maricopa U of A Farm (Sandy loam soil)** **Root Dry Wt (g/m) and length (cm)**											
	August (4 mo)		October (6 mo)		December (8 mo)		February (10 mo)		April (12 mo)		June (14 mo)	
	Wt(g)	L (cm)	Wt (g)	L (cm)	Wt (g)	L (cm)	Wt(g)	L (cm)	Wt (g)	L (cm)	Wt (g)	L(cm)
Drip 50%	78	20	129	30	267	28	308	31	307	32	325	32
Drip 100%	85	21	162	31	205	30	246	31	350	35	545	39
Flood 50%												
Flood 100%	89	25	179	37	261	35	360	29	326	33	334	37

Table 10. *Proportion of flowers (Fls), leaves (Lvs), and stems (St) from each harvest at the Bridgestone Guayule Research Farm, Eloy, Arizona.*

Irrigation Treatment	**Bridgestone Eloy Farm (Clay soil) Flowers, Leaves, Stems (% of total)**																	
	August (4 mo) (g)			October (6 mo)			December (8 mo)			February (10 mo)			April (12 mo)			June (14 mo)		
	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St
Drip 50 %	5	62	21	8	55	28	3	33	46	3	26	50	4	21	57	10	22	51
Drip 100 %	5	64	19	7	61	26	2	42	43	3	28	51	4	26	54	8	27	53
Flood 50 %	4	65	19	9	61	23	3	34	49	3	28	51	5	29	48	7	28	52
Flood 100%	5	63	22	7	59	29	4	39	45	3	24	56	3	26	57	6	20	54

Table 11. *Proportion of flowers (Fls), leaves (Lvs), and stems (St) from each harvest at the Maricopa Agricultural Center, Maricopa, Arizona.*

Irrigation Treatment	**Maricopa U of A Farm (Sandy loam soil) (% of total)**																	
	August (4 mo) (g)			October (6 mo)			December (8 mo)			February (10 mo)			April (12 mo)			June (14 mo)		
	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St
Drip 50 %	3	65	21	7	64	17	3	36	41	3	28	49	4	25	52	4	26	51
Drip 100 %	4	64	21	5	67	18	3	37	44	3	30	54	6	23	54	5	25	53
Flood 50 %																		
Flood 100%	3	63	22	7	65	17	3	35	43	3	26	50	6	25	52	7	25	51

Table 12. *Rubber and resin content (%) of stems (leaves and flowers removed) harvested at 4, 6, 8, 10, 12, and 14 months from a replicated irrigation experiment at the Bridgestone Guayule Research Farm, Eloy, Arizona. Each value is the average of 3 1-m replications.*

Irrigation Treatment	**Bridgestone Eloy Farm (Clay soil) Rubber / Resin (%)**											
	August (4 mo)		October (6 mo)		December (8 mo)		February (10 mo)		April (12 mo)		June (14 mo)	
	Rub	Res	Rub	Res	Rub	Res	Rub	Res	Rub	Res	Rub	Res
Drip 50 %	0.30	4.3	2.5	5.7	2.0	5.7	2.9	6.2	3.1	6.7	2.9	6.2
Drip 100 %	0.39	4.3	1.6	4.4	1.5	4.9	2.5	5.2	2.2	5.6	1.8	5.7
Flood 50 %	0.37	3.6	2.2	5.3	2.1	5.7	3.0	6.1	2.6	6.3	2.4	6.1
Flood 100 %	0.49	4.2	2.0	4.7	1.8	5.5	2.6	5.6	2.6	5.7	1.9	5.5

Table 13. *Rubber and resin content (%) of stems (leaves and flowers removed) harvested at 4, 6, 8, 10, 12, and 14 months from a replicated irrigation experiment at the Maricopa Agricultural Center, Maricopa, Arizona. Each value is the average of 3 1-m replications.*

Irrigation Treatment	**Maricopa U of A Farm (Sandy loam soil)** **Rubber / Resin (%)**											
	August (4 mo)		October (6 mo)		December (8 mo)		February (10 mo)		April (12 mo)		June (14 mo)	
	Rub	Res	Rub	Res	Rub	Res	Rub	Res	Rub	Res	Rub	Res
Drip 50 %	0.66	7.6	1.3	7.2	2.1	6.5	3.3	6.4	3.5	7.4	4.0	7.6
Drip 100 %	0.78	7.6	1.1	6.5	2.1	6.2	3.4	6.8	2.8	7.2	1.8	6.3
Flood 50 %												
Flood 100 %	0.69	7.3	1.1	6.8	2.1	6.5	3.6	6.5	3.3	7.5	3.1	7.4

Table 14. *Rubber yield (kg/ha) based on stems and roots harvested at 4, 6, 8, 10, 12, and 14 months from a replicated irrigation experiment at the Bridgestone Guayule Research Farm, Eloy, Arizona. Each value is the average of 3 1-m replications.*

Irrigation Treatment	**Bridgestone Eloy Farm (Clay soil)** **Rubber yield (kg/ha)** (shrub + roots)					
	August (4 mo)	October (6 mo)	December (8 mo)	February (10 mo)	April (12 mo)	June (14 mo)
Drip 50 %	29.5	133.9	335.6	509	628	760
Drip 100 %	7.9	114.2	250.6	475	517	727
Flood 50 %	2.9	106.9	463.5	522	577	607
Flood 100 %	4.6	111.4	364.2	526	472	698

Table 15. *Rubber yield (kg/ha) based on stems and roots harvested at 4, 6, 8, 10, 12, and 14 months from a replicated irrigation experiment at the Maricopa Agricultural Center, Maricopa, Arizona. Each value is the average of 3 1-m replications.*

Irrigation Treatment	**Maricopa U of A Farm (Sandy loam soil)** **Rubber yield (kg/ha)** (shrub + roots)					
	August (4 mo)	October (6 mo)	December (8 mo)	February (10 mo)	April (12 mo)	June (14 mo)
Drip 50 %	33.7	93.8	378.0	553	644	762
Drip 100 %	39.2	92.3	302.2	753	717	745
Flood 50 %						
Flood 100 %	33.6	99.4	379.5	708	708	652

The proportion of flowers, leaves, and stems changed over time significantly. Since February, the proportion of leaves and stems on the plant is stable. Flower proportion increased from April to June.

Rubber % was higher in June at Maricopa compared to Eloy. That has been the trend since February. It is interesting that peak rubber content for the 50% treatments remains about the same from February to June. In the 100% treatments, rubber begins to decrease in June. Resin content has increased slightly over time but most resin content is present in the plant by 4 months. The overall rubber yield was very similar between the two locations despite the higher biomass at Eloy. The higher rubber content on the sandy soil made up for this. There is not much difference between treatments so far, indicating the lower water treatments have not had the proportional effect on yield.

Guar Response to Moisture Stress:
Processed plants harvested from the guar moisture stress response and ground samples for analysis. Analyzed data on final harvest seed yield and yield attributing characteristics from the guar moisture stress response study.

Guar Response to Planting Densities:
Completed the final harvest seed yield and yield attributing characteristics from planting density study. Planted 2019 studies on guar germplasm evaluation and planting density and spacing evaluation.

Collaboration with Herbicide Manufacturers in Support of 24cSLN Registrations:
Protocols were developed for the spring 2019 Eloy and Maricopa experiments based in part on data analysis of the fall 2018 experiments at Marana and Maricopa.

See first quarter report. At the request of FMC, additional carfentrazone (Aim) guayule tolerance studies were planned for Eloy and Maricopa. A revised Prowl H_2O SLN for Prowl use during guayule seedling establishment will be requested through the ADA based on experiments conducted in fall 2018 and spring 2019. To support registration efforts, an educational tour of guayule plots at Eloy and MAC and of the Bridgestone processing plant in Mesa was conducted for chemical industry scientists on May 6, 2019.

Guayule Herbicide Tolerance Study, Fall 2018:
Three preemergence herbicide experiments and three preplant-incorporated experiments (each experiment included two herbicides) were established at MAC in October 2018 and data collection was completed in January 2019. Similarly, three preemergence herbicide experiments were established in Marana at Gary Deen's farm in September 2018 and completed in December 2018 to obtain additional data on a course textured soil (see previous quarterly report).

The postemergence Aim (carfentrazone) and clethodim experiments planned for Fall 2018 in Eloy were not conducted due to fall rains and an abrupt weather change; the experiments were postponed to the spring of 2019.

Publication of research reports were delayed to June 30, 2019 as we did not finish collecting data in the preemergence herbicide experiments until January 2019 and data analysis was not completed until the end of March.

Guayule Herbicide Tolerance Study, Spring2019:

Three preemergence herbicide experiments and three preplant-incorporated experiments (each experiment included two herbicides, herbicides studied: ethalfluralin, pendimethalin, acetochlor, metolachlor, bensulide, and sulfentrazone) were established at MAC in the second quarter of 2019. The data collected to date is listed in the table below.

Four postemergence guayule tolerance studies with Aim (carfentrazone) and two studies with paraquat (Gramoxone SL 2.0) were conducted at MAC in the second quarter of 2019. Similarly two grass herbicide tolerance studies including clethodim (Select 2E), fluazifop-p-butyl (Fusilade DX) were also conducted at MACin the second quarter (Tables 16-17).

Table 16. *Preliminary results from the 2019 preemergence experiments in Maricopa, Arizona.*

Spray Date	Chemicals Applied	Location/ Field	Method of Incorporation	ARM File Name / Data Tables?	Data Collected to Date
4-23-2019	Prowl H2O Sonalan	MAC / F1 / B42	PPI-flat, field cultivator, lister, furrow irrigation	Prowl Sonalan PPI-Flat MAC Spring2019	6/5/2019 – Guayule 2 m stand counts 7/1/2019 – Guayule 2 m stand counts 7/11/2019 – Nadir photographs
4-23-2019	Prowl H2O Sonalan	MAC / F1 / B43	PPI-bedtop incorporvator, rolling cultivator	Prowl Sonalan PPI-bedTop MAC Spring2019	6/5/2019 – Guayule 1 m stand counts 7/1/2019 – Guayule 1 m stand counts 7/1/2019 – Nadir photographs
4-23-2019	Dual Warrant	MAC / F1 / B44	PPI-flat, field cultivator, lister, furrow irrigation	Dual Warrant PPI-Flat MAC Spring2019	6/5/2019 – Guayule 2 m stand counts 7/2/2019 – Guayule 2 m stand counts 7/11/2019 – Nadir photographs
4-23-2019	Dual Warrant	MAC / F1 / B45	PPI-bedtop incorporvator, rolling cultivator	Dual Warrant PPI-Bed Top MAC Spring2019	6/5/2019 – Guayule 1 m stand counts 7/2/2019 – Guayule 1 m stand counts 7/1/2019 – Nadir photographs
4-23-2019	Spartan Prefar	MAC / F1 / B46	PPI-flat, field cultivator, lister, furrow irrigation	Spartan Prefar PPI-Flat MAC Spring2019	6/5/2019 – Guayule 2 m stand counts 7/2/2019 – Guayule 2 m stand counts 7/11/2019 – Nadir photographs
4-23-2019	Spartan Prefar	MAC / F1 / B47	PPI-bedtop incorporvator, rolling cultivator	Spartan Prefar PPI-BedTOP MAC Spring2018	6/5/2019 – Guayule 1 m stand counts 7/1/2019 – Guayule 1 m stand counts 7/1/2019 – Nadir photographs
4-23-2019	Prowl H2O Sonalan Dual Magnum Warrant Spartan Prefar	MAC / F4 / B50-51	PPI-flat with field cultivator, sequential PPI-bedtop with incorporvator	Guayule Herb Systems MAC Spring 2019 F4B50-51	6/11/2019 30 foot stand counts Poor emergence due to lack of pre-irrigation Project abandoned

Table 17. *Preliminary results from the 2019 post emergence herbicide experiments in Eloy and Maricopa, Arizona.*

Spray Date	Chemicals Applied	Location/Field	Method of Irrigation	ARM File Name / Data Tables?	Data Collected to Date
5-13-2019	Aim Activator 90 0.5% v/v	Bridgestone / B2W	Furrow	Aim Guayule Spring 2019 4 LEAF Eloy Aim Guayule Spring 2019 7 LEAF Eloy	5/10/2019 – Guayule Pre-spray 2 m stand Counts in both 4 & 7 leaf exp. 5/21 – Post-spray 2 m stand counts in both 4 & 7 leaf experiments 5/21 – Visual estimates of necrosis and stunting in 4 & 7 leaf experiments 5/30 – Visual estimates of stunting in 4 leaf experiment.
6-4-2019	Aim	MAC / F1 / B48 / east	Sprinkler for establishment than furrow	MAC Aim Guayule Spring 2019 2 LEAF F2_B48E	4/22 – Prowl H_2O applied PPI-flat @ 2 pt/A 6/3/2019 – Prespray 2 m stand count 6/4 – Leaf count in control plots 6/12 – Visual injury ratings (necrosis, burning) 6/21 – Stand counts 2 m 7/11 – Visual injury rating (necrotic spots) 7/12 – Stand counts 2m 7/12 – Nadir pictures
6-13-2019	Aim	MAC / F1 / B48 / middle	Sprinkler for establishment than furrow	Aim Guayule Spring MAC2019 4 LEAF	4/22 – Prowl H_2O applied PPI-flat @ 2 pt/A 6/13/2019 – Leaf count in control plots 6/24 – Stand count 2 m (also counted dead plants to simulate prespray count) 7/11 – Visual injury rating (necrotic spots) 7/12 – Stand counts 2 m 7/12 – Nadir pictures
6-25-2019	Aim	MAC / F1 / B48 / west	Sprinkler for establishment than furrow	Aim Guayule Spring MAC2019 7 LEAF	4/22 – Prowl H_2O applied PPI-flat @ 2 pt/A 6/21/2019 – Prespray 2 m stand count 6/25 – Leaf count in control plots 7/11 – Visual injury rating (necrotic spots) 7/12 – Stand counts 2 m 7/12 – Nadir pictures
6-25-2019	Aim Gramoxone 2SL Talinor Callisto	MAC / F3 / B68 / west	Sprinkler for establishment than furrow	MAC Aim Paraquat Talinor Guayule Spring2019 3 LF F3B6	6/26/2019 – Prespray 2 m stand count 6/26 – Leaf count in control plots 7/15 – Stand counts 2 m
6-6-2019	Fusilade DX Poast Select 2E	MAC / F1 / B49 / north	Sprinkler for establishment than furrow	MAC Aim Paraquat Talinor Guayule Spring2019 3 LF F3B6	4/22 – Prowl H_2O applied PPI-flat @ 2 pt/A 6/4/2019 – Prespray 2 m stand count 6/6 – Leaf count in control plots 7/11 – Visual rated injury symptoms 7/12 – Stand counts 2 m 7/12 – Nadir pictures
6-18-2019	Fusilade DX Poast Select 2E Gramoxone 2SL	MAC / F1 / B49 / south	Sprinkler for establishment than furrow	MAC Aim Paraquat Talinor Guayule Spring2019 3 LF F3B6	4/22 – Prowl H_2O applied PPI-flat @ 2 pt/A 6/21/2019 – Prespray 2 m stand count (dead (plants included for starting count) 6/18 – Leaf count in control plots 7/11 – Visual rated injury symptoms 7/12 – Stand counts 2 m 7/12 – Nadir pictures

I was just too busy with spring 2019 schedule of experiments to get the reports done so they will not be completed until September 30, 2019. Research technician Bryan Pastor was largely responsible for setting up the experiments, spraying the herbicide treatments, and collecting the data with some help from me. Bryan is (was) also responsible for all data entry into a database program for field research (Agricultural Research Manager; Gylling Data Management, Inc.) and for the analysis of the nadir photographs.

Literature Review for Field/Plant Growth Models:

We are focusing more on the Aquacrop model and working on adapting the model to predict guayule growth. We continue to focus on completing a sensitivity analysis related to all of the parameters given and adding some macros to the model so that we can graphically see the simulation results. Drone data will be incorporated in the future.

Phase I Growth Models Developed:

We are making good progress in the AquaCrop model.

Aquacrop model: We were successful in obtaining most of the data required in the model. We have also acquired the model code, which is written for seasonal crops. We are working on optimizing the model as well as applying/rewriting the code for guayule and perennial crops.

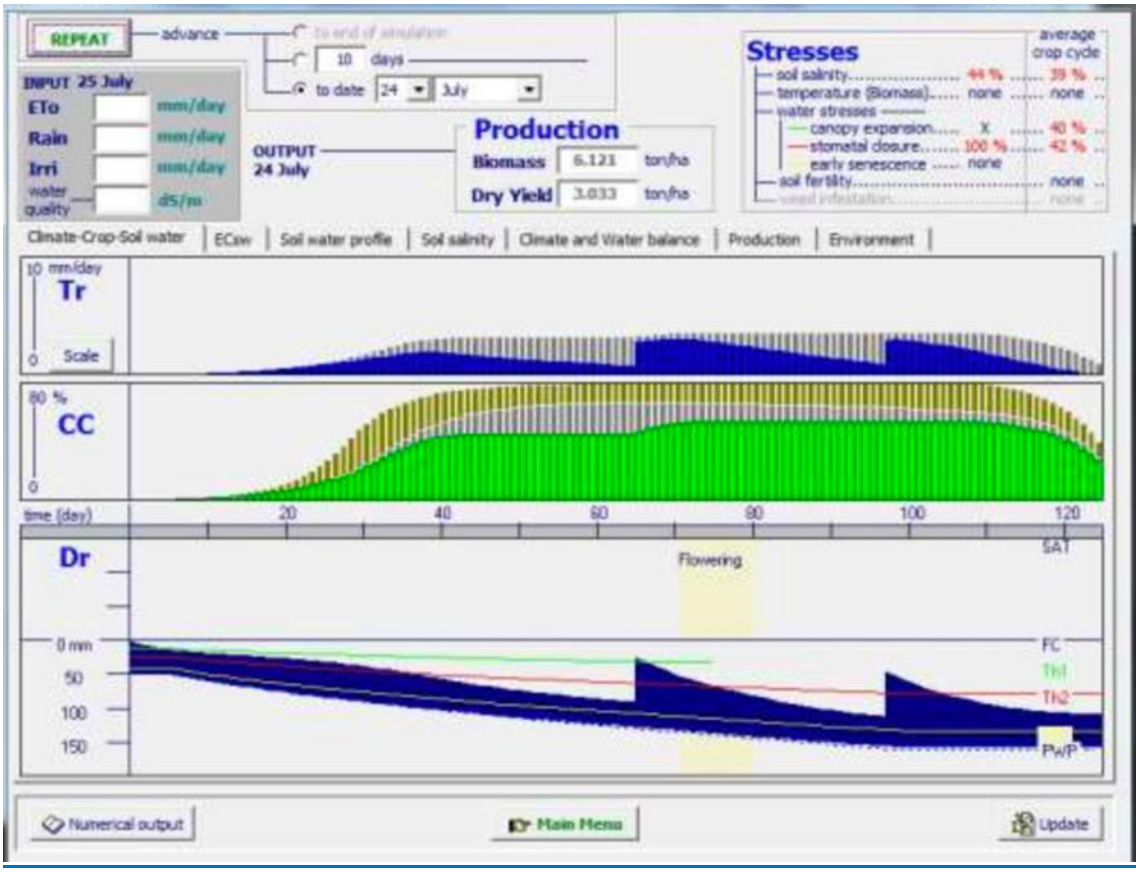


Figure 10. *Aquacrop model simulation.*

Plant Density Trials:
Research for this objective is complete; no new data to report.

Biomass Drying Experiment:
First biomass drying experiment was completed in June 2018, but the experiment will be repeated in June 2019.

Guayule Trials (Direct-Seeded and Transplant-Established):
The planting date was in April 2019; plant heights were measured on May 20 and June 20 (Table 18-21). No clear trend is seen, except that AZ2 is growing taller than Sel1

Table 18. *Mean heights of plants in guayule density trial treatment, measured on 20 May 2019. Values followed by the same letter are not significantly different.*

Treatment	N	Mean	Std Dev	
1 plant /76 cm	40	24.8	7.4	a
1 plant/46 cm	40	23.6	7.4	ab
1 plant/30 cm	40	21.3	6.8	b
1 plant/15 cm	40	25.0	6.0	a
1 plant/7 cm	40	20.5	7.1	b

Table 19. *Mean heights of plants in guayule density trial by variety and treatment, measured on 20 May 2019. Values followed by the same letter are not significantly different.*

Variety AZ2				
Treatment	N	Mean	Std Dev	
1 plant /76 cm	20	30.0	6.6	a
1 plant/46 cm	20	28.3	7.1	ab
1 plant/30 cm	20	26.2	5.7	ab
1 plant/15 cm	20	28.6	4.5	ab
1 plant/7 cm	20	24.3	7.8	b

Variety Sel1				
Treatment	N	Mean	Std Dev	
1 plant /76 cm	20	19.5	3.3	ab
1 plant/46 cm	20	18.9	4.0	ab
1 plant/30 cm	20	16.5	3.7	b
1 plant/15 cm	20	21.5	5.3	a
1 plant/7 cm	20	16.7	3.5	b

Table 20. *Mean heights of guayule plants by treatment, measured on 20 June 2019. No significant differences were found.*

Treatment	N	Mean	Std Dev	
1 plant /76 cm	40	40.0	11.5	a
1 plant/46 cm	40	36.9	9.6	a
1 plant/30 cm	40	37.3	9.1	a
1 plant/15 cm	40	37.3	8.6	a
1 plant/7 cm	40	41.2	12.0	a

Table 21. *Mean heights of plants in guayule density trial by variety and treatment, measured on 20 June 2019. Values followed by the same letter are not significantly different.*

Variety AZ2				
Treatment	N	Mean	Std Dev	
1 plant /76 cm	20	50.2	5.7	a
1 plant/46 cm	20	44.7	6.9	b
1 plant/30 cm	20	44.5	6.8	b
1 plant/15 cm	20	44.8	4.7	b
1 plant/7 cm	20	52.3	4.1	a

Variety Sel1				
Treatment	N	Mean	Std Dev	
1 plant /76 cm	20	29.9	4.8	a
1 plant/46 cm	20	29.2	3.8	a
1 plant/30 cm	20	30.2	3.8	a
1 plant/15 cm	20	29.8	3.3	a
1 plant/7 cm	20	30.1	4.4	a

The roots from the guayule plants were harvested June 25-26, 2019. Dried for 48 hours. Above-ground biomass and 20 cm sections of roots were weighed (Table 22). Transplanted seedlings are significantly greater than direct-seeded in above-ground biomass and root weights in 0-20 and 20-40 cm

Table 22. *Mean above-ground guayule biomass and root weights by depth (g) measured at 49 days after planting. Values in a column marked with * are significantly different.*

	Above ground	0-20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	100-120 cm
Direct seeded (n=4)	0.52	0.09	0.03	0.03	0.01	0.01 (n=1)	na
Transplanted (n=4)	2.70*	0.63*	0.22*	0.21	0.10	0.25 (n=2)	na

Installation of TDR, Infrared Cameras, and Flowmeter System:

Murdoch-Hoare and Katterman finished designing and constructing the field sensor systems for flowmeter monitoring, soil moisture monitoring (TDR), and infrared cameras (Photo 2). They are powered by solar power and automatically send data to the cloud and to our server on campus. The flowmeter sensor has been installed and the TDR and infrared camera sensors should be installed this week. Murdoch-Hoare and Katterman submitted an abstract on the sensors to the AAIC conference in September. We are collaborating again with Sangu Angadi on the 2019 guar experiments in Clovis, NM. Diaa El-Shikha is taking three trips to Clovis this summer in order to conduct drone flyovers of the guar experiments, and Dr. Angadi is taking coordinated plant and neutron probe measurements.

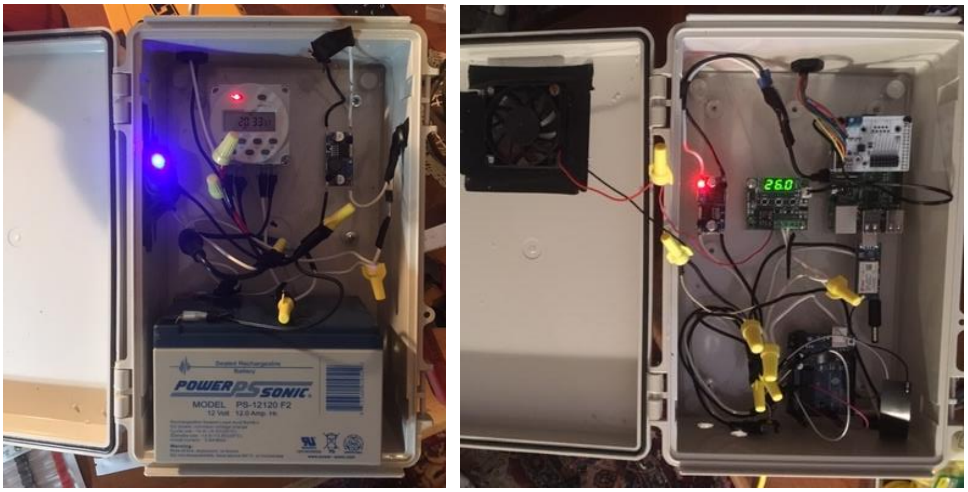


Photo 2. *Newly created field sensor systems for flowmeter and soil moisture monitoring (TDR), prior to field installation.*

Python MySQL WINDS Model Integration with Existing Tools:

Maqsood is continuing to develop the WINDS model for irrigation scheduling and is working with our guar and guayule partners. She submitted two abstracts on irrigation and use of WINDS to the AAIC conference in September 2019. One focuses on the guayule experiment in Maricopa

and the other focuses on the guar experiment in Clovis, NM. We are collaborating with Dr. Haiquan Li and a high school intern to develop a phone app for the WINDS model.

Irrigation Experiments – Guayule and Guar:
The neutron probe data and irrigation model data to schedule irrigation for the two fields at MAC and Eloy. Our team also collected remote sensing data once a week from the field at MAC and once a month from Eloy. Images were processed (stitching/ orthomosaic generation) using desktop image processing software. Some signs of clogging showed up on the collected remote sensing data. After investigating the affected area, the issue was confirmed and fixed by injecting a cleaning solution in the drip irrigation system. Field data was collected (height, width) once a month from both locations. Rubber, resin, and biomass data was obtained for the samples collected in March 2019 from all plots (1-year old guayule samples). First year's data was analyzed and a guayule paper was written and published at the 2019 ASABE annual meeting in Boston, Massachusetts. An abstract was written and submitted to the AAIC annual meeting, schedule for September 2019.

Other Tasks:
Guayule Resin Applications – Further investigation on the adhesion properties of guayule resin were performed in the Biomaterial Laboratory, Kansas State University. Adhesion test, rheological and thermal properties of resin were studied. Resins have high viscosity at room temperature and the viscosity decreases with elevated temperature and higher shear rate (Figure 11). The adhesion study was performed under different pressing conditions. The results indicate that some resins and natural rubbers with lower elastic modulus is a weak adhesive and have an ability to re-stick multiple times. Further development and study are needed to find suitable applications.

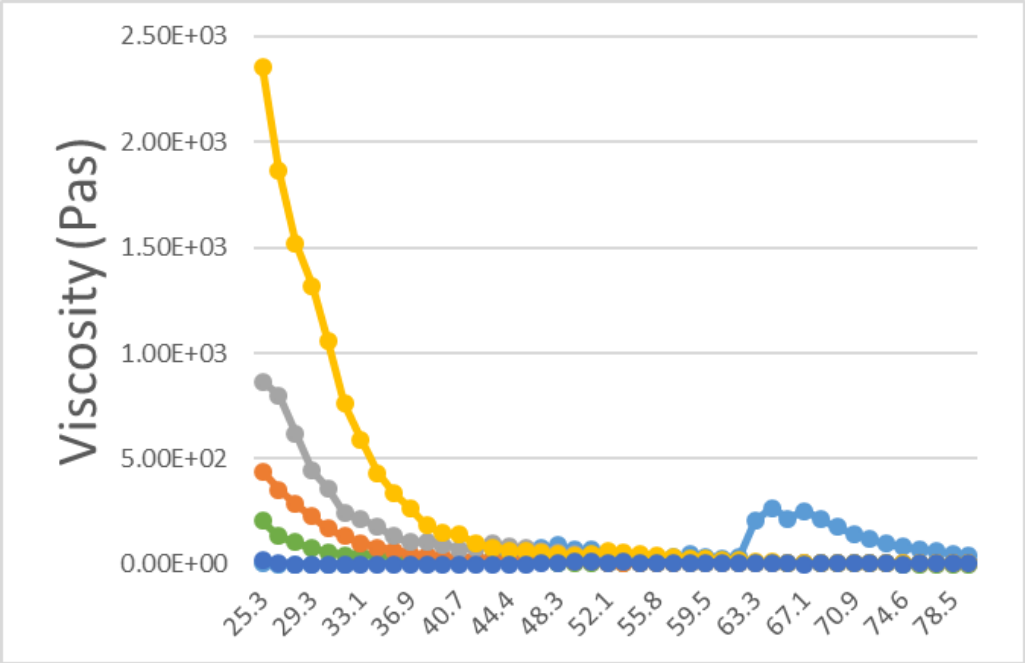


Figure 11. *Resin viscosity as a function of temperature (C).*

In order to improve the adhesion property of the resins, different modification methods were studied. Solvent extraction and base modification method tended to be the promising treatment to improve the adhesion properties of the resin. However, the resin had very low water resistance. Therefore, the modified resin was used to enhance the water resistance of soy protein adhesive. Both wet and dry adhesion strength of soy protein adhesive mixed with Resin 1, 2, 3, 4, 5 were measure (Figure 12). Approximately 60-80% increase in wet adhesion strength were observed. More studies are needed for further development of the adhesion property of resin-soy protein adhesive.

Figure 12. *Wet and Dry adhesion strength of soy protein adhesive used with Resin samples: 1, 2, 3, 4, and 5.*

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

Task #	Description of Task	Deliverable	Target Completion Date
1 Maier/ Neilson	Chemical and physical analysis of 108 soil samples	pH, EC, OrgM, NO3-N, P, K, cations, and SAR analysis complete Soil texture characterization complete	1 May 19 1 July 19
2 Maier/ Neilson	DNA extraction of soil samples for microbiome analysis	Quantify available biomass for 108 samples for amplicon sequencing	1 Jun 19

3 Maier/ Neilson	Generate baseline microbiome profile and assess spatial variations	Determine community composition metrics for 108 samples Identify differences within and between field variations in community composition metrics Identify functional gene traits to be quantified in Yr3	30 Jun 19 30 Jun 19 30 Jun 19
4 Maier/ Neilson	Soil sample collection for guayule-microbe winter dormancy studies	Collect and archive soil samples for DNA and RNA analysis from 3 time points (Nov – Mar)	1 Apr 19
5 Maier/ Neilson	Organize and execute Yr2 guayule plant and soil sampling	Plan field sampling day, process and archive samples Coordinate chemical analysis of samples with NMSU	1 Apr 19 1 Apr 19

Chemical and Physical Analysis:

We have continued to work closely with Barbara Hunter at NMSU to establish quality control standards for the soil chemical analysis. The primary focus in Q2 was the analysis of soil phosphorus and organic matter. Our collaboration has enabled us to refine the standard protocols. The complete Year 1 soil chemical data set should be available by September 1. We anticipate that Year 2 samples will be processed more quickly as a result of the work done this year on protocol development.

As explained in the Q1 report soil texture analysis is complete for Year 1 MAC soils. Jessica Ledesma, the new undergrad hired in Q1 has been trained and has established quality control standards for the soil texture analysis. We have obtained the soil standard described in the Q1 report and analysis of the Eloy soils is in progress. She will repeat the analysis of a subset of the MAC soils to evaluate the differences in texture analysis obtained by our lab and the USDA ALARC research facility.

DNA Extraction for Microbiome Analysis:

Kyle Brown has completed the quality control trials to refine the DNA extraction and purification protocols. DNA extractions are complete on all Eloy Year 1 soils and the samples have been submitted to the UA Microbiome Core for amplicon sequencing of bacterial, archaeal and fungal communities. The target date for baseline microbial community analysis of the Eloy field is the 2019 SBAR Annual meeting on September 12th. Brown is continuing with DNA extraction of Year 1 soil samples from MAC farm.

Baseline Microbiome Profile and Spatial Variations:

The primary focus in the 2019 second quarter was to continue the chemical, physical and biological analysis of the baseline soil samples collected during Year 1 at the Eloy and MAC fields as described in tasks. Year 2 soil samples were collected in March 2019 and have been dried and preserved for chemical and biological analysis. The protocols being developed for the Year 1 samples will be applied to all year 2 soils samples. Plant samples were collected in collaboration with Dave Dierig in parallel with soil sampling in March 2019. This coordinated

sampling effort will facilitate an analysis of associations between soil heath parameters and guayule production metrics.

Soil Sampling for Guayule Microbiome Winter Dormancy Studies:
Field sampling for this study was completed on April 22, 2019 in collaboration with Colleen McMahan. We sampled 6 plants from the Drip100 treatment in November 2018, February 2019 and April 2019 to capture 3 guayule growth stages relevant to rubber production. A total of 18 plants and their associated root zone soils were sampled for this study. Lia Ossanna was hired in Q2 as a research specialist to analyze temporal transitions in the composition and activity of the soil bacterial, archaeal and fungal communities characterizing the guayule plant root zone.

Preliminary plant analysis results indicate that our three sampling time points have captured the three guayule growth stages targeted by this study; (1) the spike in rubber transferase associated with decreasing fall temperatures; (2) winter dormancy when rubber production is initiated; and (3) initiation of flowering and growth in the spring that signals down regulation of rubber production. Preliminary results indicate that there is no significant change in overall soil biomass in the root zone during these three growth stages. Soil bacterial populations will be quantified and the composition of bacterial, archaeal, and fungal communities associated with each growth stage will be compared. Soil chemical analysis will also be performed on all root zone soils. This analysis was begun this summer by our *Project Puente* intern. A summary of her results are included below.

Project Puente **Intern Results**

Ana Lucia Soto joined our research team this summer as a *Project Puente* intern. She is working with Lia Ossanna on Task 2. She completed an analysis of the association between guayule plant growth stage and three soil chemical properties. Soto evaluated soil pH, soil electrical conductivity (EC), and soil ammonium content. Soto found that both EC and soil ammonium varied with guayule growth stage. The EC values were very low, thus we concluded that this significant variation is not significant to guayule growth dynamics; however, the variation in ammonium could reflect significant variation in microbial activity or plant nitrogen dynamics.

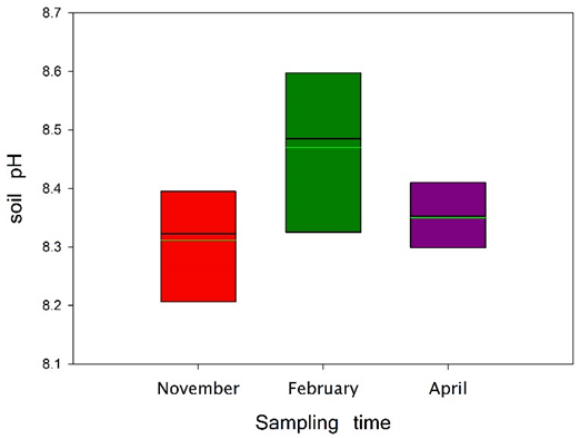


Figure 13. *Soil pH.*

No significant difference was observed between soil pH at the three sampling time points.

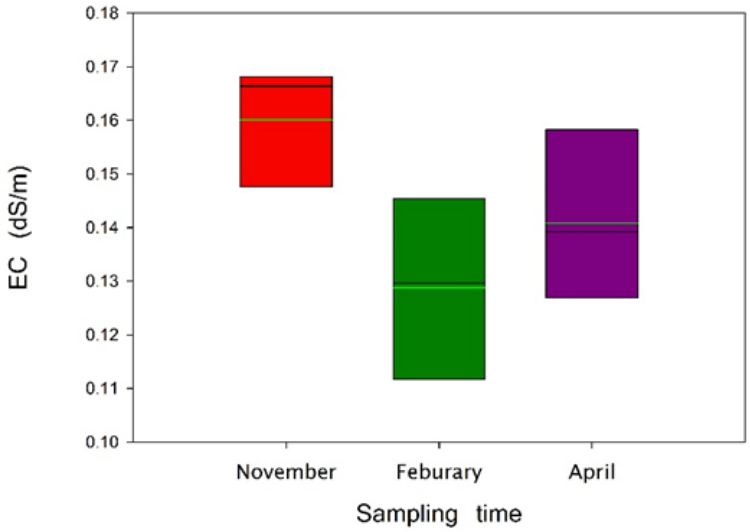


Figure 14. *Soil Electrical Conductivity (EC).*

EC values were significantly higher in November than at the other sampling times (p=0.015), however, the values are low and should not affect plant growth dynamics.

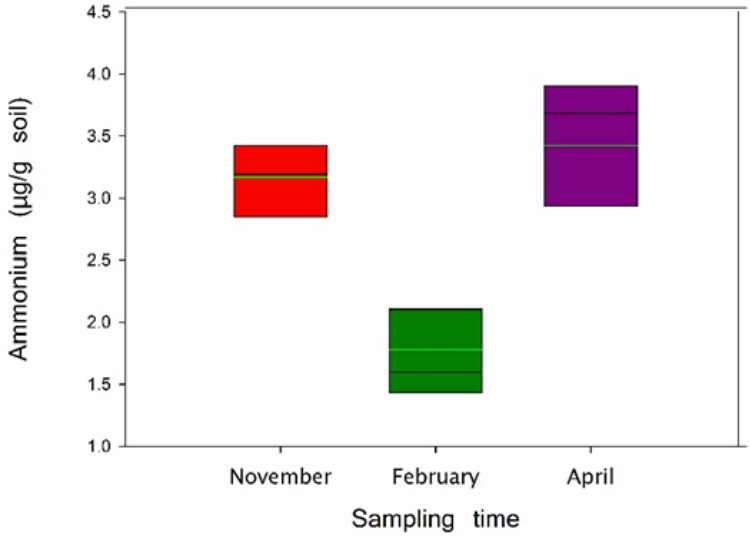


Figure 15. *Soil Ammonium Content.*

Root zone ammonium concentrations were significantly lower during winter dormancy than in November and April (p=0.002). This difference could be associated with plant nutrient uptake or the microbial activity of bacteria and archaea in the root zone.

Year 2 Guayule Plant and Soil Sampling:

Research for this objective is complete; no new data to report.

POST-HARVEST LOGISTICS & CO-PRODUCTS

Project Coordination: The Logistics working group meetings are hosted by NMSU twice monthly. 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.

Issues/Risks:
Preparation of the manuscript on the guar variety trials incorporating the bagasse characterization information is delayed as growth information and gum characterization are still needed from the Grover group.

Only a limited number of guayule bagasse samples have been analyzed, likely due to guayule being in its first year of growth. Additional communication will be sought with the members of the Feedstock Production group and Bridgestone to ensure that analysis needs are being met as samples become available.

Dehghanizadeh's visit to USDA ARS has been postponed until Q3 or Q4 due to international visitor clearances and the need for more time to plan his experimental work there on guayule resin separation/analysis.

Regarding the "integrate and analyze the economic benefits and environmental influences into the optimization models" task, in order to analyze the greenhouse emissions in all of the operations in a biomass supply chain, we need to understand clearly about each operation, including collection and harvest, storage, pretreatment, transportation, conversion and product distribution. Although we have most information from our partners and other group members (especially Sustainability team), converting the information that can be used as input of our optimization model is challenging. We keep communicating with other team members, checking with industrial partners, and reading references in order to handle this issue.

One of the issues was that the work on chemical transformations of guayule coproducts did not proceed as anticipated causing delays in completing follow-on work related to terpene solutions and investigations of rubber for low molecular weight constituents.

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

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Provide guayule (and guar) bagasse characterization support for ongoing feedstock trials	Capture and collate data on the average variability of bagasse lignocellulosic biomass characteristics	31 Aug 19
2 Holg	Biochemical composition analysis of guayule and respective products	Develop standard operational procedures	31 Aug 19

		Composition information and sample extracts completed Generate manuscript on cold tolerance in guayule	31 Aug 19 31 Aug 19
3 Holg	Biochemical composition analysis of guar and respective products	Develop standard operational procedures Composition information and sample extracts completed Generate manuscript on cold tolerance in guayule	31 Aug 19 31 Aug 19 31 Aug 19
4 Holg	Analytical evaluation of thermochemical conversion products	Determine composition information and sample extracts	31 Aug 19

Bagasse Characterization Support:
Rosalez supervised a community college student, Valdez, on the HTL of guayule bagasse alone as the first part of his thesis work on co-HTL of guayule bagasse and wastewater algae. Valdez was participating in NSF's RENUWiT Engineering Research Center (Research Experience in Water-Environment Science and Technology (REinWEST) six-week summer research experience program for community college students in NM; he recently completed his associate's degree and will be continuing his bachelor's in computer science at New Mexico Tech. Once enough algae is available from the pilot plant at the wastewater treatment plant in Las Cruces, Rosalez will be coordinating the combined HTL runs for comparison with the work at PNNL on HTL of lignocellulose biomass and sewage sludge.

Guayule Biochemical Composition Analysis:
We continue to perform biomass characterization methods with Dr. Brewer's group on bagasse material. Dr. Jacqueline Jarvis at NMSU along with researchers in Dr. Brewer's group have compared the findings by Dr. Gunatilaka with the FTICR/MS data on the resin. Generated are carbon number distribution plots along with a table of assignments of the compounds cross-identified by the two research groups.

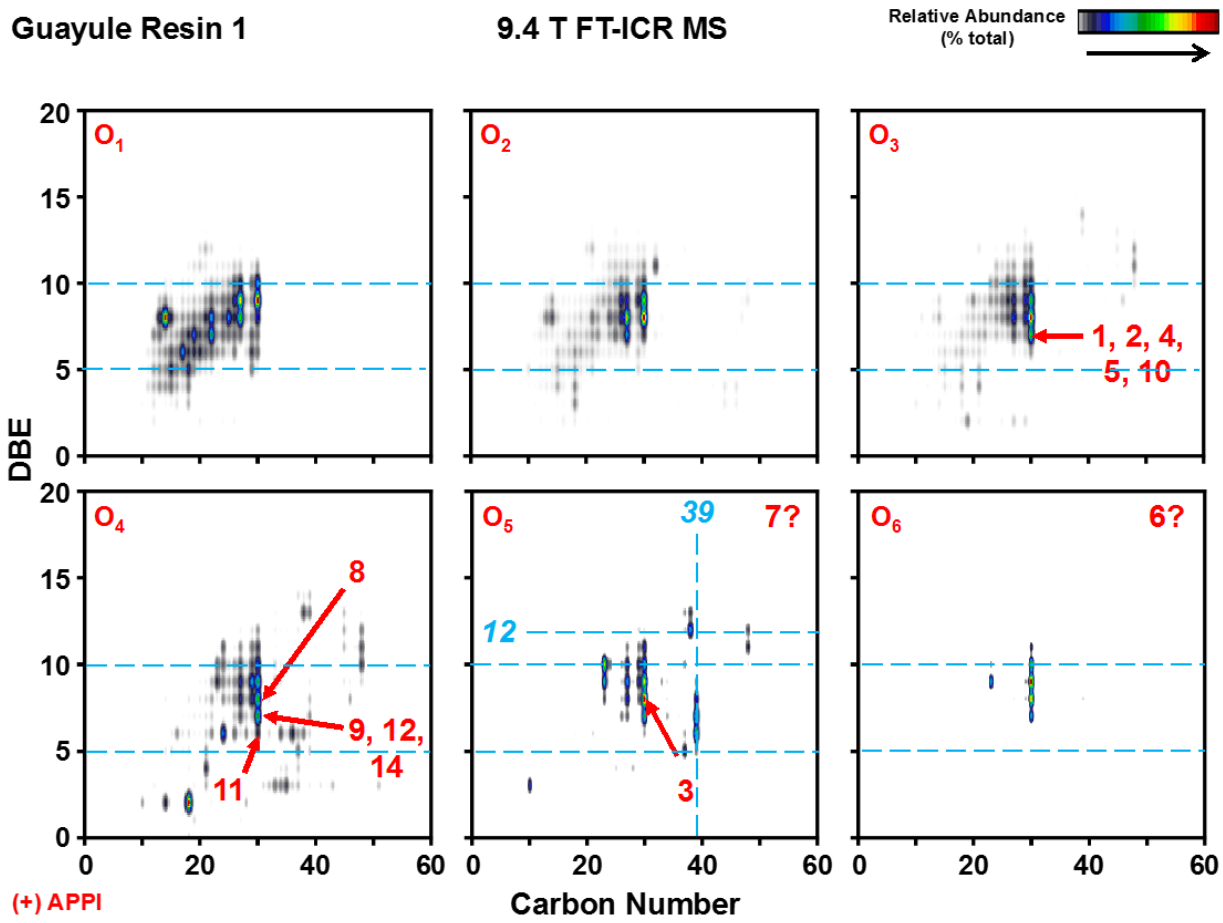


Figure 16. *Ultrahigh resolution and accurate Mass FT-ICR MS of argentatin analogs.*

Table 23. *Corresponding identifications of argentatin analogs from Figure 16.*

#	Compound ID	Formula	DBE
1	16-deoxyargentatin A	$C_{30}H_{48}O_3$	7
2	16-deoxyisoargetatin A	$C_{30}H_{48}O_3$	7
3	7-oxo-isoargentatin A	$C_{30}H_{46}O_5$	8
4	argentatin H	$C_{30}H_{48}O_3$	7
5	24-epiargentatin H	$C_{30}H_{48}O_3$	7
6	24-p-anisoyl-argentatin C	$C_{38}H_{56}O_6$	11
7	24-trans-cinnamoyl-argentatin C	$C_{39}H_{56}O_5$	12
8	argentatin I	$C_{30}H_{46}O_4$	8
9	argentatin J	$C_{30}H_{48}O_4$	7
10	isoargentatin H	$C_{30}H_{48}O_3$	7
11	isoargentatin C	$C_{30}H_{50}O_4$	6
12	argentatin A	$C_{30}H_{48}O_4$	7
13	quisquagenin		
14	isoargentatin A	$C_{30}H_{48}O_4$	7
15	argentatin C	$C_{31}H_{52}O_4$	6
16	argentatin B	$C_{31}H_{52}O_3$	6
17	argentatin D	$C_{30}H_{50}O_3$	6
18	3-epi-argentatin D		
19	isoargentatin B	$C_{30}H_{48}O_3$	7

Guar Bagasse Biochemical Composition Analysis:
We have completed the enzyme analysis and size exclusion analysis for all guar samples and our know combining the results into a report. We expect to provide a completed report in August 2019.

Analytical Evaluation of Thermochemical Conversion Products:
Research continues as planned; no new data to report.

Other SBAR Collaborative Work:
Soil Analysis – Soil samples (108) received from Dr. Julie Neilson are greater than 97% complete. We are still lacking NO3 data due to a backlog on 54 samples. Full completed is data for pH, EC, Mg, Ca, Na, SAR, Organic Matter, K, PO4, Zn, Mn, Fe and Cu. Dr. Neilson along with our technician are working closely together to QA/QC the data. We anticipate the full completion of the soil samples prior to the next quarterly report.

Pesticide Analysis – We completed a round of Nipsit Analysis on Guayule leaf and pollen and have provided the data to Bridgestone for further review and evaluation (Table 24).

Table 24. *Nipsit results for pesticide analysis on guayule.*

		Nipsit results			
Sample Date	**Sample Name**	**Sample No.**	**Tissue Weight (g)**	**Conc. (ng/mL)**	**C (ng/g)**
7/13/18	209_1	1	2.0	7.1	35.3
6/29/18	210_2	2	2.1	7.6	36.7
7/1/18	309_3	3	2.0	5.7	28.4
7/27/18	309_ck_4	4	2.1	4.1	19.6
6/29/18	209_5	5	2.0	9.4	47.0
7/6/18	209_6	6	2.0	6.8	33.8
7/13/18	308_7	7	2.0	4.3	21.2
7/6/18	203_ck_8	8	2.1	4.0	19.2
7/13/18	309_ck_9	9	2.0	5.0	25.0
7/6/18	309_ck_10	10	2.0	4.9	24.3
7/13/18	303_11	11	1.7	4.1	24.1
7/6/18	307_12	12	2.0	4.3	21.6
7/6/18	304_13	13	2.1	4.2	20.0
7/27/18	304_14	14	2.0	4.4	22.4
7/13/18	210_15	15	1.6	4.4	26.8
7/27/18	210_16	16	2.0	4.6	22.8
7/27/18	308_17	17	1.9	1.6	8.2
7/27/18	307_18	18	2.0	1.5	7.5
7/3/18	304_19	19	2.0	2.1	10.5
7/29/18	303_20	20	2.1	5.8	27.5
7/27/18	309_21	21	2.0	1.9	9.5
6/29/18	307_22	22	2.0	4.3	21.8
6/29/18	304_23	23	1.9	5.9	30.6
7/13/18	307	24	1.9	2.2	11.5
6/29/18	308_25	25	2.0	6.0	30.3
7/27/18	209_26	26	2.0	2.6	12.9
7/6/18	303_27	27	2.0	4.4	22.3
7/6/18	308_28	28	2.0	3.2	15.7
7/6/18	210_29	29	2.0	4.4	22.6
7/27/18	210F_30	30	0.1	<0.5 ng/mL	NA
7/27/18	303F_31	31	0.1	<0.5 ng/mL	NA
7/27/18	209F_32	32	0.1	0.5	6.3
7/27/18	308F_33	33	0.1	<0.5 ng/mL	NA
7/27/18	307F_34	34	0.1	<0.5 ng/mL	NA
7/27/18	304F_35	35	0.1	<0.5 ng/mL	NA
7/27/18	309ckF_36	36	0.1	0.2	2.5

Metabolomics and Biochemical Analysis – We have continued our work with Dr. Von Mark V. Cruz and Dr. David Dierig on characterization of cold adaptation of guayule leaf material. We

have generated a couple of tables with the most relevant information on how Guayule or the previously mentioned plants get acclimated to cold or respond to cold/drought stress.

Dr. Rodriguez prepared the first draft of the guayule paper “Metabolic Responses of Guayule (*Parthenium argentatum* A. Gray) to Cold Acclimation and Freezing” and placed on DropBox for the review and input of the Coauthors on May 2019.

The guayule leaf metabolome from plants exposed to cold acclimation and freezing and the time course experiments carried out at Bridgestone was re-annotated by Hasti Mozaffari. A total of 337 metabolites were annotated; (154 more than the first time including a few internal controls). I created a new folder in DropBox with an excel file that contains the list of the more recently annotated metabolites that were normalized to the internal standard (ribitol) and the sample dry weight as requested by Bridgestone.

Dr. Rodriguez repeated the identification of Metabolic biomarkers in Metaboanalyst 4.0 with the newly annotated metabolite/normalized data. The number of newly identified metabolic biomarkers is bigger than the initial and only a single metabolic biomarker replicated the original results. As with the original metabolic biomarkers many of them cannot be correlated to metabolic pathways other than Kreb’s cycle, galactose metabolism, amino acid metabolism and fatty acid metabolisms.

Objective 2. Develop and optimize system-level logistics models for demand-driven harvesting.

Task #	Description of Task	Deliverable	Target Completion Date
1 Fan	Feedstock logistics data collection (farm fields, road networks, water supply, existing facilities, etc.)	Define data and parameter settings for input Preliminary model and algorithm developed	1 Aug 19 1 Aug 19
2 Fan	Integrate and analyze economic benefits and environmental influences within optimization model	Identify parameter settings for optimization model Complete data input within optimization model Complete sensitivity analysis for future model and algorithm development	1 Aug 19 1 Aug 19 1 Aug 19
3 Fan	Develop hybrid optimization models for operations (flexible biomass harvest scheduling, etc.)	Complete hybrid optimization model for operations Present research findings at regional/national conferences Generate publication(s) highlighting research	31 Aug 19 31 Aug 19 31 Aug 19

Feedstock Logistics Data Collection:
Data collection work is almost finalized. In Quarter 2 of 2019, Fan's group continued the date collection, and mainly focused on the environmental issues and social impacts. Among them, minimizing the total annual CO2-equivalent greenhouse gas emission, and maximizing the accrued local jobs, including the jobs created during the construction phase of bioreneries, construction of collection facilities, and the operation of the supply chain. Working with the Sustainability group of this SBAR project, Fan's group has received some relevant data, information and model in this direction.

Economic Benefits and Environmental Influences:
Integration and analysis of environmental and social influences into optimization models are under way. To this end, Fan's group has formalized the framework for sustainability and economics analysis for biomass supply chain of guar and guayule (Figure 17).

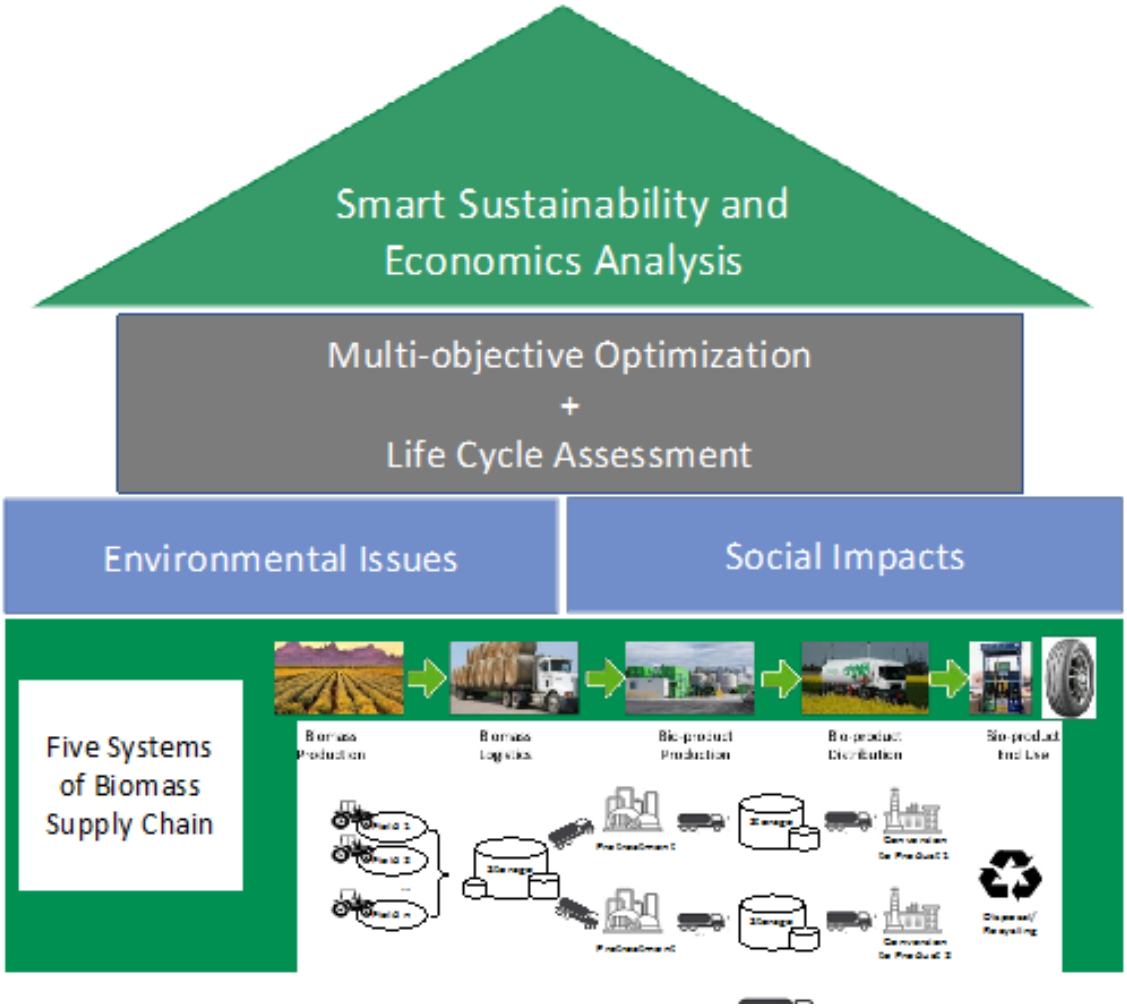


Figure 17. *Framework for sustainability and economics analysis for biomass supply chain of guar and guayule.*

Within the framework, the data and information is collected as shown. The preliminary mathematical optimization model, the multi-objective optimization, is constructed, and we plan to perform preliminary numerical experiments this August.

Hybrid Optimization Models for Operations:
Developing the hybrid optimization models for different operations is in process. As mentioned above, Fan's group has wrapped up the component for facility location and transportation for logistics from the perspective of planning plan uncertainty. With the third component for sustainability and economics analysis, and future work in the component of smart farm production and scheduling, Fan's group is now in the process of integrating them together as a decision framework for smart biomass supply chain for guar and guayule.

Among these three components, some data and information are shared across components and optimization algorithms designed will be applied in multiple occasions.

Objective 3. Demonstrate feasibility of farm to fuel conversion of bagasse.

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Prepare 2 manuscripts on guayule/guar bagasse composition, biomass-to-conversion method matching (HTL product yields)	Manuscripts prepared Manuscripts submitted for peer-review process	31 Aug 19 31 Aug 19

Manuscript Preparation:
After deciding to split up the single, larger document, Cheng and Bayat continued preparation of three review manuscripts on conversion of low-cost, higher-nitrogen biomass residues: one focused on feedstock descriptions, one focused on biochemical conversion methods, and one focused on pyrolysis conversion methods. The plan is to submit these in Q3. In July, Cheng began a one-year postdoc at Worchester Polytechnic Institute with Dr. Michael Timko working on biomass fuel upgrading.

Cheng and Audu continued work on guar and guayule bagasse sections of the manuscripts in collaboration with the Holguin, Jarvis, and Grover groups. Submission of an article on guayule resin and bagasse characterization is expected in Q3.

Objective 4. Identify economic co-products in guayule and guar, e.g., biologically active components.

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Literature review at experiment design/set-up for isolation/purification of guayule resin	Define research questions for guayule resin separation methods	31 Aug 19

	compounds in commercially relevant quantities	Preliminary experimental designs defined for guayule resin separation methods	31 Aug 19
2 Gunat	Comprehensive literature search for commercially important small-molecules structurally related to major metabolites of guayule	Identify major metabolites of guayule Determine conversion ability of metabolites to value-added co-products	30 Sep 18 30 Sep 18
3 Gunat	Chemical and microbial transformations	Identify and select two major metabolites for experiment Develop chemical and/or microbial methods for the conversion of guayule by-products into value-added products	31 Aug 19 31 Aug 19
4 Gunat	Evaluate major metabolites of guayule	Identify promising biologically active metabolites of guayule Isolate and characterize potential anticancer and anti-microbial activities of metabolites Investigate bagasse for polysaccharide coproducts Investigate terpene solution for useful coproducts Investigate rubber for low molecular weight constituents	30 June 19 30 Jun 19 30 Jun 19 31 Aug 19 31 Aug 19
5 Gunat	Evaluate extracts and fractions of guayule resin, bagasse, and unusable seeds	Identify promising extracts/fractions for bioactivity guided fractionation to isolate minor biologically active metabolites	31 Aug 19

Literature Review and Experiment Design/Set-up for Isolation/Purification of Guayule Resin Compounds:

Dehghanizadeh continued his literature review and characterization method training on resin. A request for partial funding of a lab-scale supercritical fluid (CO_2) extracted included in the Year 3 budget and approved; the remainder of the funding will be supplied by the NMSU College of ACES research dean. The instrument will be ordered in Q3. Dehghanizadeh and Cheng worked with Jarvis to analyze the high resolution mass spectroscopy data for resin collected in March. Specifically, they were able to locate the resin molecules identified by the Gunatilaka group within the mass spectra abundance data; next steps are to identify the derivatives from these molecules, especially those larger and less volatile.

Comprehensive Literature Search for Commercially Important Metabolites of Guayule:
Investigation of guayule resin – Continuation of the chemical work on guayule resin led to the isolation and characterization of the following three additional minor metabolites including the new natural product, 3 *α*-hydroxyargentatin A (Figure 18).

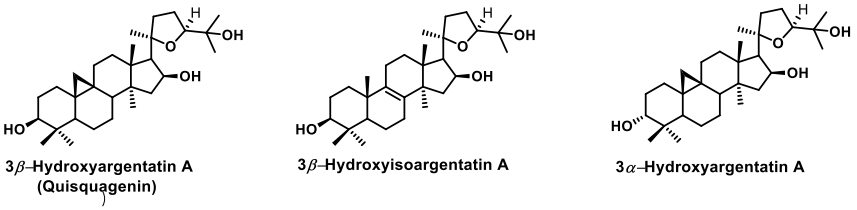


Figure 18. *Chemical structures of additional minor constituents of guayule resin.*

Chemical and Microbial Transformations:
Chemical and microbial transformations – The pyrimidine analogue obtained by chemical transformation of argentatin C (see previous report) showed enhanced cytotoxic activity (IC_{50} = 8.5–9.1 µM) against four different cancer cell lines compared to argentatin C (IC_{50} = >30.0 µM) suggesting that structural modifications of guayule coproducts may lead to value-added products. Thus, argentatin A was subjected to the following chemical transformations (Figure 19).

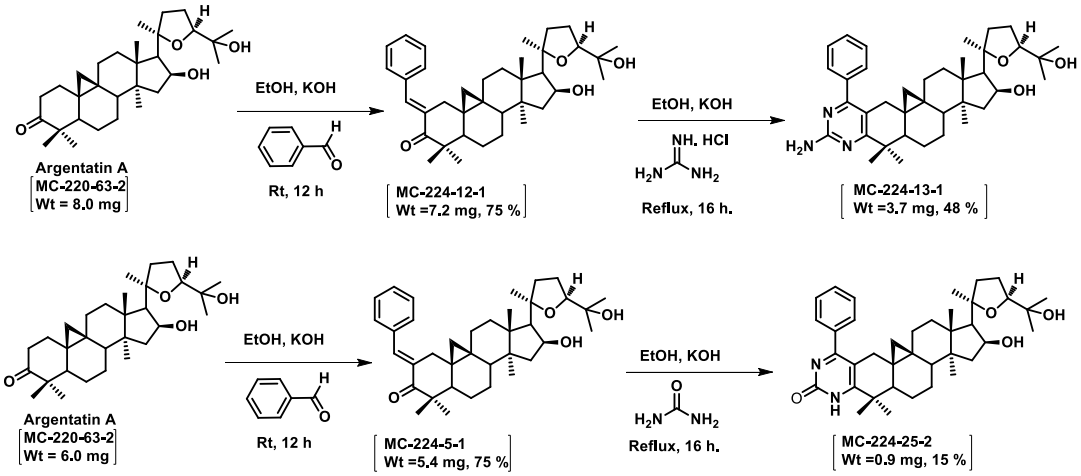


Figure 19. *Chemical transformations of argentatin A to its fused pyrimidine analogues.*

Evaluate Major Metabolites of Guayule:
Investigation of guayule bagasse for polysaccharide coproducts – Quantification of inulin in guayule bagasse by HPLC and spectrophotometric methods suggested its content in crude polysaccharide to vary from 13.3 and 23.5%. The crude de-proteinated polysaccharide (2.9 g) after decolorization yielded inulin as a light yellow powder (1.3 g).

Evaluate Extracts and Fractions of Guayule Resin, Bagasse, and Unusable Seeds:
Research continues as planned; no new data to report.

SYSTEM PERFORMANCE & SUSTAINABILITY

Project Coordination: Colorado State University (CSU) leads the bi-monthly working group webinar/phone calls. The meetings are leveraged to ensure all team members are on schedule and work can seamlessly integrate across institutions. The focus this quarter has transitioned from integration to monthly updates and monthly seminars. All notes and presentation materials are maintained in a community workspace available to all partners for future reference.

Issues/Risks:
Experimental data represents a current risk. CSU is working with CSM to connect with the agricultural members of the SBAR Team to seamlessly integrate experimental data from field trials.

Gathering the current cost and price data continues to be difficult, but gradual progress is being made. It's critical that the scenarios we develop are as accurate as possible, yet there are some variables that are not readily available, and we will have to back into them.

We continue to work with tribal farms and Bridgestone on their interest in collaborating but changes in tribal farm management and new crops being lower on their priority list for many of the tribal farms is slowing the process. Looking into two other Tribal farms one in central AZ and one on the Colorado River.

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

Task #	Description of Task	Deliverable	Target Completion Date
1 Gutierr	Functional integration of economic analysis into system model	Gather information for farm level scenarios using different avg. farm sizes, irrigation, and acreages	30 Jun 19
		Complete economic impact of guar and guayule at the farm level on employment, labor income, taxes and household spending (among others)	30 Jun 19
		Validate preliminary analysis; finalize farm level analysis	30 Jun 19
		Generate publication on the economic analysis for guar and guayule	30 Jun 19
2 Landis	First order LCA model	Complete preliminary LCA	30 Sep 18

3 Landis	LCA first order model integration	Integrated modular model in collaboration with broader team	31 Dec 18
4 Landis	Collect agricultural data from field trials	Update agriculture model inputs Re-run model with new information	31 Mar 19 31 Mar 19
5 Landis	Clarify social sustainability metrics	Develop overview of sustainability tools and list of potential metrics Generate publication/presentation for conference proceedings	30 Jun 19 30 Jun 19
6 Quinn	Techno-economic and Life Cycle Assessment results	Update/finalize economic and environmental impact results	1 Aug 19
7 Seav	Co-develop enterprise budgets that contain costs/returns of growing current cropping system and new crops that include outputs for LCA	Completed budgets for integration into Sustainability model	28 Jan 19
8 Seav	Develop financial ratios and performance measures for representative farms in AZ and NM	Meet with area lenders and accountants to gather info Complete two whole-farm case studies (AZ and NM) Case study info integrated into Sustainability model	31 Mar 19 31 Mar 19 31 Mar 19
9 Teeg	Facilitate working agreement between Tribal Farms and Bridgestone to establish experimental plots	Signed agreement established between Gila River Farms and Bridgestone Experimental plots established on Tribal lands	1 Jan 19 1 Jan 19
10 Teeg	Co-develop enterprise budgets that contain costs/returns of growing current cropping system and new crops that include outputs for LCA	Completed budgets for integration into Sustainability model	28 Jan 19
11 Teeg	Develop financial ratios and performance measures for representative farms in AZ and NM	Meet with area lenders and accountants to gather info Complete two whole-farm case studies (AZ and NM) Case study info integrated into Sustainability model	31 Mar 19 31 Mar 19 31 Mar 19

Functional Integration of Economic Analysis into System Model:
The current status of the project in meeting defined milestones for the recent quarter (Q1), 2019 is on schedule. The proactive bi-weekly meetings with project partners motivated the team to meet the identified task and set targets.

Farm Level Economics for Integrated Systems Model – The goal of identifying farm level inputs to be used in the integrated systems model was accomplished. The first draft of the farm

level economics has been integrated into the systems model. NMSU has been in collaboration with OSU and UA in developing the farm level model. The whole farm level economic analysis has been successfully developed for integration into system model.

Accomplishments include:

- Identify crop mix and potential acreage of crops in southern NM counties.
- Analyze potential acreage for adoption of guar and guayule at 10%, 15%, and 20% adoption rates.
- Validate preliminary analysis; finalize farm level analysis

First Order LCA Model:
No new progress to report.

LCA First Order Model Integration:
First order LCA modeling for guayule resin has begun in summer internship work at USDA-ARS WRRC.

Collect Agricultural Data from Field Trials:
We have lead the sustainability team's communication efforts with all field trial teams where data inquiries and requests have been sent for field emissions, field inputs, ag scheduling, and overall trial layouts and specifics. Data collection from groups is in progress.

Clarify Social Sustainability Metrics:
No new activity to report.

Techno-economic and Life Cycle Assessment Results:
Research for this objective is complete; no new data to report.

The CSU SBAR team traveled to Portland, OR to present at the International Symposium on Sustainable Systems and Technology (ISSST) on the environmental work from the project. Summers and Sproul presented the work and received 1st place in the student poster competition. This is a testament to the quality of work and their presentation skills.

Enterprise Budget Development:
Continue to meet with Seavert to refine scenarios and create additional budgets for upload to the team shared file. Refinements will reflect the new production information. (Figure 20)

Cash Costs and Returns of Producing Guayule, Growing Year, $/acre.	
Returns	Unit
Guayule - Biomass	Pounds
Guayule - Rubber Content	$/kg-rubber
Total Returns	
Variable Cash Costs	
Non-Harvest Production Inputs and Machine Costs	Unit
Fertilizer - N_2	Pound
Fertilizer - P	Pound
Herbicide 1	Pint
Herbicide 2	Ounce
Herbicide 3	Ounce
Irrigation Water (Flood)	/AC FT
Irrigation Labor Flood)	Hour
Irrigation Water (Drip)	/AC FT
Irrigation Labor Drip)	Hour
Irrigation, Drip	Acre
Other Expenses	Percent
Interest on Operating Capital	
Total Non-Harvest Costs	
Fixed Cash Costs	Unit
Property insurance	Acre
Property taxes	Acre
Total Fixed Cash Costs	
Total Annual Costs	
Returns minus Total Annual Costs	

Figure 20. *Cash cost parameters used to generate whole-farm enterprise budget scenarios for guayule.*

Development of Financial Ratios and Performance Measures for Representative Farms in AZ and NM:
Continue enhancement to the farm level scenarios using different average farm sizes, irrigation technologies and different crop mix is in progress for both New Mexico and Arizona.

Enterprise budgets are complete for Guar and Guayule; budgets are formatted for publication when the team feels confident in the cost and return data.

Created a “Break-even” model for growers and Extension to show the results of growing both Guar and Guayule, showing varying break-even yields and prices for each crop as they are adopted into a whole farm production system. In addition to the break-even yields and prices, whole farm net returns on an acre basis is calculated for each yield and price level of Guar and Guayule production. From this model, growers will be able to determine the break-even yield and price for Guar and Guayule as they incorporate each crop into their cropping system and how that level of adoption impacts their whole farm net returns.

Working Agreements between Tribal Farms and Bridgestone to Establish Experimental Plots:
Continue to assist in securing experimental plots on at least two tribal farms. 1) Connect Bridgestone and CRIT farms for experimental acreage agreement, establish introduction meeting and started contract negotiations 2) Connecting Bridgestone and Fort McDowell Farm for experimental acreage agreement. Started the conversation and in the process of setting up the first meeting with both farms. This is a long process and will take some time to complete.

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	Model integration	Integration of upstream and downstream modeling efforts	1 Jan 19
2 Quinn	Sensitivity analysis	Generate results for sensitivity analysis Present results of sensitivity analysis to SBAR LEADS for feedback	1 Apr 19 1 Apr 19
3 Quinn	Process modeling	Improve downstream process modeling fidelity Re-run results for further analysis (and to identify next steps)	1 Jun 19 1 Jun 19

Model Integration:
CSU continues to lead the integration effort with the development of a modeling framework to support the integration of the research across all research groups. As previously reported, an integrated model has been developed and the CSU team continues to work with collaborators in improving the fidelity of individual components of that model. The integration effort has identified areas that have required improvement from various partners and CSU continues to support the seamless integration of those components. The areas where improvement is needed are being addressed.

Sensitivity Analysis:
Two separate efforts are moving forward. A team-wide sensitivity analysis was completed and was a way of demonstrating connectivity across the different research efforts. The results from the sensitivity analysis are being used to identify areas for improving the fidelity of the modeling work. Scenario analysis is currently being developed in support of evaluating the process with different system boundaries and alternative processing pathways.

Engineering Process modeling:
The process modeling foundation is continuing to evolve and be improved. The focus this past quarter has been on the development of downstream process models. A short summary of accomplishments on each of the crops and downstream process modeling is provided below:

Guar: Scenario and sensitivity analyses brought to light some room for improvements within the Guar model. Efforts within the Guar specific modeling work has focused on a refinement and improved resolution of the process model. Validation efforts began with Guar Resources to make sure all equipment is accounted for, processing flow rates are representative of reality and

costing is appropriate. Additionally, work has focused on lining up model formatting for inputs, outputs, and figures between the Guar and Guayule models such that an integration between the two models can be performed with more ease.

Guayule: The Guayule model was the pioneer for scenario and sensitivity establishment. Codes were developed within the Guayule model to run both analyses and then use results for data feedback. The methodology for these analysis was adapted for the Guar model seamlessly. Guayule specific modeling efforts focused on understanding the sensitivity and scenario analyses results. These analyses uncovered a few minor errors amongst linkages across teams as well as inconsistencies within LCI data usage throughout. All errors have been fixed and continued efforts are focused on development of scenarios such that continued improvement and validation is possible.

Downstream Processing: Efforts are focused on developing multiple conversion pathways for the bagasse stream of guayule. Process flow diagrams and excel models have been developed for pyrolysis and hydrothermal liquefaction conversion pathways. A more rigorous model is currently being developed for the gasification/Fischer-Tropsch pathway via Aspen Plus process modeling software. This work has been focused on developing the materials and energy balances associated with biofuel production from guayule bagasse with the goal to integrate the data with the TEA and LCA models.

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

Task #	Description of Task	Deliverable	Target Completion Date

NO PLANNED ACTIVITIES FOR THIS OBJECTIVE IN YEAR 2.

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 summer 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 tasks and project implementation in Arizona and New Mexico.

Issues/Risks:
Inoculum of plant growth promoting microbes/rhizobium mix (Micronoc, Sono Ag, Brownfield TX) did not show significant impact at all demonstration locations. Modified the project to assess nitrogen and phosphorous response of guar.

Evaluation tools generated by the Evaluator have not yet been implemented during Extension & Outreach activities. Idowu and Evancho will schedule a time to meet with Fields to identify strategies to ensure data and information is captured appropriately.

This year we feel that we were successful in recruitment of new SBAR faculty to serve as *Project Puente* mentors for high school students. However, we still feel that broader participation from SBAR faculty would be helpful in meeting our program objectives to recruit a higher number of interns into the program. Because our budget request to include *Project Puente* students in 2020 in New Mexico was denied, we will spend efforts for 2020 in additional recruitment of SBAR Tucson-based faculty to participate. We will do this by re-enforcing the message as to the importance of mentoring students at a young age as well as the importance of training the next generation of STEM-related scientists and extension professionals. We will aim to attend at least one research team meeting in person in 2020 to be more available to answer questions and concerns of SBAR faculty to host high-school interns in their research programs. Additionally, we will call upon Dr. Neilson and Dr. Lopez to speak about their positive experience in 2019 as participants of the program.

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	Arrange guar field day/field walks at Agricultural Science Center, Clovis NM	Present guar crop info to ~100 producers in the region Visit guar farmers' fields to identify future research needs	31 Aug 19 31 Aug 19

		Visit Guar Resources to identify research needs	31 Aug 19
2 Angadi	Guar phosphorus and rhizobium study	Gather/analyze data; develop peer-reviewed paper on guar Phosphorus and rhizobium needs Train graduate students in guar agronomic management	31 Aug 19 31 Aug 19
3 Angadi	Guar deficit irrigation study	Gather/analyze data; develop peer-reviewed paper on guar deficit irrigation management Analyze/present results at regional and national meetings	31 Aug 19 31 Aug 19
4 Evan	Produce guayule newsletter articles	At least 2 guayule articles drafted and published – targeting AZ growers	31 Aug 19
5 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 18 31 May 19 31 Jul 19 31 Aug 19
6 Grover	Establish guar trial and showcase guar as potential crop in NM	Host field day Collect data; results synthesized Generate peer-reviewed Extension publication	31 Aug 19 31 Aug 19 31 Aug 19
7 Gutierr	Develop producer-level partial budget analysis for guayule and guar	Generate Extension bulletin reporting cost of production for guayule and guar	15 Mar 19
8 Idowu	Travel to conferences	Present SBAR info/materials at 4-5 grower commodity conferences	31 Aug 19
9 Idowu	Distribute Needs Assessment to farmers in NM	Compile survey information for at least 100 farmers/growers in NM Analyze/synthesize results Identify gaps for future SBAR work in NM	31 Aug 19 31 Aug 19 31 Aug 19
10 Idowu	Establish guayule and guar trials in Las Cruces, NM and Los Lunas, NM	Showcase trial experiments at field days	31 Aug 19 31 Aug 19

		Gather data/synthesize results (toward generating an Extension bulletin) Generate first year trial summary (published on SBAR website)	31 Aug 19
11 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 18 31 May 19 31 Jul 19 31 Aug 19
12 Rock	Deploy stakeholder needs assessment survey in AZ	Survey results collected from grower stakeholders in AZ	31 Dec 18
13 Rock	Survey results from Arizona	Summarize survey results; generate Extension publication Generate peer-reviewed manuscript using AZ survey results	31 Mar 19 31 May 19
14 Seav	Generate updated cost-production budgets for current cropping systems (guayule and guar)	Develop 5 enterprise budgets showcasing different scenarios Generate summary; publish results (SBAR website)	30 Jun 19 30 Jun 19
15 Seav	Participate in Extension meetings; disseminate economic info for guar and guayule	Provide 2 presentations to growers in NM Provide 2 presentations to growers in AZ	31 Aug 19 31 Aug 19
16 Teeg	Generate updated cost-production budgets for current cropping systems (guayule and guar)	Develop 5 enterprise budgets showcasing different scenarios Generate summary; publish results (SBAR website)	30 Jun 19 30 Jun 19
17 Teeg	Participate in Extension meetings; disseminate economic info for guar and guayule	Provide 2 presentations to growers in NM Provide 2 presentations to growers in AZ	31 Aug 19 31 Aug 19
18 Teeg	Develop input tool to identify potential adoption rates of guayule and guar in AZ and NM	Gather data for adoption potential during Extension meetings Synthesize data; generate report highlighting adoption probability in AZ and NM	31 Aug 19 31 Aug 19

Field Days and Site Visits:

Frequent rainfall in the region affected planting different crops and farmers struggled to plant most of their crops. Dr. Angadi's team had arranged for a large demonstration of guar on a

farmer's field. Guar Resources provided the seeds needed for the demonstration. However, the farmer backed out of it due to other field activities in the last minute. Next year, Dr. Angadi's team hopes to find a more committed co-operator for the demonstration.

Guar Phosphorus Rhizobium Study:
Dr. Idowu led a trial on P fertilization and plant growth promoting microbes/rhizobium mix (Micronoc, Sono Ag, Brownfield TX), which did not show useful treatment effects. Therefore, we modified the demonstration trial to include N and P. The trial is planted and the emergence is good. Fertilizer treatments were applied with the help of Dr. John Idowu's students.

Guar Deficit Irrigation Study:
Graduate student took a few time-lapse videos of guar emergence in the field. We will process the video and try to extract a brief clip for use. We will also take regular pictures at different growth stages during the season. In the incubator, we will take some videos with different temperature treatments.
A poster was presented in ACES-Open House on April 6, 2019, which was meant for communicating our research work to public and school children. We also setup SBAR Display and distributed guar and guayule handouts in Spring Field Day at Clovis, NM on April 11, 2019.

Preliminary results of the deficit irrigation trial was presented as poster and two presentations in two different conferences. Graduate student Jagdeep Singh's poster presentation in Western Society of Crop Science 2019 Annual Meeting, Pasco, WA won the first prize, while his oral presentation got the second prize. The project will presented during Annual Field Day of Agricultural Science Center at Clovis on August 8th, 2019.

Produce Guayule Newsletter Articles:
One newsletter has been written and will be in the next Pinal County Cooperative Extension Quarterly Newsletter.

Design and Implement Evaluation Tools:
Grower-Focused Extension – In Q1, Fields provided the grower-focused group with a tool to help them capture their outreach efforts, including the type of event, the approximate numbers served and the demographics of the group, and any pertinent information to be documented (i.e. important contact information, notes on people to follow up with or relationships to cultivate.) Fields did not receive any requests for changes to the tool, so assumed this to mean that it is a useful tool for them in documenting the types of outreach being done, the variety of stakeholders being reached (i.e. growers, industry, general public, K-12, etc.), and the overall impact (estimated numbers reached and demographics.) To date, Fields has received only one outreach capture form from Evancho and none from Idowu. Receiving an update, Idowu indicated that he has a number of forms to send to Fields that will allow for documentation of the outreach conducted by NMSU.

Fields has acquired the NM needs assessment surveys and will begin compiling data. More details from phone interviews, the compiled outreach efforts, and the NM needs assessment will be included in the final evaluation report to be submitted in August.

4-H Youth Development – Fields met several times with the UA 4-H team as they planned for the summer camp implementation. Fields advised on program modifications based on the year 1 evaluation and also reviewed the curriculum as it was being designed to understand how they were incorporating successful elements from the previous summer, and augmenting those with new activities and protocols for this summer's camp activities.

The AZ and NMSU 4-H teams collaborated in creating and testing some new SBAR-related hands-on activities that would be incorporated into the summer camp. The AZ 4-H team recruited a number of undergraduate and graduate students to work on the project, both in planning for the summer camp and implementing it. In order to do this, the UA 4-H lead had to leverage other sources of funding as the SBAR budget wasn't enough to cover all required expenses. The UA 4-H team (staff and student workers) engaged students at Pueblo High School to test many of the activities prior to the summer camp, and made adjustments as needed based on that experience and feedback from the high school students. The UA students who participated in the testing at Pueblo High School were the same students who were then hired as the instructors for the summer camp. This was a change in approach based on feedback from the first summer camp where only one instructor was used, proving to be overwhelming and too much responsibility for one person.

This summer, the 4-H lead, G. Lopez, leveraged a number of additional resources in order to implement a one-week, residential camp in conjunction with two other 4-H STEM camps that took place at the same time. This way, the camp was able to have more than adequate personnel to support the efforts. The camp was held from June 3-7, 2019 and was attended by 18 campers (9F, 9M). Students were ethnically diverse (9 Native American, 2 Hispanic, 2 Multi-racial, 2 Asian, 3 White) and ranged in age from 11-14. There were 8 total staff, including 1 coordinator, 1 lab coordinator, 3 instructors who led the scientific activities, and 3 counselors that supported breaks and evening activities.

Fields observed the camp on two separate days, and implemented 4 evaluation tools including a post-camp logistics survey, a 4-H common measures survey, a concept mapping activity to evaluation content knowledge gains, and a rating scale for the individual activities. In the post-camp logistics survey, students overwhelmingly indicated that the camp was a success in terms of learning and engagement (median scores in these categories tended to be a 9 on a 10-pt scale). The campers indicated that the instructors were knowledgeable and friendly (9.5 -10) and that the accommodations, evening activities and food were good (9-10). The camp was also highly successful in encouraging college (10) and teaching about careers generally (9.5), biofuels (10), sustainability (9) and conducting scientific research (10), but slightly less successful in motivating career interests in science (8), engineering (7) and agriculture (6). A 4-H common measures survey was also given to students. This survey measures personal gains and impressions about the value of the camp. The camp was rated highly in a number of categories including feeling safe (100% agree), goal setting (89% agree), learning new skills (94%) and making new friends (94%), interest in attending college (89%) and attending future STEM camps (89%). Responses were slightly less favorable in regards to interest in STEM careers (78%), teaching others the same content (67%) and feeling that their opinions were valued (67%). Additional evaluation tools were implemented to measure content knowledge gains around SBAR content areas as well as rating each individual activity for fun, learning and

career engagement, but that data has not been analyzed yet. It will be included in a final evaluation report to be completed in early August.

NMSU 4-H activities were meant to include a 'Train-the-Trainer' workshop in early July that would be offered to NM 4-H agents and volunteers. Dr. Brewer developed the training. As the team in NM began to reach out to 4-H agents, they did not get the response that they had hoped. Many of the agents/volunteers that were invited indicated that summer is not a good time for such a training as they are very busy implementing 4-H summer activities. Idowu has advised Rodriguez-Uribe to travel and meet in person with the various 4-H agents to see where there may be interest and schedule a training in the fall/winter time period when she has gotten enough interest. As a result of this, Catie shifted the training to focus exclusively on teachers and fellows. This is described further in the Education section below.

Additionally, the *Project Puente* summer internships outcomes are being gathered and compiled. All information related to *Project Puente* evaluation will be included in the final evaluation report in August.

Showcase Guar as Potential Crop in New Mexico:
Dr. Grover's group visited grower fields, presented information related to guar, and discussed the potential of guar for production and demonstration in Anthony, New Mexico. Data continues to be collected and compiled from on-station guar demonstrations.

No progress has been made toward the development of a peer-reviewed Extension publication on guar.

Develop Producer-Level Partial Budget Analysis for Guayule and Guar:
Partial Budget Analysis for Guar and Guayule – The enterprise budgets dealing with costs and returns and narrative detailing the ergonomic and cultural practices in production of guar and guayule have been developed in draft form and is under the peer review among SBAR teams. Sensitivity analysis associated with net returns of guar and guayule production has been developed with varying costs, yields and price per pound of dry matters from our key assumption.

Guar Needs Assessment Survey – New Mexico Producers:
A total of 54 needs assessment surveys have been completed and collected from producers in New Mexico. Those survey data were entered in the online system Qualtrics and have been summarized for analysis. The team will analyze the survey data and use the information to create extension bulletins to answer producer's questions on sustainability and production of guar and guayule in southern New Mexico.

Travel to Conferences:
A Field Day was held on June 26, 2019 at Fabian Garcia Research Center in Las Cruces, NM, during which SBAR information was presented to the participants in a session that lasted for about one hour. In addition, there was also a table display of SBAR informational materials and a sign-on sheet for those who wish to have more information about the progress of SBAR project. Fourteen people who wish to learn more about SBAR provided their contact information.

Distribute Needs Assessment to farmers in New Mexico:
A survey was conducted at the Field Day event (held June 26th) to evaluate the level of knowledge gained by the audience of about 55 participants. Summary of data is provided in Table 25.

Table 25. *Results of a post-survey of participants at the Guar Presentation hosted during the Field Day at Fabian Garcia Research Center, Las Cruces, New Mexico.*

Before the Program
57.89% said **poor** level of understanding
31.58% said **average** level of understanding
5.26% said **good** level of understanding
5.26% said **excellent** level of understanding
After the Program
5.26% said **poor** level of understanding
10.53% said **average** level of understanding
15.79% said **good** level of understanding
68.42% said **excellent** level of understanding

Establish Guayule and Guar Trials in New Mexico:
This quarter was mostly devoted to establishing on-station and on-farm demonstration trials. Four on-station guar trials were established at the Leyendecker Plant Science Center, Los Lunas Ag. Science Center, Clovis Ag. Science Center and Tucumcari Ag. Science Center in New Mexico. The trials focused on the effects of nitrogen and phosphorus on the growth and yield of guar. Two on-station guayule trials are located at the Leyendecker Plant Science Center. The first trial is the on-going guayule cold tolerance study in collaboration with Bridgestone. The second on-station trial is focused on establishing direct seeded guayule in New Mexico. Two on-farm trials were initiated with two farmers in the Dona Ana County of New Mexico, testing guar growth and yield under farmer-managed conditions. Guar trials were all established in June/early July, while guayule direct seeded trial was established in May.

Graduate student/technician (Darien Pruitt) and the two undergraduates (Julia Miller and Adah Gellis) that were hired have actively participated in outreach activities, supervision of field trials and collection of data at on-station and on-farm sites. Darien has continued to make progress with her graduate research focusing on mycorrhizae colonization of guar roots as a function of soil amendments.

Design and Implement Extension & Outreach Evaluation:
No progress has been made on this task.

Stakeholder Needs Assessment in Arizona:
This task is complete.

Cost-Production Budgets for Current Cropping Systems:
Completed the first templates of the whole farm analysis and crop budgets. This information will now be adapted to extension publications and used within the extension producer meetings.

Created a “Break-even” model for growers and Extension to show the results of growing both Guar and Guayule, showing varying break-even yields and prices for each crop as they are adopted into a whole farm production system. In addition to the break-even yields and prices, whole farm net returns on an acre basis is calculated for each yield and price level of Guar and Guayule production. From this model, growers will be able to determine the break-even yield and price for Guar and Guayule as they incorporate each crop into their cropping system and how that level of adoption impacts their whole farm net returns.

Dissemination of Guayule and Guar Economic Information through Extension Meetings:
The results from Sustainability integrated models will provide Extension faculty an interactive tool that generates the costs to grow and harvest guayule and guar to be used in meetings in AZ and NM.

The results from break-even model mentioned above provides Extension faculty an interactive tool that calculates the break-even yield and price and whole farm net returns based on acres of Guayule and Guar as growers determine if or how much of each crop to incorporate into their current cropping system.

Input Tool for Potential Adoption Rates in Arizona and New Mexico:
Continue to refine the AZ and NM whole farm scenarios, but the baseline for whole farm analysis and presentation during the extension/outreach activities. We are working with the Extension team to start setting dates for inclusion in extension workshops using the whole farm and budgeting tools.

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 Evan	Hold workshops and present information to growers in Arizona	Host two presentations on guayule agronomic production and irrigation at regional extension events Present guayule production to Native American farming communities Collect needs assessment information directly from Native American farming communities	31 Aug 19 31 Aug 19 31 Aug 19
2 Grover	Hold workshops and present information to growers	Host 2 presentations on guar agronomic production as an interim step to bulletin Present SBAR project information and materials	31 Aug 19 31 Aug 19

Grower Workshops in Arizona:
5/30/2019 Held collaborative guayule field day with University of Arizona Cooperative Extension, Bridgestone and SBAR. Attendees toured Bridgestone research farm and guayule extraction facility and were given presentations on all aspects of current guayule research.

Present Guayule Information to Native Nation Communities
Presentation to tribe members is scheduled for 8/31/19.

Contact has been made with 2 Native American farming communities to discuss the potential of guayule production on their land. Both are interested and discussions have commenced about the requirements for guayule production. Teegerstrom, U of A Native American Liaison, and Dierig of Bridgestone, were also involved with these conversations and we are working towards installing acreage with one community as early as 2019. Meetings with Native American communities will continue throughout the year.

Needs Assessment Information from Native Nation Communities
Relationships are being built with Native American communities, when it feels appropriate we will approach them about filling out the survey.

Grower Workshops in New Mexico:
No progress has been made on this task.

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

Task #	Description of Task	Deliverable	Target Completion Date
1 Gutierr	Develop/improve SBAR 4-H Camp curriculum	Adapt camp curriculum for use in NM (train-the-trainer and 4-H camps)	31 May 19
2 Gutierr	SBAR 4-H Day camps and/or mini-camps	Plan/Host 6 SBAR 4-H Day camps and/or mini-camps targeting Hispanic and Native youth in Southern and Northern NM	31 Aug 19
3 Lopez	Order equipment/supplies for biofuel activities	4-H Biofuel outreach activities prepped/ready for implementation Summer camp curriculum finalized	30 Apr 19 30 Apr 19
4 Lopez	Provide 4-H biofuel activities to 4-H youth	Hold 2 biofuel activities (at least one reaching rural 4-H youth)	31 Jul 19
5 Lopez	Expand 4-H biofuel camp	Host a biofuel-focused 4-H summer camp Increase participation to 20 students	31 Jul 19 31 Jul 19

6 Lopez	Refine evaluation instrument for the BYOE program	Revised and updated evaluation instrument available for SBAR biofuel activities Revised and updated evaluation instrument available for SBAR biofuel summer camp	31 Jul 19 31 Jul 19
7 Rock	Develop SBAR internal factsheets on *Project Puente*	Generate *Project Puente* resource document(s) for SBAR faculty	28 Feb 19
8 Rock	Recruit students for summer *Project Puente* internships	Update application materials to highlight on-going SBAR research opportunities Recruit 6 students for Yr2 cohort of *Project Puente* interns	1 May 19 1 May 19
9 Rock	*Project Puente* student project development and deployment	Work with SBAR faculty to identify appropriate internship projects (research and extension) Facilitate SBAR internship projects; final poster presentations highlighting student work	26 Jul 19 31 Aug 19

SBAR 4-H Camp Curriculum:
Curriculum for use in NM train-the-trainer and 4H was developed and used in the train the trainer and in the SBAR 4H Day camps and/or mini-camps.

SBAR 4-H Day Camps or Mini-Camps:
A total of three 4-H Camp activities were developed and tested by 38 Native American high school students from the NMSU DreamKeepers Summer program, 180 junior age 4-H students, 23 Senior 4-H'ers, and 8 Hispanic sophomore students from the NMSU-CAMP/Medicinal Plants Internship.

Biofuel Activities Supplies:
UA and NMSU 4-H Team held several planning meetings; we finalized activities that would integrate the research components: Feedstock Development & Production, Post-Harvest Logistics & Co-Products and System Performance & Sustainability into the biofuel summer camp in 2019; UA 4-H selected Dr. Rodriguez-Uribe and Dr. Brewer activities to implement into the 4-H Biofuel camp; additional supplies were ordered after the April completion date.

4-H Biofuel Activities to Youth:
UA undergraduate students Jasmine Lopez – AmeriCorp member, Shiara Perez and Kaitlyn Benally held one 1-hour sessions at Pueblo High School chemistry club to provide Biofuel activities, on average 8 students have participated. Jasmine Lopez, Shiara Perez and Gloria Villa Barbosa provided biofuel activities (Burn the nut and Guar Bubbles) to 4-H youth at two camps at Mingus Springs reaching 85 youth from 4 counties.

Photo 3. *Youth actively engaged in hands on activities.*

Expand 4-H Biofuel Camp:
The recruitment and implementation of the biofuel camp was a great success. D. Cabrera, did a fantastic job coordinating all aspects of the camp. J. Lopez, S. Perez and G. Barbosa did a tremendous job learning and teaching the biofuel lessons. We partnered with 4-H staff from other camps to leverage resources for evening activities and camp supervisors during the day. There were 18 campers total; 9 female and 9 males; camper ages were: 11 (1 camper); 12 (12 campers); 13 (3 campers); 14 (2 campers). Camper Ethnicity: 9 Native American, 2 Hispanic/Latino, 2 multi-racial (white/Hispanic and white/black), 2 Asian/Pacific Islander, 3 white. Additional evaluation results are available in Appendix 3.

Photo 4. *2019 4-H Biofuel summer camp participants hosted at the University of Arizona, Tucson, Arizona.*

Refine Evaluation Instrument for the BYOE Program:
Dr. Lopez, Cabrera and Jennifer Fields completed reviewing the Bioenergy Youth Outreach and Engagement (BYOE) evaluation used at last year SBAR 4-H Biofuel Summer Camp. Fields provided updated versions of last year evaluations used at the 4-H Biofuel Camp along with a logistics survey. Cabrera coordinated with 4-H Staff to prepare a 4-h common measures survey used at the camp.

Internal Factsheets on *Project Puente* Internships:
No new activity to report this quarter.

Project Puente Internship Recruitment:
During this reporting period the Arizona Extension team worked alongside Central Arizona College to recruitment of *Project Puente* student interns to participate in in the SBAR internship program for Summer 2019. Outreach materials and flyers were developed as resources for students interested in the program as well as SBAR faculty interested in mentoring students.

Project Puente Student Project Development and Deployment:
Student interns were located at the Maricopa Agricultural Center as well as on campus at the University of Arizona in Tucson. Student interns participated in both research and Extension projects related to the focal areas of SBAR and were able to interact with SBAR industry members, faculty, staff and students as part of their project(s). Each student worked on projects for a total of 6 weeks under the director of a SBAR faculty mentor and is scheduled to share their findings at a culmination event in July 25th of 2019 at the Maricopa Agricultural Center with the faculty mentors, teachers, and families. The Extension team was able to recruit a total of 4 interns for the 2019 program. While we did not meet the target of 6 interns, we were able to recruit two additional SBAR faculty to participate in the mentoring program this year, Dr. G. Lopez and Dr. J. Neilson.

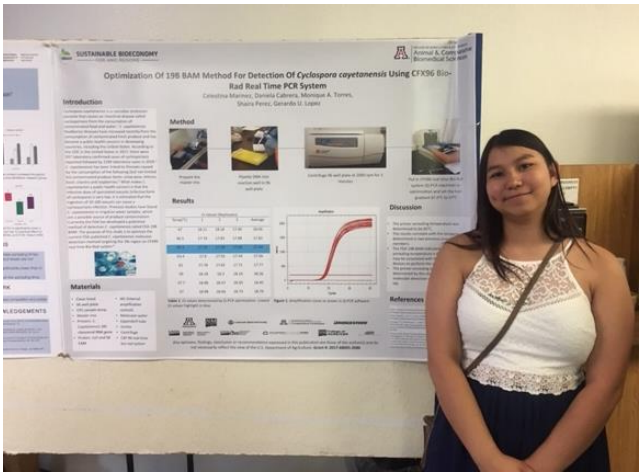


Photo 5. *Project Puente Intern, Celestina Marinez (hosted by the University of Arizona), presents her final poster presentation during the Project Puente Finale, Maricopa, Arizona.*

Photo 6. *Project Puente Intern, Chloe Gonzalez (hosted by Bridgestone), presents her research on guayule germplasm pollen viability at the Project Puente Finale, Maricopa, Arizona.*

One of the tactics that we used this year that was different from last year, to better facilitate meaningful student intern experiences, was to partner with 4H STEM specialist Dr. Lopez. Dr. Lopez worked to recruit local High school students in Tucson for the extension team. Additionally, in-order to aid in information transfer to student interns across the State, we arranged for Zoom classroom sessions that linked Maricopa and Phoenix-based students with those in Tucson. We feel that this is a successful model for future engagement of students in year 2020 of the grant.

Photo 7. *2019 Project Puente Finale, Maricopa, Arizona.*

EDUCATION

Project Coordination: Dr. Sara Chavarria (University of Arizona) serves as the lead for the Education Team, which meets at least twice monthly to cover broader topics related to specific Education objectives and tasks. Smaller working groups meet weekly 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 4-H workshops and camps.

Issues/Risks:
Due to schedule conflicts with other summer activity commitments, Uribe-Rodriguez, Gutierrez, and Brewer decided to offer a separate workshop in winter 2020 for the 4-H agents/volunteers in New Mexico.

As of this report, an Education PhD student had not yet been recruited in New Mexico, however, Year 3 planning discussions based on long-term project goals indicate the PD group is likely to seek an education/outreach coordinator who will focus on Native American communities at UA instead of a PhD student at NMSU.

A potential delay is procuring a web designer to assist with developing a workable webpage that allows access to the lesson plans in a clear and organized way. We need to work through how to design the SBAR Arid Regions Lesson Plan framework so that it's clear and easy to use online. This will involve understanding what website options are available within the SBAR website and thinking through the design and functions that will make it easy for an educator to access, search, and interact with the lesson plans.

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 Brewer	Supervise/Assist NM SBAR Fellows and Teacher Mentors through 2018-2019 school year	Design/deliver after school program for middle school Design/vet STEM activities	31 May 19 31 May 19
2 Brewer	Recruit and train SBAR Fellows and Teachers for 2019-2020 school year	Identify 2 new NM SBAR Fellows and any replacements, as necessary Identify 2 new NM SBAR Middle school teachers Identify 1 PhD student for education component; provide training	31 Jul 19 31 Jul 19 31 Jul 19
2 *cont* Chav	Recruit and train SBAR Fellows and Teachers for 2019-2020 school year	Identify 2 new AZ SBAR Fellows and any replacements, as necessary	31 Jul 19

		Identify 2 new AZ SBAR Middle school teachers	31 Jul 19
3 Chav	Plan/Design/Coordinate Fall 2018 and Spring 2019 SBAR Fellow seminar	Plan Fall 2018 seminar content Plan Spring 2019 seminar content Generate education products on SBAR Fellow activities (digital publications)	31 Aug 18 31 Dec 18 31 Jul 19
4 Chav	Visit classrooms for observations (Teacher delivery of SBAR content)	Implement Fall 2018 teacher observation Implement Fall 2018 SBAR Fellow observation Implement Spring 2019 teacher observation	30 Nov 18 30 Nov 18 30 Apr 19
5 Fields	Design/Schedule evaluation tools, protocols and metrics for all Education activities	Fall tools developed/refined; evaluation data gathered Spring tools developed/refined; evaluation data gathered Summer tools developed/ refined; evaluation data gathered Data synthesized; evaluation report generated	31 Dec 18 31 May 19 31 Jul 19 31 Aug 19

New Mexico SBAR Fellows and Teacher Mentors (2018-2019):
Four graduate fellows were recruited to replace the two current SBAR Fellows. Audu will graduate in August 2019 and begin his PhD studies at Worchester Polytechnic Institute in Fall 2019. Dehghanizadeh will shift to an SBAR research assistantship starting in August. Both Audu and Dehghanizadeh will continue their fellowships through the summer to assist with the Train-the-Trainer event and to help orient the new SBAR Fellows: Usrey, Rosalez, Pruitt, and Singh.

Recruit and Train SBAR Fellows and Teachers (2019-2020):
Two additional middle school teachers from Las Cruces Public Schools were recruited to join the two returning NM teachers. One teacher from a school district near Clovis, NM was recruited to work with Singh for the 2020-2021 school year when Singh returns to the NMSU Clovis Ag. Science Center to continue his field irrigation research. For 2019-2020, Singh needed to be paired with a Las Cruces teacher to enable him to complete his coursework on campus.

In June, Brewer met with the current NM teachers and SBAR Fellows to debrief from the 2018-2019 school year and to plan for the coming school year. The fellows and teachers continued the SBAR-based afterschool program, Guardians of the Biosphere, where they had

approximately 10 students in a given week. Both pairs also conducted activities during the school day in their respective classrooms.

In June, Dehghanizadeh and Audu developed and led a half-day hands-on activity on biofuels for the 24 middle school students participating in the NMSU College of Engineering summer Pre-Engineering (PREP) academy, assisted by the other SBAR undergraduates. Brewer also offered a half-day activity on paper recycling for the same group.

Recruitment information was shared with faculty and administrators from the College of Education to recruit a PhD student in science education.

Four fellows were successfully recruited at UA. Two are science education majors with strong backgrounds in teaching and literacy and the other two have backgrounds in Environmental Engineering and Plant Sciences.

Two new educators were recruited. One is a middle school teacher in Sells, AZ working with students and community members on Tohono O'odham (TO) Indian reservation. The second is an informal educator, who provides teaching/educational experiences outside of a traditional classroom. She is TO, has worked with community members through the park service and currently works for a San Xavier radio station. The decision to bring in an informal educator (Tina Andrews) was because we needed to explore how best to make stronger educational and community education connections with the TO community. By bringing in Andrews, we are addressing the need to have stronger indigenous representation in the SBAR project. One of our teachers, Wilma Amaro, is retiring so is trying to lessen her commitments. But in her leaving, we reached out to Traci Klein who had participated with SBAR in the past.

Fellow and Teacher mentor recruitment flyers were produced and disseminated via the SBAR website and through college departments and classes. (Appendix 4)

SBAR Fellow Seminar (Fall 2018 and Spring 2019):

Fellow Seminar – The second semester of the seminar finished strong. Each fellow finalized their lessons for SBAR and shared them with their partner teachers. The teachers then worked on these during the Teacher PD session.

Summer Teacher Professional Development (PD) – The summer PD program will take place July 1-3, 2019 and July 8-12, 2019. The ongoing meeting on the PD workshop included plans for how to: explore participants' prior knowledge of SBAR and connect it to the NM train the trainer, working with the Arid Lands SBAR Lesson Framework so the lesson plan connects to the broad theme related to arid lands, curriculum mapping so teachers/fellows can see where their lessons will fit in throughout the year, presentation of SBAR lesson ideas as well as relevant tours/presentations. With the needs of fellows and teachers being different we're building in as much time as possible for teachers and fellow pairs to work together on their lesson plans and work plan for the year. During this time, teachers from cohort 1 will refine their lessons from their first year in the program. Teachers from cohort 2 will work with their graduate students and begin to plan activities for their classrooms or community programs. We expect to have lesson plans that the education team will then refine and work on through August. Hence

why this is slightly behind schedule. We have the products, but we need to edit them for digital placement.

Classroom Observations:
Classroom visits in the Spring and check-ins with teachers and fellows were very informative. The teacher's face very different circumstances in their classroom and work with different populations. Having an education person work with the NM teachers locally and visiting their classrooms would provide needed support for the NM group.

Design and Implement Evaluation Tools:
Evaluation efforts related to the Education team activities were focused on 1) documenting fellow outcomes and getting feedback from graduate fellows about their overall experience working with teachers in the classroom, and about the weekly seminar offered by the education team and 2) preparing evaluation tools for the summer PD experience that was split between NMSU and UA.

A focus group interview was held with graduate fellows on the last day of the spring semester seminar, along with observations of their final projects that were created for use in the classrooms. Overall, fellows reported that the seminar was extremely useful in preparing them for their work in classrooms. The experience was perceived as slightly more valuable for the UA students, only because the NMSU fellows had to participate via zoom. The hope is to hire an education specialist in NMSU who can conduct a similar weekly seminar in person with the NMSU fellows, collaborating with UA via zoom when it is useful. Dr. Brewer had thought she had a candidate identified, but it fell through so this is ongoing.

The fellows also created video lessons/projects to share in classrooms. They were given the latitude to choose the specific topic they would cover, and these ranged from historical and cultural use of guar to specific scientific experiments. More detail about the feedback from fellows will be included in the final evaluation report.

In addition, several evaluation tools were refined or developed to be implemented during the 2-week Professional Development (PD) on July 1-3 (NM) and July 8-12 (AZ). Tools include a concept map to gauge content knowledge changes; a core concept pre/post test; and a post-survey that will 1) gauge the usefulness of PD activities and the amount of time spent on each; 2) the confidence in carrying out SBAR related activities/lessons and 3) open ended feedback about the PD experience and how it might be improved. This data will be analyzed and included in the final evaluation report due in August.

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

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Develop/Offer train-the-trainer biofuels education program for 4-H agents/volunteers and teachers/fellows	Develop/Host 3-day summer train-the-trainer program at NMSU	31 Jul 19

		Recruit 4-H youth and GK-12 participants	31 Jul 19
2 Chav	Connect with 4-H Team to ensure lesson transfer to teachers	Lessons posted on Schoolology	30 Sep 18

Design and Implement Train-the-Trainer Education Program for 4-H Youth Development:
Final arrangements for the July 1-3 Train the Trainers workshop at NMSU were made for the SBAR teachers, fellows, and researchers.

4-H Team Connection:
All activities continue as planned; no new information to report.

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

Task #	Description of Task	Deliverable	Target Completion Date
1 Molnar	Develop MS and/or PhD education opportunities within the University of Arizona around the theme of "Sustainable Bioeconomy"	At least 2 tracks (study concentration areas) within UA GIDPs	31 Dec 19

Development of Education Opportunities:
All activities for this task are complete.

PRODUCTS GENERATED.
September 2017 – June 2019

PUBLICATIONS, CONFERENCE PAPERS AND PRESENTATIONS

Publications

1. **Abdell-Haleem H.*; Luo Z.; Ray, D. 2019.** Genetic improvement of guayule (*Parthenium argentatum* A. Gray): An Alternative Rubber Crop. *In.* J. Al-Khayri (ed.). Advances in Plant Breeding Strategies, Volume 4; Nut and Industrial Crops. Springer Nature Switzerland AG (Invited Book Chapter, *In press*).
2. **Sun, O.; Fan, N.* 2019.** A Review on Optimization Methods for Biomass Supply Chain: Models and Algorithms, Sustainable Issues, Challenges and Opportunities. *Submitted*.

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.

Scholarly Presentations

1. **Angadi, S.V. 2018.** *Sustainable Bio-economy for Arid Regions: Growing Guar.* Extension Field Day. Clovis, New Mexico. 9 August.
2. **Angadi, S.V.*; 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.
3. **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.
4. **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.
5. **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.
6. **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.
7. **Brewer, C.E. 2018**. *Pairing biomass residues with conversion technologies*. Advanced Bioeconomy Leadership Conference, Washington, D.C. 28 February.
8. **Brewer, C.E. 2018**. *Polymerization and guar gum bubbles*. Outreach event activity. New Mexico 4-H State Conference. 11 July.
9. **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.

10. **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]
11. **Brown, K.S.*; Neilson, J.W. 2018.** *Microbial contributions*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. April.
12. **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]
13. **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 Biobased Products. Auburn, Alabama. 9 October.
14. **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 Biobased Products. Auburn, Alabama. 9 October.
15. **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.
16. **Cheng, F.*; Rosalez, R.; Dehghanizadeh, M.; Brewer, C.E. 2019.** *Co-Hydrothermal Liquefaction of Guayule Bagasse and Wastewater Treatment Microalgae*. AIChE Annual Meeting, Orlando, Florida. 10-15 November.
17. **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.
18. **Dehghanizadeh, M.*; Cheng, F.; Jarvis, J.M.; Holguin, O.; Brewer, C.E. 2019.** *High Resolution Mass Spectroscopy for Characterization of Resin from Guayule (Parthenium argentatum)*. 31st Association for the Advancement of Industrial Crops (AAIC) Annual Meeting, Tucson, Arizona. 8-11 September.
19. **Deirig, D. 2017.** *Bridgestone's perspective on a domestic source of natural rubber in the desert.* Invited Speaker at the New Mexico Sustainable Agriculture Conference. Los Lunas, New Mexico. 13 December.
20. **El-Shikha, D.E.M. 2018.** *Update – Guayule irrigation experiments at Maricopa Agricultural Center*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 12 September.
21. **El-Shikha, D.E.M.; Waller, P.M.; Hunsaker, D.J.; Dierig, D.; Wang, S.; Cruz, V.M.; 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]
22. **Evancho, B.*; Teetor, V.H.; Willmon, J.; Bennett, M.C.; Montes, M.; Schmaltzel, C.; Ray, D.T. 2018.** *Root structure differentiation between common guayule planting methods.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 2 August. [poster]

23. **Evancho, B. 2018.** *Guayule Fuels the Future*. IES – Energy Talks Seminar, Sky Bar, Tucson, Arizona. 9 October.
24. **Evancho, B. 2019.** *Guayule: How Close Are We?* Marana Winter Field Crops Clinic. Marana, Arizona. 10 January.
25. **Evancho, B. 2019.** *Guayule: How Close Are We?* Casa Grande Winter Field Crops Clinic. Casa Grande, Arizona. 15 January.
26. **Fan, N. 2018.** *Review on Optimization Methods for Biomass Supply Chain*. SBAR UA Research Team Seminar. University of Arizona, Tucson, Arizona. 28 November.
27. **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.
28. **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]
29. **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.
30. **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.
31. **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.
32. **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]
33. **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]
34. **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.
35. **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.
36. **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]

37. **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.
38. **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.
39. **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.
40. **Grover, K. 2018.** *Sustainable agriculture and guar production in New Mexico*. New Mexico State 4-H Conference, Las Cruces, New Mexico. 10 July.
41. **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.
42. **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.
43. **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.
44. **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.
45. **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.
46. **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.
47. **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]
48. **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.
49. **Grover, K. 2019.** *Guar: A potential alternative crop in New Mexico*. New Mexico Master Gardener's Meeting. Las Cruces, New Mexico. 8 May.
50. **Grover, K. 2019.** *Guar as an alternative crop in New Mexico*. New Mexico Sustainable Agriculture Field Day. Las Cruces, New Mexico. 26 June.
51. **Grover, K. 2019.** *Guar as an alternative crop in New Mexico*. SBAR Train-the-Trainer Workshop. Las Cruces, New Mexico. 2 July.
52. **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.

53. **Hoare, D.M. 2018.** *Irrigation Sensors and the WINDS Model.* SBAR UA Research Team Seminar Series, Tucson, Arizona. 26 September.
54. **Idowu, O.J. 2018.** *Introduction to the SBAR Project*. Las Cruces, New Mexico. 6 Feb.
55. **Idowu, O.J. 2018.** *Sustainable Bio-economy for Arid Regions: Update*. Extension Field Day, Clovis, New Mexico. 9 August.
56. **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.
57. **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.
58. **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]
59. **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.
60. **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.
61. **Lopez, E.; Fox, S.; Brewer, C.E. 2018.** *GK-12 Lesson Documentation Spreadsheet*. American Institute of Chemical Engineers Annual Meeting, Pittsburg, Pennsylvania. 29 October.
62. **Maqsood, H. 2018.** *Guar Crop Coefficient Development for New Mexico Environments*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 7 November.
63. **McCloskey, W. 2018.** *Weed Trial Results for Guayule*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 14 November.
64. **McMahan, C. 2018.** *Flowering Reduction in Guayule*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 19 September.
65. **McMahan, C. 2019.** *USDA-ARS Rubber Lab Update*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 27 March.
66. **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.
67. **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.
68. **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]
69. **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.
70. **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.

71. **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]
72. **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]
73. **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]
74. **Niu, D., 2018.** *Partial cloning of APETALA1 (AP1) gene from guayule*. cDNA Lab Seminar, USDA-ARS Western Regional Research Laboratory. 28 March.
75. **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]
76. **Ogden, K. 2017.** *Sustainable Bioeconomy for Arid Regions*. Biomass Research and Development Technical Advisory Board Meeting. 15 November. [invited speaker]
77. **Ogden, K. 2018.** *Sustainable Bio-economy for Arid Regions*. Southwest Indian Agricultural Association Meeting. Laughlin, Nevada. 16-18 January.
78. **Ogden, K. 2018.** *Potential of the Bioproducts and Biofuels Economy*. AIChE Annual Meeting, Pittsburg, Pennsylvania. October [invited speaker]
79. **Ogden, K.*, White, R., Brewer, C.E. 2018.** *Public Private Partnerships*. ABLC Conference. Washington, D.C. 27-28 February.
80. **Rock, C.*, Brassill, N. 2018.** *Importance of Cooperative Extension in University Research*. University of Arizona, Tucson, Arizona. 14 March.
81. **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]
82. **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]
83. **Singh, J.*; Angadi, S.V.; Begna, S.H.; Guzman, I.; Idowu, 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]
84. **Singh, J.*; Angadi, S.V.; Begna, S.H.; Idowu, J.; Guzman, I.; VanLeeuwen, D. 2019.** *Water extraction patters of guar under different irrigation strategies in the Southern High Plains.* Western Society of Crop Science Annual Meeting. Pasco, Washington. 25-26 June. [poster] Won 1st Place in student poster competition.
85. **Singh, J.*; Angadi, S.V.; Begna, S.H.; Idowu, 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.

86. **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]
87. **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.
88. **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.
89. **Sun, O. 2018.** *GIS-Based Two-stage Stochastic Facility Location Considering Planting Plan Uncertainty*. INFORMS Annual Meeting, Phoenix, Arizona. 5 November.
90. **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.
91. **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.
92. **Sun, O. 2019.** *Biomass Supply Chain Configuration and Management*. SBAR UA Research Team Seminar. University of Arizona, Tucson, Arizona. 10 April.
93. **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.
94. **Sun, O.; Fan, N. 2018.** *Harvest scheduling*. SBAR Logistics Team Group Meeting. (webinar) New Mexico State University. Las Cruces, New Mexico. 5 February.
95. **Sun, O.; Fan, N. 2018.** *Optimization of feedstock logistics*. SBAR UA Research Seminar. University of Arizona. Tucson, Arizona. 14 February.
96. **Sun, O.; Fan, N. 2018.** *Optimally locating biorefineries*. SBAR Sustainability Working Group Seminar. (webinar) Colorado State University. Lakewood, Colorado. 8 March.
97. **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.
98. **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.
99. **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.
100. **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.
101. **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.

102. **Waller, P. 2018.** *WINDS Model: A status report and connection to SBAR research*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 10 October.
103. **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.
104. **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]

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

Audience Demographic Parameter	Previous Total (Cumulative)	This Quarter Total	Cumulative Project Total
Gender			
Males	874	154	***1028***
Females	367	66	***433***
Race/Ethnicity			
Hispanic	174	30	***204***
Asian	107	20	***127***
Native American	174	31	***205***
African American	41	7	***48***
Anglo/White	745	132	***877***

Audience Cumulative Total *(when captured)****: 1,461 ppl***

WEBSITE(S) OR INTERNET SITE(S)

SBAR Project Website

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

NEW TECHNOLOGIES OR TECHNIQUES GENERATED

None this reporting period.

INVENTIONS, PATENT APPLICATIONS, AND/OR LICENSES

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

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

OTHER PRODUCTS GENERATED

Brochures, Factsheets, and Flyers

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

Press Releases and News Articles

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

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

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

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

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

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

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

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

Tabling Events and Workshops – Marketing and Outreach

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

17. 10 Jan 2019. Marana Winter Field Crop Clinic. University of Arizona Cooperative Extension, Marana, Arizona.
18. 15 Jan 2019. Casa Grande Winter Field Crop Clinic. University of Arizona Cooperative Extension, Casa Grande, Arizona.
19. 23 Jan 2019. New Mexico Cotton Growers Association Conference, Ruidoso, New Mexico.
20. 13 Feb 2019. Desert Hills S.T.E.A.M. Night. (Science, Technology, Engineering, Art, and Math) Desert Hills Elementary School, Las Cruces, New Mexico.
21. 15-16 Apr 2019. New Mexico Organic Farming Conference, Albuquerque, New Mexico.
22. 11 Apr 2019. Spring Extension Field Day, New Mexico State University Agricultural Science Center, Clovis, New Mexico.
23. 15 May 2019. Annual Agricultural Research Congressional Exhibition and Reception. Rayburn House, Washington, D.C.
24. 30 May 2019. Market Discussion and Field Day. Bridgestone Guayule Research Farm, Eloy, Arizona.
25. 26 Jun 2019. Extension Field Day. Fabian Garcia Research Center, Las Cruces, New Mexico.

→Total Reach via Tabling Events and Workshops (when captured): ***2,312 participants***

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.

Youth participation through classroom activities is tracked at the beginning of the school year because the same students are being reached each week by the teacher fellow pairs.

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	503	-	***503***
14-16 years	64	-	***64***
Gender			
Males	281	-	***281***
Females	286	-	***286***
Race/Ethnicity			
Hispanic	303	-	***303***
Asian	1	-	***1***
Native American	8	-	***8***
African American	6	-	***6***
Anglo/White	66	-	***66***

Youth Cumulative Total *(when captured)****: 567 ppl***

PARTICIPANTS AND COLLABORATING ORGANIZATIONS. September 2017 – June 2019

PARTNER ORGANIZATIONS

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

Nico Carrero-Little	Undergrad Student	Post-Harvest Logistics & Co-Products
Pedro Castillo	Undergrad Student	Feedstock Development & Production
Feng Cheng	Post-doc	Post-Harvest Logistics & Co-Products
Mostafa Dehghanizadeh	Graduate Student Fellow	Education Post-Harvest Logistics & Co-Products
Barry Dungan	Professional	Post-Harvest Logistics & Co-Products
Miguel Flores	Undergrad Student	Extension & Outreach
Sarah Fox	*Undergrad Student*	*Post-Harvest Logistics & Co-Products*
Alonso Garcia	Graduate Student	Feedstock Development & Production
Adah Gellis	Undergrad Student	Extension & Outreach
Saba Gill	Graduate Student	Post-Harvest Logistics & Co-Products
Thomas Gloria	*Undergrad Student*	*Feedstock Development & Production*
Kulbhushan Grover	Key Collaborator	Extension & Outreach Feedstock Development & Production
Erin Gutierrez	Undergrad Student	Post-Harvest Logistics & Co-Products
Paul H Gutierrez	Key Collaborator	Extension & Outreach System Performance & Sustainability
Befekadu Habteyes	*Professional*	*System Performance & Sustainability*
F. Omar Holguin	Key Collaborator	Post-Harvest Logistics & Co-Products
John Idowu	Key Collaborator	Extension & Outreach
Jackie Jarvis	Professional	Post-Harvest Logistics & Co-Products
Umakanta Jena	Professional	System Performance & Sustainability
Sita Khanal	Graduate Student	System Performance & Sustainability
Kelly Laje	Graduate Student	Post-Harvest Logistics & Co-Products
Travis Le-Doux	*Undergrad Student*	*Post-Harvest Logistics & Co-Products*
Esai Lopez	*Undergrad Student*	*Education*
Alberto Lorenzo	*Undergrad Student*	*Feedstock Development & Production*
Sicilee Macklin	*Undergrad Student*	*Education* *Post-Harvest Logistics & Co-Products*
Cesar Martinez-Bejarano	*Undergrad Student*	*Post-Harvest Logistics & Co-Products*
Julie Miller	Undergrad Student	Extension & Outreach
Sa'Rae Montoya	*Graduate Student*	*Post-Harvest Logistics & Co-Products*
Kyle Moore	*Undergrad Student*	*Feedstock Development & Production*
Hasti Mozaffari	Graduate Student	Post-Harvest Logistics & Co-Products
Jasmine Paquin	Graduate Student	Extension & Outreach
Kaavya Polisetti	Graduate Student	Post-Harvest Logistics & Co-Products
Camila Prieto	Undergrad Student	Extension & Outreach
Darien Pruitt	Graduate Student Fellow	Education Extension & Outreach
Lucas Ramirez	Undergrad Student	Feedstock Development & Production
Joram Robbs	*Graduate Student*	*Extension & Outreach* *System Performance & Sustainability*
Laura Rodriguez-Uribe	Professional	Extension & Outreach Post-Harvest Logistics & Co-Products
Rodrigo Rosalez	Graduate Student Fellow	Education Post-Harvest Logistic & Co-Products
Kimberly Salinas	*Undergrad Student*	*Extension & Outreach*
Nathan Schavz	*Undergrad Student*	*Post-Harvest Logistics & Co-Products*
Tarah Schuman	*Undergrad Student*	*Post-Harvest Logistics & Co-Products*
Parameer Singh	Graduate Student Fellow	Education
Jagdeep Singh	Graduate Student Fellow	Education Feedstock Development & Production
Peter Skelton	*Professional*	*Extension & Outreach*

Nicolas Soliz	Undergrad Student	Post-Harvest Logistics & Co-Products
Stephen Taylor	*Undergrad Student*	*Education*
Brian Treftz	*Graduate Student*	*Education* *Post-Harvest Logistics & Co-Products*
Jacob Usrey	Graduate Student Fellow	Education Post-Harvest Logistics & Co-Products
Justin Valdez	*Undergrad Student*	*Post-Harvest Logistics & Co-Products*
Victoria Valenzuela	Undergrad Student	Feedstock Development & Production
Stephanie Willette	*Graduate Student*	*Post-Harvest Logistics & Co-Products*
April Wright	Undergrad Student	Post-Harvest Logistics & Co-Products
Scott Woolf	*Undergrad Student*	*Post-Harvest Logistics & 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 Vill Barbosa	Undergrad Student	Extension & Outreach
Armando Barreto	Professional	Feedstock Development & Production
Holly Barton	*Graduate Student* *Fellow*	*Education*
Megan Bennett	Undergrad Student	Feedstock Development & Production
Natalie Brassill	Professional	Extension & Outreach
Kyle Brown	Graduate Student	Feedstock Development & Production
Daniela Cabrera	Professional	Extension & Outreach
Madasu Chandrashekar	Professional	Post-Harvest Logistics & 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	Professional	Education Extension & Outreach
Diaa El-Shikha	Post-doc	Feedstock Development & Production
Blase Evancho	Key Collaborator Graduate Student	Extension & Outreach Feedstock Development & Production
Neng Fan	Key Collaborator	Post-Harvest Logistics & Co-Products
Krista Farmer	*Undergrad Student*	*Feedstock Development & Production*
Charles Ferini	Undergrad Student	Feedstock Development & Production
Daryan Godfrey	*Undergrad Student*	*Feedstock Development & Production*
Leslie Gunatilaka	Key Collaborator	Post-Harvest Logistics & Co-Products
Wolfgang Grunberg	Professional	ALL AREAS
Matthew Harmon	Undergrad Student	Feedstock Development & Production
Danielle Hoare	Graduate Student	Feedstock Development & Production
Stephanie Honeker	*Undergrad 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
Jessica Ledesma	Undergrad Student	Feedstock Development & Production
Ashton Leo	*Graduate Student Fellow*	*Education*
Taylor Levy	Intern	Extension & Outreach
Manping Liu	Professional	Post-Harvest Logistics & 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
Hadiqa Maqsood	Graduate Student	Feedstock Development & Production
Celestina Marinez	Intern	Extension & Outreach
William McCloskey	Key Collaborator	Feedstock Development & Production
Wenzhe Mi	*Intern*	*Feedstock Development & Production*
Istvan Molnar	*Key Collaborator*	*Education*
Madison Montes	*Undergrad Student*	*Feedstock Development & Production*
Leobardo Moreno	Undergrad Student	Feedstock Development & Production
Madison Morris	Undergrad Student	Feedstock Development & Production
Julie Neilson	Professional	Feedstock Development & Production
Andrew Nelson	*Post-doc*	*Feedstock Development & Production*
Kim Ogden	Key Collaborator	ALL AREAS
Huitzilin Ortiz	Graduate Student Fellow	Education
Lia Ossanna	Professional	Feedstock Development & Production
Tenzin Phakdon	Graduate Student Fellow	Education
Bryan Pastor	Professional	Feedstock Development & Production
Duke Pauli	*Key Collaborator*	*Feedstock Development & Production*
Alexandra Peck	Undergrad Student	Feedstock Development & Production
Livvi Pearson	Undergrad Student	Feedstock Development & Production
Shaira Perez	Undergrad Student	Extension & Outreach
Sam Pernu	Undergrad Student	Feedstock Development & Production
Sarocha Pradyawong	Post-doc	Feedstock Development & Production
Dennis Ray	Key Collaborator	Feedstock Development & Production
Jaspreet Rekhi	*Professional*	*Post-Harvest Logistics & 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
Stephanie Sikora	Professional	Education
Ana Lucia Soto	Intern	Feedstock Development & Production
Seth Steichen	Graduate Student Fellow	Education
Ou Sun	*Graduate Student*	*System Performance & Sustainability*
Trent Teegerstrom	Key Collaborator	Extension & Outreach System Performance & Sustainability
Valerie Teetor	Professional	Feedstock Development & Production
Mira Theilmann	*Undergrad Student*	*Feedstock Development & Production*

Christine Toering	*Undergrad Student*	*Feedstock Development & Production*
Gianni Velasco	Undergrad Student	Feedstock Development & Production
Peter Waller	Key Collaborator	Feedstock Development & Production
Quinn Waltz	*Undergrad Student*	*Feedstock Development & Production*
John Willmon	Undergrad Student	Feedstock Development & Production
Ya-ming Xu	Post-doc	Post-Harvest Logistics & Co-Products
Ali Yaylali	Graduate Student Fellow	Education
Stevi Zozaya	Undergrad Student	Extension & Outreach
Daniel Zuniga-Vazquez	Graduate Student	Post-Harvest Logistics & 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
Greg Leake	*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*
Matthew Canonizado	*Professional*	*Feedstock Development & Production*
George Chong	*Professional*	*Feedstock Development & Production*
Chen Dong	Professional	Feedstock Development & Production
Niu Dong	Professional	Feedstock Development & Production
Trinh Huynh	Professional	Feedstock Development & Production
Colleen McMahan	Key Collaborator	Feedstock Development & Production
Grisel Ponciano	Professional	Feedstock Development & Production
Dante Placido	Post-doc	Feedstock Development & Production
Mariano Resendiz	Professional	Feedstock Development & Production

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

Total Active Key Collaborators: ***23***
Total Active Professional Staff: ***39***
Total Active Postdoctoral Researchers: ***6***
Total Active Graduate Students: ***31***
Total Active Undergraduate Students: ***36***
Total Active Fellows: ***13***
Total Active /Interns: ***4***

Total Past Participants (no longer active): ***51***

COLLABORATIONS AND OTHER CONTACTS

Collaborations:

Academic Institutions:	CSM (Colorado School of Mines) - Dept. of Civil and Environmental Engineering CSU (Colorado State University) - Dept. of Mechanical Engineering FSU (Florida State University - National High Magnetic Field Laboratory NMSU (New Mexico State University) - Cooperative Extension - Dept. of Agricultural Economics and Agricultural Business - Dept. of Chemical Engineering - Dept. of Plant and Environmental Sciences UA (University of Arizona) - 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 Soil, Water and Environmental Sciences - Dept. of Systems and Industrial Engineering - Institute of Energy Solutions - Natural Products Center - School of Natural Resources and the Environment - School of Plant Sciences
Nonprofits:	
Industrial or Commercial Firms:	BASF Bridgestone Americas, Inc. Central Arizona Project (CAP) FMC Guar Resources Syngenta
Federal Government	Saguaro National Park (West), Tucson AZ - Environmental Education Department USDA – Agricultural Research Service, Western Regional Research Center, Albany CA - Chemistry (Bioproducts)

	- Plant Genetics USDA – Agricultural Research Service, Grassland Soil and Water Research Laboratory, Temple TX - Crop Modeling
State or Local Governments:	Arizona Department of Agriculture, Environmental Services Division
Tribal Governments:	
Schools or School Systems:	**BASIS Charter Schools**, BASIS Tucson North (high school), Tucson, Arizona **Flowing Wells Unified District**, Walter Douglas Elementary School, Tucson, Arizona **Las Cruces Public Schools**, Camino Real Middle School, Mesa Middle School, Mesilla Valley Leadership Academy, and Sierra Middle School, Las Cruces, New Mexico **Marana Unified School District**, Quail Run Elementary School, Marana, Arizona **Tucson Unified School District**, Pueblo High School, and Valencia Middle School, Tucson, Arizona **Santa Rosa Ranch School District**, Santa Rosa Ranch School, Sells, Arizona **Sunnyside Unified School District**, Apollo Middle School, Tucson, Arizona
Other Organizations (foreign or domestic):	

Other Contacts:

Contacts with others within recipient's organization (interdepartmental or interdisciplinary collaborations):	UA (University of Arizona) - Applied Biosciences - Arid Lands Resource Sciences - College of Agriculture and Life Sciences - College of Architecture, Planning and Landscape Architecture - College of Science - Institute of the Environment - Water Resources Research Center
Contacts with others outside the organization:	Denver Museum of Nature and Science, Denver Colorado Central Arizona College

Contacts with others outside the United States or with an international organization:	

APPENDICES

APPENDIX 1. GUAYULE HERBICIDE TRIALS – FIELD TOUR

Tour Date: May 6, 2019
Tour Host: Dr. Bill McCloskey (UA) and Dr. Sam Wang (Bridgestone)

Agenda: University of Arizona – Bridgestone Guayule Herbicide Trials Field Tour

Time	Location	Event
8:00 am	Bridgestone Bio-Rubber in Eloy	Presentation on Guayule as a source of bio-rubber and other potential products (Sam Wang)
9:00 am	Bridgestone Bio-Rubber in Eloy	Field tour of guayule experiments at the Bridgestone Research Farm.
10:00 am	Drive to the University of Arizona Maricopa Ag Center	
11:00 am	Maricopa Ag Center	Tour of guayule herbicide tolerance studies
12:00 pm	Maricopa Ag Center MPR	Lunch and guayule preemergence herbicide tolerance data presentation (Bill McCloskey)
1:00 pm	Drive to the Bridgestone Bio-Rubber processing plant in Mesa, AZ	
2-4 pm	Bridgestone Bio-Rubber Processing Plant, Mesa, AZ	Presentation on guayule rubber extraction (Bob White) and tour of processing plant

APPENDIX 2. GUAYULE FIELD TOUR

Documents Included

1. **Invitation** – An invitation that was widely distributed to encourage Arizona growers to attend the Guayule Field Tour on Thursday, May 30, 2019.
2. **Agenda** – Planned discussion topics and tours hosted at Bridgestone facilities in Eloy, Arizona and Mesa, Arizona on Thursday, May 30, 2019.
3. **List of Attendees** – Sign-in sheets from the Guayule Field Tour hosted at Bridgestone facilities in Eloy, Arizona and Mesa, Arizona on Thursday, May 30, 2019.

Sponsored by Bridgestone and the University of Arizona Cooperative Extension

GUAYULE INFORMATION & FEEDBACK SESSION

Thursday, May 30, 2019
9:30am - 4:00pm
Eloy and Mesa, Arizona

Join us for info, tours and lunch. Help us improve research and grower opportunities

9:30am @ Bridgestone : 4140 W Harmon Road; Eloy, AZ 85131

Presentations, Q&A

11:30 ~ LUNCH

2:30pm @ Bridgestone : 6533 S Mountain Road; Mesa, AZ 85212

Tour, Q&A, Wrap Up

RSVP by May 1, 2019

Link: https://docs.google.com/forms/d/e/1FAIpQLSfnzJFYtOsPIP0Pk7384vSnq6jIJj6TtowxYs2Bt00lTBqeOA/viewform?usp=sf_link

Phone: Blase Evancho at 520-705-0871

Bridgestone Guayule Tour

Market Discussion & Field Day
May 30, 2019

BRIDGESTONE

Worldwide Olympic Partner

Bridgestone Guayule Research Farm
4140 West Harmon Road
Eloy, AZ 85131

9:30-9:45am	Registration
9:45-10:15am	Dr. Dave Dierig - Guayule Market & Demand Discussion
10:15-10:40am	Dr. Dave Dierig – Farm Tour
10:40-11:00am	Dr. Sam Wang - Agronomic Research
11:00-11:20am	Dr. Bill McCloskey – Weed Management Strategies
11:20-11:30am	Dr. Peter Ellsworth – Insect Management Discussion
11:30-11:35am	Ms. Alix Rogstad – SBAR Description & Goals
11:35-12:00pm	Blase Evancho – Grower Discussion w/ 2 growers with active fields.
12:30-2:00pm	Travel to Rubber Extraction Facility

Bridgestone Guayule Rubber Extraction Facility
6533 South Mountain Road
Mesa, AZ 85212

2:00-3:15pm	Bob White – Tour of Facility & Extraction Process
3:15-3:30pm	Guayule Wrap-up

SBAR SUSTAINABLE BIOECONOMY FOR ARID REGIONS

ARIZONA · NM STATE UNIVERSITY · Colorado State University · THE UNIVERSITY OF ARIZONA COLLEGE OF AGRICULTURE & LIFE SCIENCES Cooperative Extension · BRIDGESTONE

USDA United States Department of Agriculture · National Institute of Food and Agriculture · USDA ars Agricultural Research Service · COLORADO SCHOOL OF MINES EARTH · ENERGY · ENVIRONMENT · NM STATE College of ACES/CES · GR GUAR RESOURCES, LLC

"The Sustainable Bioeconomy for Arid Regions (SBAR) Project funding is provided by the USDA NIFA – Agriculture and Food Research Initiative. Grant # 2017-68005-26867."

PARTICIPANT LIST
Market Discussion and Field Day (Guayule Information Day)
30 May 2019

Paul Brown, Arizona Cooperative Extension
John Idowu, New Mexico State University
Newt McCarty, New Mexico State University
Kevin Rogers, Arizona Cotton Growers
Paco Ollerton, Arizona grower
Cathy Martinez, Arizona Cooperative Extension (Pinal County)
Darien Pruitt, New Mexico State University
Steve Naranys, USDA
Mitchell Bartlett, Fertizona
Tom Harris, Valent
William McCloskey, University of Arizona
Bill Thelinda, Arizona grower/Farmer
Ross Rayner, Tumbling T Ranches
Edward Carr, Arizona Department of Agriculture
Jamilah McCoy, USDA Natural Resources Conservation Service
Alix Rogstad, SBAR/University of Arizona
Wolfgang Grunberg, University of Arizona
Blase Evancho, University of Arizona

APPENDIX 3. 4-H BIOFUEL SUMMER CAMP HIGHLIGHTS

Documents Included

1. **SBAR 4-H Camp Highlights** – A summary of evaluation results obtained from participants at the SBAR 4-H Biofuel Summer Camp hosted at the University of Arizona, 3-7 June 2019.

SBAR 4-H Camp, University of Arizona, June 3-7, 2019
Camp Highlights, prepared by SBAR evaluator.

The Numbers:

- √ **18** total campers
- √ **9 female** and **9 male** campers
- √ **Campers ages:** 11 (1 camper); 12 (12 campers); 13 (3 campers); 14 (2 campers)
- √ **Camper Ethnicity:**
  - **9** Native American,
  - **2** Hispanic/Latino,
  - **2** multi-racial (white/Hispanic and white/black),
  - **2** Asian/Pacific Islander
  - **3** White
- √ **8** total staff – 1 Coordinator, 1 lab supervisor/instructor, 3 instructors, 3 counselors

Camp Post-Survey Questionnaire (developed by evaluator):

1. Was there enough information about the camp in the recruitment materials to get you excited about participating in the camp? **Median Score: 9**
1 = No, I didn't know what to expect 10 =Yes, I was super excited

2. How would you rate the application process? **Median Score: 3**
1= Easy 10=Difficult

3. How would you rate the camp instructors' knowledge? **Median Score: 9.5**
1=Not very informative 10=Very informative

4. How would you rate the camp instructors' attitude/approach? **Median Score: 10**
1=Not very friendly or engaging 10=Very friendly and engaging

5. How would you rate the evening camp staff? **Median Score: *9***
1= Not very friendly or helpful 10=Very friendly and helpful

6. How would you rate the evening activities (bowling, the REC center, Funtastiks)? **Median Score: 10**
1=Kind of boring 10=Super fun and a good way to end the day

7. How would you rate the food at bear down kitchen (breakfast, lunch, dinner)? **Median Score: 10**
1=Gross, made me want to gag 10=Super delicious and healthy

8. How would you rate the dorm accommodations? **Median Score: 9**
1=Not good 10=Fantastic

9. How important was it to you that this camp took place on the UA campus? **Median Score: 9**
1=Made no difference 10=Super important, go Cats!

10. How likely would you be to attend this camp if it was NOT on a college campus (i.e. was at your local museum or youth center)? **Median Score: 8.5**
1=Wouldn't come, I wanted to experience the college life 10=No problem, I'd still come

11. How likely would you be to attend this camp if it was a DAY camp (no overnight stay)? **Median Score: 6**
1=I was only interested in overnight camps 10=I would have preferred just days

12. How much do you feel you learned about BIOFUELS in this camp? **Median Score: 10**
1=Not much 10=A whole lot

13. How much do you feel you learned about SUSTAINABILITY in this camp? **Median Score: 9**
1=Not much 10=A whole lot

14. Did you learn more about conducting scientific research in this camp and get to use cool equipment? **Median Score: 10**
1=Not really 10=Yes, I did some stuff I've never done before

15. How much do you feel you learned about possible CAREERS related to biofuels/sustainable bioeconomies in this camp? **Median Score: 9.5**
1=Not much 10=A whole lot

16. Did this camp make you more committed to going to COLLEGE? **Median Score: 10**
1=Not at all 10=Yes, college is in my future!

17. Did this camp make you consider being a scientist as a future career? **Median Score: 8**
1=Not at all 10=Yes, seems fun & rewarding!

18. Did this camp make you consider being an engineer as a future career? **Median Score: 7**
1=Not at all 10=Yes, seems fun & rewarding!

19. Did this camp make you consider being a farmer/grower as a future career? **Median Score: 6**
1=Not at all 10=Yes, seems fun & rewarding!

20. Would you recommend this camp to a friend? **Median Score: 10**
1=Not at all 10=Yes, it was great!

4-H Common Measures Survey (developed by 4-H nationally)

1. I felt safe while attending camp at the UA campus this week: **100% agree or strongly agree**
2. In my camp, I learned to set an achieve goals: **89% agree or strongly agree**
3. My camp experience gave me a safe place to make and learn from my mistakes: **94% agree or strongly agree**
4. My camp gave me the opportunity to learn a new skill in an area I am interested in: **94% agree or strongly agree**
5. Because of my camp, I am interested in a career in Science, Engineering or Food Science: **78% agree or strongly agree**
6. Because of my camp, I am interested in attending college: **89% agree or strongly agree**
7. Because of my camp, I am interested in teaching what I learned in my county: **67% agree or strongly agree**
8. My opinions were valued by my peers and instructors in my camp: **67% agree or strongly agree**
9. I am willing to attend future camp experiences in STEM because of my participation this week: **89% agree or strongly agree**
10. I made new friends because of this camp experience: **94% agree or strongly agree**

Observations

Strengths:

- Daniela was an effective coordinator and leader, keeping the activities organized and moving as per the schedule. She interacted with the campers quite a bit, even though she was very busy with logistics. The lab manager was great too, often 'suggesting' that supervisory staff change locations or groups or get more involved.
- There was plenty of supervision in the lab. Daniela was there for overall coordination and help with logistics (i.e. supplies), a lab manager/instructor, three additional instructors who had been training on the activities for months in advance, and three 'supervision' staff who helped with classroom management and safety. So, in total, there were 8 staff for 18 kids, which may seem like a lot but is very helpful when doing a hands-on science camp with equipment and a variety of supplies/chemicals.
- The group of campers was very ethnically diverse. Half of campers were male, half female.
- The camp seemed very well organized and well planned.
- The staff seemed very patient with campers and their many questions and normal middle-school behavior.
- The camp was very effective at modeling a real science research experience including the lab space in Koffler (which was a big improvement over the space last summer), lab equipment, safety equipment including gloves, glasses, and lab coats, and clear lab procedures and rules.
- Campers were clearly having fun and engaged.
- The staff was very engaged with the campers. They were right beside the campers during experiments and there to help.

- The staff was very cognizant of safety and ensured that kids had their safety equipment on.
- The campers were separated into groups, with group names, which is an effective and evidence-based approach for this type of camp. Active and collaborative learning was happening during every activity.
- The lessons taught real lab procedures and used real scientific equipment.
- The campers seemed very comfortable asking instructors questions about not only experiments, but also about high school and college. The staff was very responsive to all questions.
- Procedures were in place to get the campers' attention and re-group when needed (hand raising gesture).
- Each camper had a binder with activity instructions and worksheets that had been prepared in advance.
- There was lots of inquiry happening as the campers did their experiments. Campers received lots of guidance from adults.
- Instructors asked lots of follow-up questions to help the student arrive at more understanding of 'why?' rather than just giving answers.
- One instructor I noticed specifically encouraged teamwork when a student was 'taking over'.

Potential areas for improvement:

- The camp staff would have been more identifiable if they had t-shirts or name tags (day 1). I asked Daniela about this and she mentioned that they encountered some roadblocks because of UA branding requirements for t-shirts and additional expenses for 2-color graphics (last year's version of the logo/t-shirt). Also, the name badge materials that had been ordered well in advance (i.e. lanyards) did not arrive on time. On my second day of observing, they had name tags.
- Some of the supervisory staff (counselors) were more engaged in the activities than others, but that is expected, given that they were not trained specifically on the science activities and were there for supervisory support.
- The activities had lots of science, data, and especially math involved (i.e. in the biodiesel lab.) I'm curious if it really is fun or too much like school? In the Biodiesel lab, even the instructors were struggling a little bit with the math involved and had to ask another instructor for help. The post-surveys indicate that campers feel that they learned a lot and would recommend it to a friend. I will be interested to see the activity ratings (which have not been analyzed yet.)
- There was little if no integration with SBAR researchers or specific SBAR research/labs. I know that Jerry & Daniela had planned to include lab tours and talks from SBAR researchers or graduate students as part of the camp. This did not seem to happen as planned, so there remains a disconnect between the research/researchers and the education components. It is unclear (without talking to the camp staff yet) whether this happened due to lack of planning, or lack of enthusiasm/willingness to participate on the researchers' part, or if there is still some lack of communication or lack of

understanding about what is needed/wanted by educators and how researchers can best contribute. I will dig deeper into this issue, not only for camp, but also in regards to the Train-the-Trainers experience and education summer PD.

- 20 campers were recruited from a large pool of diverse applicants. 2 campers did not show up, which is quite common for a summer camp as things arise after people have accepted a slot and they don't always notify the camp registrar. Perhaps in future years, they can have a more specific alternative camper process to quickly get replacements in place or could 'overbook' by a couple of campers, knowing that likely one or two will not show up.

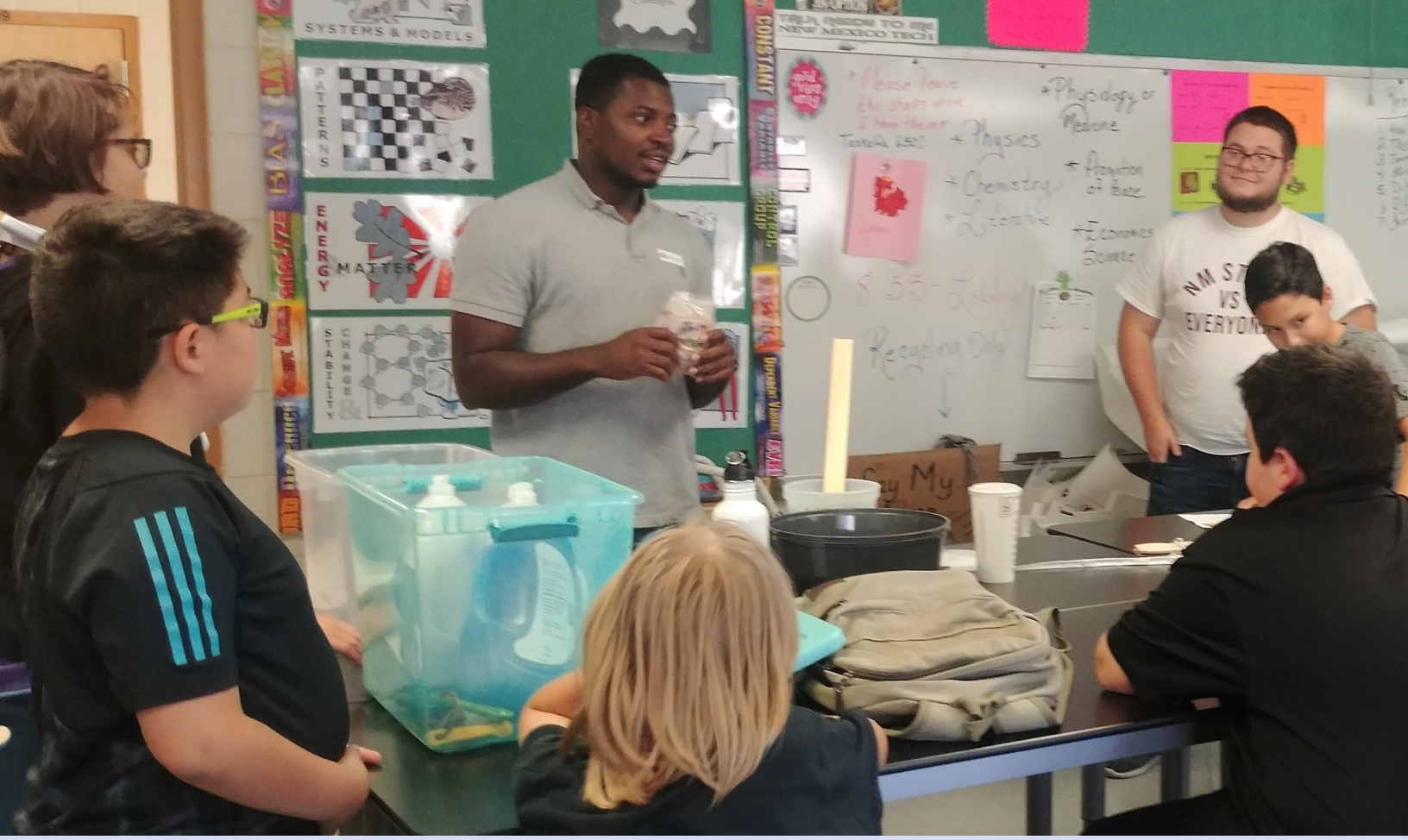
Note on additional evaluation data:
Data was also collected from students to rate each activity for engagement (fun), learning, and science identity (career aspirations) but the data has not been analyzed yet.

Data was collected on content knowledge and gains in understanding by using pre and post concept mapping, but the data has not been analyzed yet.

APPENDIX 4. 2019 RECRUITMENT FLYERS FOR FELLOWS AND TEACHERS

Documents Included

1. **Graduate Science Education Fellowship** – One-page general recruitment flyer for student fellows. Distributed at New Mexico State University and the University of Arizona. March 2019.
2. **Call for Middle & High School Science Teachers** – One-page recruitment flyer for teacher mentors. Distributed at New Mexico State University and the University of Arizona. March 2019.
3. **USDA-NIFA Graduate Student Fellowship** – One-page recruitment flyer for graduate student fellowship hosted at the University of Arizona. April 2019.
4. **USDA-NIFA Graduate Student Fellowship** – One-page recruitment flyer for graduate student fellowship hosted at New Mexico State University. April 2019.



USDA-NIFA

Graduate Science Education Fellowship

SBAR: Sustainable Bioeconomy in Arid Regions

Now recruiting students who are passionate about educating the next generation of innovators

sbar.arizona.edu/education

SBAR
SUSTAINABLE BIOECONOMY
FOR ARID REGIONS

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

ARIZONA

NM STATE UNIVERSITY

NM STATE College of ACES/CES

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

COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

BRIDGESTONE

Colorado State University

USDA ARS Agricultural Research Service

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

Grant #: 2017-68005-26867

SBAR

Call for Middle & High School Science Teachers

A USDA-funded program to introduce K-12 students to the sustainable desert agriculture industry and careers in biofuels and bioproducts.

4-H and UA education specialists provide focused, small-group summer training for Science Teachers and Graduate Student Fellows to fit relevant experiments and lessons into the existing curriculum.

SBAR: Sustainable Bioeconomy for Arid Regions

Information: sbar.arizona.edu/education

Teacher Commitments :

- Intensive training July 1-3 & 8-12 at NMSU
- Host a graduate student in your classroom
- Incorporate SBAR modules into your curriculum

Teacher Perks:

- $5,000 annual stipend
- Graduate student dedicated to your classroom
- Teaching modules that fit into your curriculum
- Access to teaching kits

TRAINING PARTNERS

UNIVERSIY OF ARIZONA
Institute for Energy Solutions
Department of Chemical & Environmental Engineering
College of Education
College of Agriculture & Life Sciences - Cooperative Extension

NEW MEXICO STATE UNIVERSITY
College of Agriculture & Environmental Sciences Cooperative Extension
Department of Chemical & Materials Engineering

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SBAR: Sustainable Bioeconomy for Arid Regions

Information: sbar.arizona.edu/education

Fellowship Commitments

- Dedicate 10 hours/week to K-12 classroom
- Intensive training July 1-3 & 8-12 at NMSU
- Create and teach science experiments/lessons

UA Fellowship Perks

- GAship @ 0.25FTE + partial tuition remission
- Mentoring from a K-12 teacher
- Classroom teaching experience

TRAINING PARTNERS

UNIVERSIY OF ARIZONA'S

Institute for Energy Solutions
Department of Chemical & Environmental Engineering
College of Education
College of Agriculture & Life Sciences -Cooperative Extension

NEW MEXICO STATE UNIVERSITY'S

College of Agriculture & Environmental Sciences Cooperative Extension
Department of Chemical & Materials Engineering

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SBAR: Sustainable Bioeconomy for Arid Regions

Information: sbar.arizona.edu/education

Fellowship Commitments

- Dedicate 10 hours/week to K-12 classroom
- Intensive training July 1-3 & 8-12 at NMSU
- Create and teach science experiments/lessons

NMSU Fellowship Perks

- 12 mos. stipend @ 0.25FTE + 9 credits of tuition support
- Mentoring from a K-12 teacher
- Classroom teaching experience

TRAINING PARTNERS

UNIVERSIY OF ARIZONA'S

Institute for Energy Solutions
Department of Chemical & Environmental Engineering
College of Education
College of Agriculture & Life Sciences -Cooperative Extension

NEW MEXICO STATE UNIVERSITY'S

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