SUSTAINABLE BIOECONOMY FOR ARID REGIONS (SBAR)

Summary Report – Quarter 3, 2018

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

USDA Cover Page

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Name of Submitting Official, Title, and Contact Information (email address and phone number), if other than PD/PI	**Same**
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Name of Submitting Official	*Signature / Date*

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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 was developed and approved by the Leadership Team in mid-July 2018. The evaluation plan is a living document that will change over the project life to reflect revised research questions, project goals and big-picture, overall objectives. The plan clarifies three distinct levels of evaluation, responsible parties for each, and feedback loops that allow for adjustments and realignment of actions.

Advisory Board

Seven SBAR Advisory Board members met during the 2018 SBAR Annual Retreat (August) with Ogden and Rogstad to discuss overall progress, research questions and implementation strategies, and ways to better address the current industry realities. These discussions proved to be an exploration of new/emerging opportunities and generated suggestions for how to refine planned tasks to better address current circumstances.

Photo 1. *SBAR Team at the Annual Retreat in Tucson, Arizona, August 2018.*

At the conclusion of their meeting, Advisory Board Members (Bill Goldner and Steve Csonka) provided their general perspectives and “take-aways” to the full SBAR Team, along with suggestions for making project adjustments in the coming year to better address current conditions. The Advisory Board members also completed a comprehensive evaluation survey during the SBAR Annual Retreat that was synthesized and shared with the LEADS Team for discussion, reflection, and decision (project realignment).

Budget and Financial Management

General budget management activities are ongoing, where all project expenditures are tracked for reporting purposes. 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 and managed with New Mexico State University (NMSU), Colorado State University (CSU), and the USDA-Agricultural Research Service (USDA-ARS); sub-awards with Bridgestone Americas, Inc. and Colorado School of Mines are still pending, although progress has been made in the negotiation process.

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.

LEADS Team Meetings

The seven 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. Dr. Sara Chavarria joined the LEADS Team (as the Education Component Lead) at the end of July 2018. This change occurred to better reflect the reality of project implementation and the distinction between the Education and Extension & Outreach project components. Discussion is underway to identify a new Extension & Outreach component co-leader in Arizona, who will likely join the LEADS team in October 2018.

2018 SBAR Annual Retreat

The 2018 SBAR Annual Retreat was hosted at the University of Arizona on 1-3 August 2018. Eighty-seven (87) people affiliated with the SBAR project were in attendance, including Advisory Board members, researchers, key personnel and students. Specialized working group meetings were hosted on Wednesday, where component teams were able to interact and directly work on identified tasks and define the next year's goals.

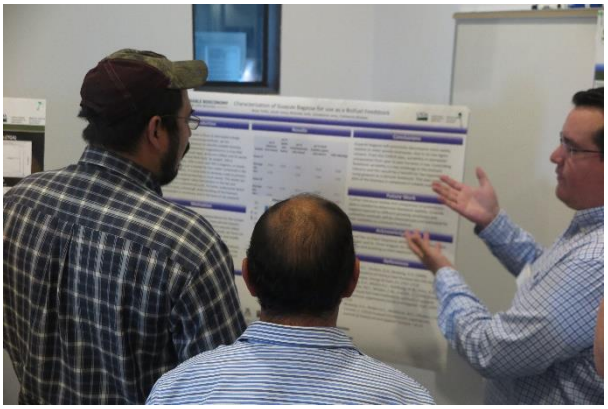

Photo 2. *Student poster session at the SBAR Annual Retreat, University of Arizona, Tucson, Arizona.*

Over 30 undergraduate and graduate students participated in the SBAR Annual Retreat, with over 20 participating in the student poster contest. Posters were scored by members of the Advisory Board on a variety of quality and presentation metrics. Prizes were awarded to the top-scoring posters in undergraduate and graduate student categories.

Photo 3. *2018 SBAR student poster contest winners. (L-R: Dr. Kimberly Ogden, Esai Lopez, Hailey Summers, Megan Bennett, Brian Treftz, and Steve Csonka)*

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 provides 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.

Rogstad and Ogden completed and submitted the project Continuation Report to USDA-NIFA in June 2018, which provides a summary of accomplishments thus far and justification for continuing the award (additional funds expected: $4,021,500). Once this has been approved, partner agreements will be modified to ensure funding allocations meet research and project implementation needs.

Website and Social Media

The SBAR-specific website (www.sbar.arizona.edu) was updated and maintained to serve as the "face" of the SBAR Center. There were 575 unique sessions reported from July – September 2018, representing 13 different countries (top two: USA and India). The highest visited website pages during this period included those that provide the project overview/general description, define the mission/objectives, and highlight our research teams and project partners. The website will be updated regularly as the project unfolds.

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:
Most of the germinated guar accessions planted under field conditions are growing well in Maricopa with variations in plant biomass. This has resulted in high soil background when HTP data is collected. We began collecting some of the HTP data and will continue collecting even at a low collection rate until the plants partially cover the soil and reduce soil background with the plant aging.

Guar seed increase for early maturing lines was ready to be harvested from Arizona fields but has been delayed due to atypical amounts of rain.

Replanting guar due to herbicide drift in Clovis has delayed guar crop development and maturity. Some observations were affected. Final harvest will also be late. Although, this is not a normal guar season, the data will be useful for future research and outreach activities. Further, the delayed guar germination and temperature incubator study will be conducted during spring 2019. Everything is planned for conducting the trial during the coming fall and spring period.

The rainfall received in late September and early October 2018 and accompanying cool temperatures delayed start of the Eloy and Maricopa herbicide studies. The Marana studies were planted and initiated on September 24, 25 and 26, 2018 and were in progress when the rain and cold temperatures began. We completed a set of stand counts on October 8, 2018 so we will be able to document the loss of plants as affected by treatment but we won't know how much of the stand loss was due to cold temperatures at night. The Eloy and Maricopa studies are delayed while we wait for the soils to dry to the point where we can rework the beds and initiate the experiments. The experiments need to get started in warm temperatures due to the cooling effects of irrigation, especially sprinkler irrigation on soil temperatures.

The baseline soil analysis is generally progressing on schedule. DNA extractions are slightly delayed due to the need to perform more protocol optimization to accommodate the clay content of Eloy soils.

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 Dec 18
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	30 Jun 19 30 Jun 19

		Confirmed transformation for invitro plants – 6 lines SEP3 Confirmed transformation for invitro plants – 6 lines FT	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):

Ploidy counts for the first of two fields were completed this quarter. Leaf samples from individual plants in each plot were analyzed at Bridgestone Americas by flow cytometry. The results (Table 1) show the predominate ploidy from each accession. In most cases a small percentage of off- types from the predominate type are found due to the facultative nature of apomixis in guayule.

Table 1. *Ploidy distribution by line from USDA Variety Trial at Bridgestone Americas, Inc. - Guayule Research Farm, Eloy AZ planted in April 2018.*

Line	2x	3x	4x	5x	6x	Total
11591		30	1	3		**34**
11604			17		1	**18**
11605			6		1	**7**
11609		19		1		**20**
11619		14	4	3	2	**23**
11633		37	1	1		**39**
11635			9			**9**
11646		11		1		**12**
11693			9			**9**
12231		37	2	2		**41**
4265-X			40		2	**42**
593			17		1	**18**
AZ2			52			**52**

AZ5			10			**10**
AZ6			14			**14**
CAL1		25	5		1	**31**
CAL2		18	14	1		**33**
CAL3						**5**
CAL5		24	16		1	**41**
CAL7			17	1		**18**
CFS18-2005		12	5			**17**
CFS21			14			**14**
CFS24		7	13	1		**21**
N396		36		1		**37**
N565		7	2			**9**
N565 II		37	8	1	1	**47**
N576		15		2		**17**
PARL 914			16			**16**
PARL 915			21			**21**
PARL 916			34			**34**
PARL 917			45			**45**
PARL 919			49			**49**
PARL 920			38		1	**39**
PARL 921			10			**10**
PARL 922			42			**42**
PARL 923			46			**46**
PARL 924		48		1		**49**
PARL 929			38		1	**39**
PARL 930			17			**17**
PARL 931			14			**14**
PARL 932			11		1	**12**
PARL 934			24			**24**
PARL 935		1				**1**
R1037			16			**16**
R1040			7			**7**
R1044		39	1			**40**
R1092		10	3			**13**
R1093		10				**10**
R1096		51		3		**54**
R1103			20			**20**
R1108		17				**17**
R1109			59			**59**
R1110		2	21		1	**24**
					Total	**1356**

Expression Vectors for Downregulating SEP3 and FT Genes:

Our project seeks to enhance natural rubber content in guayule by downregulation of flowering. Part of the 2018 work was to finalize the strategy for our bioengineering approach. Through a combination of literature reviews and transcriptome analysis for (flowering and nonflowering) guayule, we have determined the top three genetic targets to be:

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).
4. **Combination** of two or more of these approaches.

We have initiated genetic transformations of guayule AZ-2 cultivar using our initial candidate gene: *APETAL1*. An RNAi silencing construct pND6_AP1i has been prepared, and transferred to an *Agrobacterium* vector, and used to transform guayule line G-711. Several thousand transformation attempts took place over the summer. Most were not successful. But a few shoots were recovered from live calli (Figure 1):

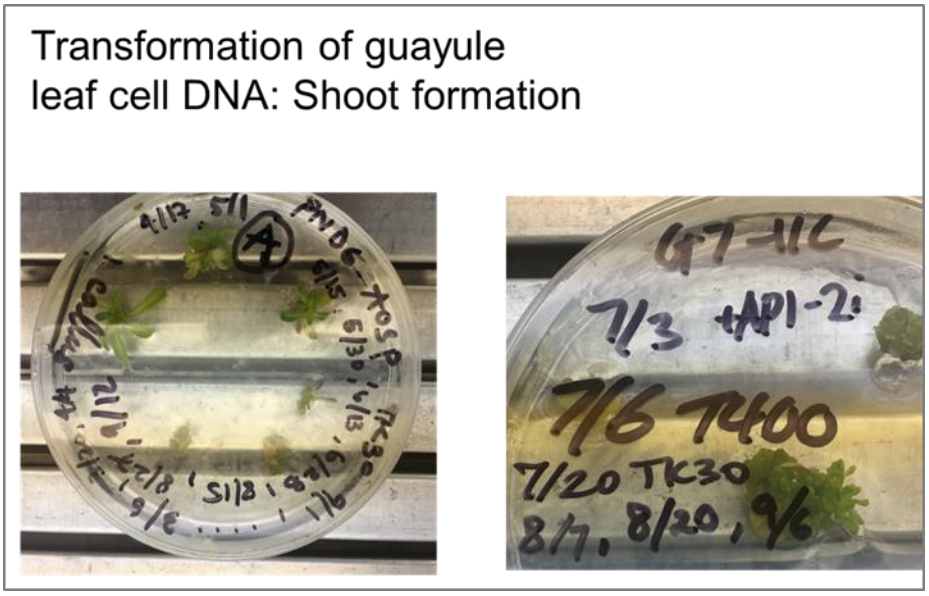

Figure 1. *Recovery of live putative transformed shoots (AP1, RNAi construct).*

Meanwhile, we have prepared a construct for downregulation of the *SEPALLATA3* (SEP3) gene from guayule and transferred it to Agrobacterium (Figure 2). The construct places the second intron (IV2) of the potato ST-LS1 gene (Vancanneyt et al., 1990) between nucleotide positions of SEP3-R and SEP3-F, as a strategy to form the hairpin structure needed to reduce transcription of the gene. Transformations with this construct will start in October.

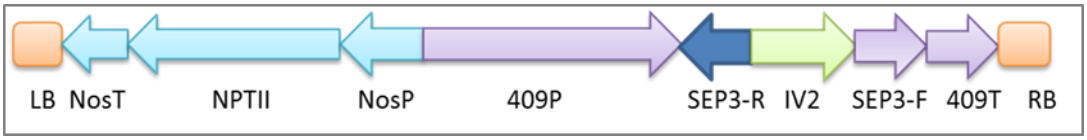

Figure 2. *Construct pND6_SEP3i.*

The third construct, pND6_FT2i, for downregulation of the *Flowering Locus T* gene, is under preparation.

Separately, a new study was initiated (with Duke Pauli) on flowering-related genes' expression in field plants. As reported previously, analysis of gene expression in guayule under (drought induced) flowering and non-flowering conditions was performed. While this analysis successfully informed our candidate gene selection, it was clear that the input data was limited in value in that it represented the transcriptome of guayule bark tissue. Since SBAR irrigation and variety trial field plants were in the early stages of flowering, the team decided to gather additional data from meristem and flower tissues. These tissues were collected from field plants in Eloy AZ in July 2018 (Figure 3). Analysis of expression of flowering-related genes, including the 3 chosen for the project work is planned. We expect the results to support our current strategy or direct us to revision if indicated.

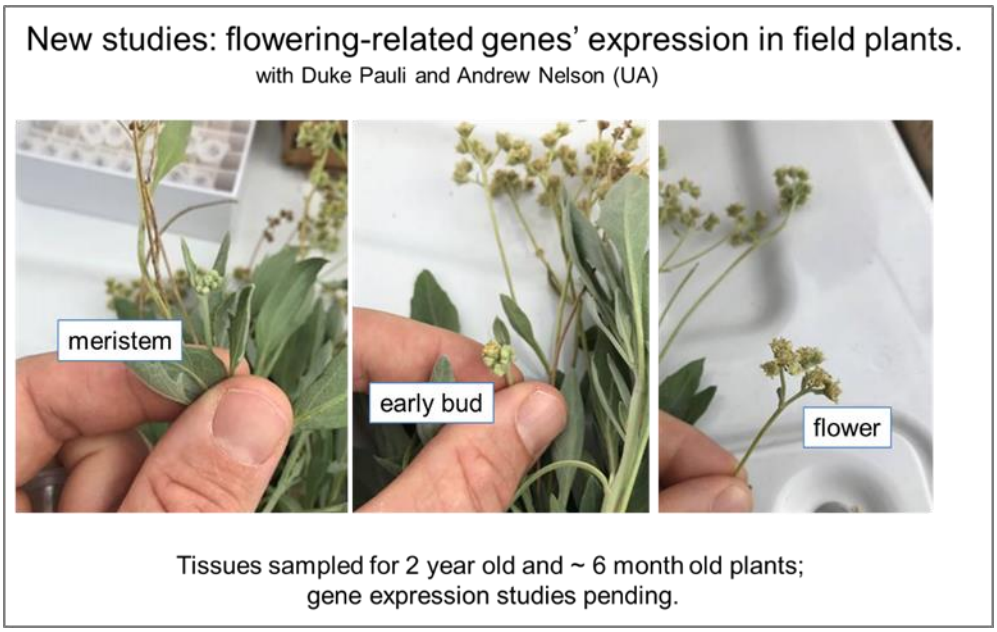

Figure 3. *Tissues sampled for future analysis of flowering-related gene expression.*

Root Tolerance Screening:
Seed from eight new accessions were treated with 500ppm gibberellic acid solution and planted in the greenhouse. Seedlings will be moved from trays to post and inoculated when roots are developed.

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

Phenotypic characterization – Guayule:

A field trial containing 48 USDA guayule accessions were planted at 4/12/2017 in Randomized completed block Design (RCBD) with four replicates each at MAC farm, Maricopa, AZ. Each replicate consists of 4 rows spaced at 40 inches, within each row ten hills were seed direct planted and spaced at 12 inches. After seedling establishment, plots are surface irrigated at weekly/bi-weekly interval based on the weather, as well as hand weeded as required. To achieve the morphological characterization of guayule USDA accessions under field conditions, plant height was recorded traditionally in cm for the four-month old plants at 8/16/2018 (Figure 4). Analysis of variance showed significant differences among the tested accessions where the tallest accessions was AZ2 with 43 cm while the shortest one was CAL3 with 9 cm long stems. That is expected since AZ2 is tetraploid plants while CAL3 is diploid, and ploidy level could has effect on plant performance. We noted that, in general, improved germplasm was taller than wild one, but interestingly wild accession R1109 was statistically as tall as AZ2 and CAL5, the improved germplasm from Arizona and California breeding programs respectively, suggesting that some of the wild accessions could have some potential to improve guayule biomass and rubber content.

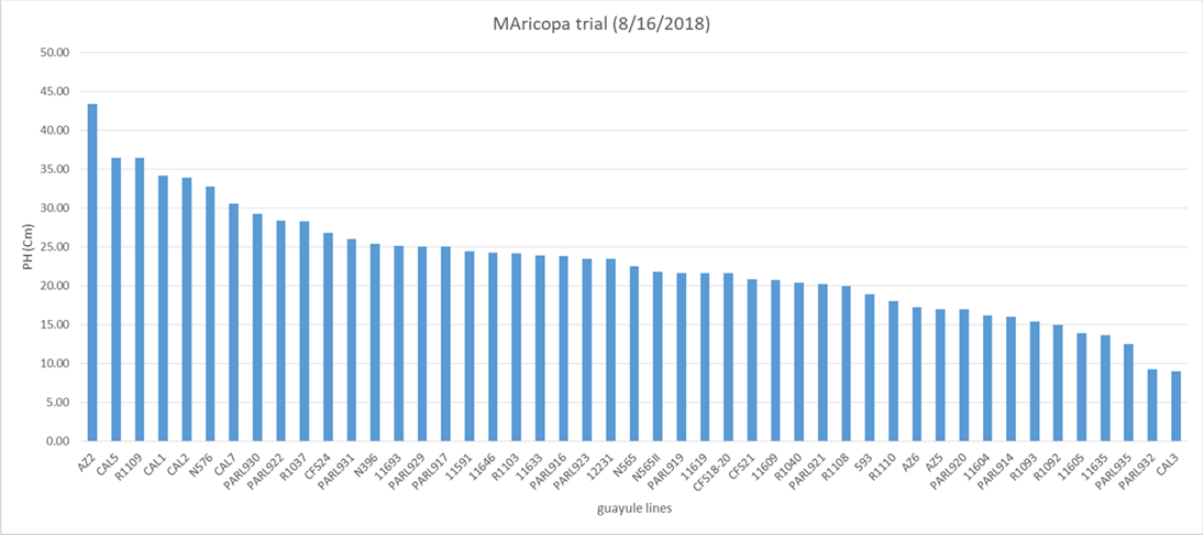

Figure 4. *Plant height (cm) of 4-month old guayule plants at Maricopa Agricultural Center, Maricopa, Arizona.*

Remote Sensing Evaluation:

Trichome and Leaf Color Analysis of 10 USDA Lines – Strong positive correlation between young and mature leaves for trichome densities (Figure 5). A very weak correlation with rubber, leaf canopy temperature, and NVDI occurred. A weak negative correlation with leaf color. No differences observed between accessions tested for trichome density (Figure 6).

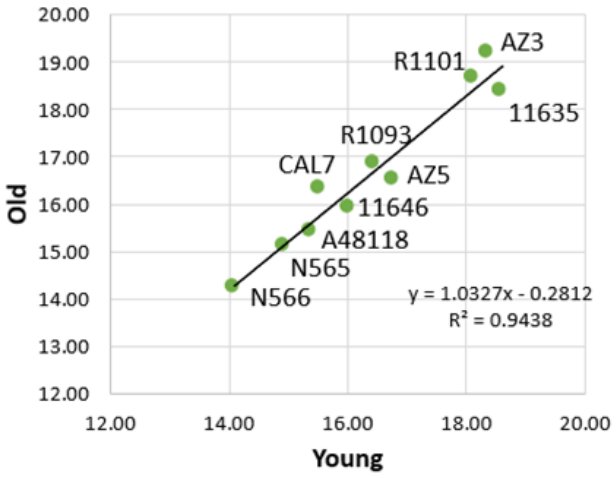

Figure 5. *High correlation between mature and young leaves from the same plant for leaf trichome density.*

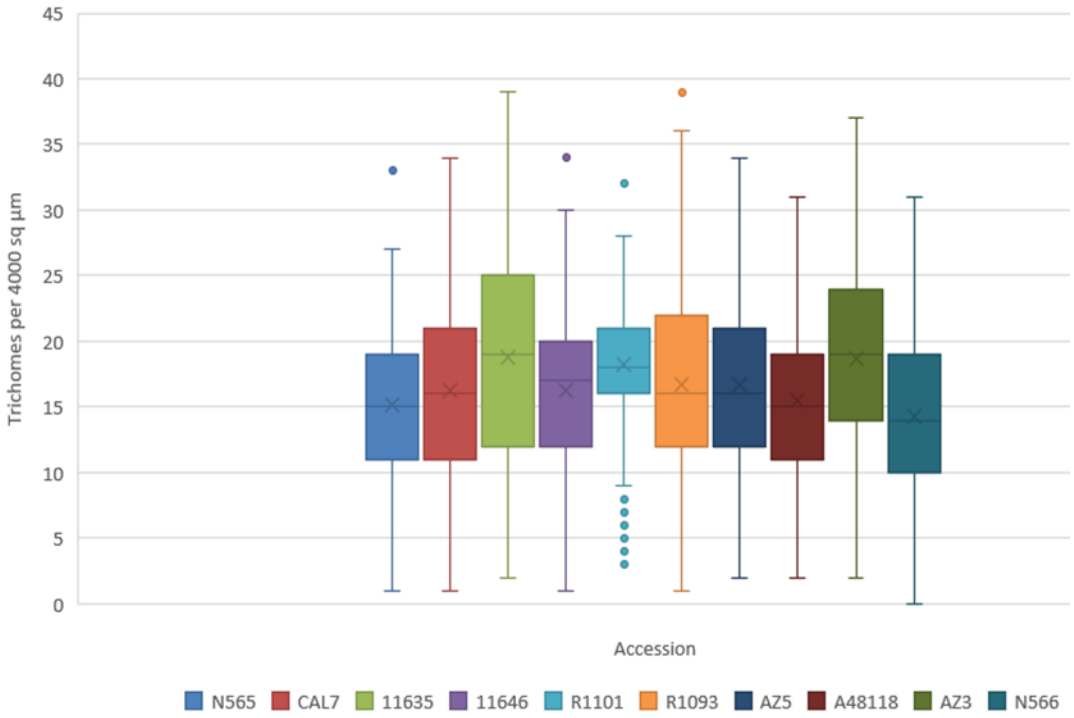

Figure 6. *The high amount of variability for trichome density resulted in a poor correlation between lines.*

Field Germination and Plant Heights – Counts from 55 entries with 4 replications of % of spaces without a plant (every 12") at 21 days after planting by direct seeding in Fields B2 at Bridgestone Americas, Inc. in April 2018. Another planting was done in May 2018 in Field C1 at Bridgestone Americas, Inc. in Eloy, AZ with 29 entries. The inverse of this percentage is the amount of 12" spaces with plants. (Table 2)

Table 2. *Plant counts per entry from 4 replications 21 days after planting, and plant heights from trials planted at Bridgestone Americas Inc. - Guayule Research Farm, Eloy AZ.*

		Eloy Field B-2east DOP April 11, 2018						Eloy Field C1 - DOP May 16, 2018					
		Counts - 21 DAP		Heights (cm) -7/25/18 - 104 DAP									
Entry #	Pedigree	count/Plot (of 40 max holes)	count/ Entry (of 160 max holes)	Average Plant Height	Average Height (Entry)	+/- Std Error by plot	+/- std Error entry (all plants)	count/ Plot (of 40 max holes)	count/ Entry (of 160 max holes)	Average Height/ Plot	Avg Height/ Entry	+/- Std Error by plot	+/- std Error entry (all plants)
1	**593**	12		19.0		1.23							
1	**593**	21		18.0		0.50							
1	**593**	11		20.7		0.87							
1	**593**	12	56	17.5	18.7	0.57	0.40						

2	**11591**	17		21.8		1.35	
2	**11591**	11		24.6		2.09	
2	**11591**	17		23.0		1.45	
2	**11591**	20	65	23.7	23.2	0.76	0.66
3	**11604**	7		23.3		1.06	
3	**11604**	8		28.1		4.36	
3	**11604**	8		23.9		1.22	
3	**11604**	3	26	19.3	24.5	1.45	1.47
4	**11605**	8		19.8		2.23	
4	**11605**	2		13.0		6.00	
4	**11605**	6		22.5		2.32	
4	**11605**	4	20	19.5	19.9	1.71	1.34
5	**11609**	8		25.4		1.00	
5	**11609**	7		22.3		2.74	
5	**11609**	7		26.6		0.65	
5	**11609**	10	32	27.6	25.5	1.45	0.84
6	**11619**	10		23.3		1.90	
6	**11619**	11		21.7		1.06	
6	**11619**	10		25.3		0.78	
6	**11619**	14	45	24.1	23.6	1.25	0.66
7	**11633**	15		22.7		1.21	
7	**11633**	15		21.6		0.89	
7	**11633**	14		23.6		1.21	
7	**11633**	9	53	22.1	22.5	0.48	0.53
8	**11635**	17		19.4		1.91	
8	**11635**	5		15.4		0.87	
8	**11635**	7		24.3		1.81	
8	**11635**	12	41	15.0	18.5	1.47	1.07
9	**AZ2**	31		49.4		0.61	

28		19.1		0.83	
19		12.6		1.01	
19		15.3		0.69	
17	83	12.9	15.5	0.90	0.53
10		14.4		2.08	
6		10.7		1.31	
9		16.9		1.88	
10	35	12.0	13.7	0.88	0.89
14		12.0		0.84	
20		12.4		0.66	
15		13.3		1.10	
26	75	15.4	13.5	0.49	0.39
21		11.7		1.20	
15		8.6		0.90	
8		8.1		1.42	
27	71	9.9	9.9	0.71	0.52
33		32.1		1.78	

9	**AZ2**	34		37.6		1.30		34		30.0		1.56	
9	**AZ2**	34		46.8		0.96		38		29.3		1.08	
9	**AZ2**	32	131	45.0	44.7	0.95	0.63	36	141	28.5	29.9	2.52	1.01
10	**11646**	16		28.0		0.63		5		13.4		1.60	
10	**11646**	13		20.9		1.74		14		17.9		1.32	
10	**11646**	14		22.1		1.45		5		15.4		1.44	
10	**11646**	15	58	23.5	23.6	1.26	0.72	5	29	11.8	15.7	1.55	0.86
11	**11693**	18		30.1		1.81		8		15.0		0.86	
11	**11693**	19		26.8		1.32		7		16.6		0.92	
11	**11693**	8		20.4		2.46		14		19.2		0.60	
11	**11693**	14	59	26.6	26.0	1.28	0.90	10	39	12.3	16.1	0.79	0.44
12	**12231**	15		20.4		0.77		21		19.0		1.00	
12	**12231**	12		21.8		1.58		28		17.4		0.99	
12	**12231**	12		22.5		1.10		29		18.5		1.08	
12	**12231**	8	47	25.4	22.5	2.46	0.71	22	100	13.8	17.2	0.85	0.50
13	**4265-X**	14		19.6		1.61							
13	**4265-X**	22		20.6		1.35							
13	**4265-X**	21		28.6		2.21							
13	**4265-X**	28	85	24.6	23.3	1.22	0.88						
14	**AZ5**	16		24.1		1.45		10		12.2		1.10	
14	**AZ5**	6		20.2		3.82		25		20.9		1.15	
14	**AZ5**	9		23.9		3.05		24		15.9		1.02	
14	**AZ5**	9	40	21.9	22.5	1.84	1.12	10	69	9.0	16.2	1.04	0.66
15	**AZ6**	7		25.4		1.60							
15	**AZ6**	9		19.4		1.72							
15	**AZ6**	5		26.8		3.48							
15	**AZ6**	15	36	19.5	22.8	1.70	1.10						
16	**CAL1**	6		27.0		3.84							
16	**CAL1**	11		29.6		1.71							

16	**CAL 1**	19		37.0		1.02									
16	**CAL 1**	18	54	37.1	32.7	1.90	1.03								
17	**CAL 2**	8		38.1		1.13		35		27.6		0.68	
17	**CAL 2**	7		32.7		2.64		17		18.7		1.57	
17	**CAL 2**	20		40.7		1.57		22		20.7		1.08	
17	**CAL 2**	10	45	32.0	35.9	1.40	1.04	25	99	18.5	22.2	0.93	0.63
18	**CAL 3**	4		34.3		2.17							
18	**CAL 3**	2		19.0		5.00							
18	**CAL 3**	3		20.7		2.19							
18	**CAL 3**	11	20	34.4	27.1	4.45	2.85						
19	**CAL 5**	17		37.5		1.27		30		23.4		1.12	
19	**CAL 5**	23		37.3		1.18		36		26.0		0.79	
19	**CAL 5**	19		31.8		1.48		20		20.4		1.57	
19	**CAL 5**	17	76	31.3	34.5	2.09	0.81	22	108	20.1	23.1	1.34	0.61
20	**CAL 7**	8		42.8		1.92		30		30.2		1.63	
20	**CAL 7**	23		43.9		1.11		29		28.3		1.19	
20	**CAL 7**	19		43.7		2.46		36		30.0		1.18	
20	**CAL 7**	17	67	42.5	43.2	2.00	0.95	24	119	30.5	29.8	1.14	0.65
21	**CFS 18-2005**	8		25.1		3.46		31		19.8		0.70	
21	**CFS 18-2005**	8		25.4		2.52		23		14.2		0.84	
21	**CFS 18-2005**	11		40.4		2.76		28		14.8		0.37	
21	**CFS 18-2005**	7	34	21.9	28.2	1.28	1.87	26	108	14.9	16.1	0.58	0.39
22	**CFS 21**	23		26.3		0.51		17		14.4		1.15	
22	**CFS 21**	23		22.6		0.98		21		17.6		0.97	
22	**CFS 21**	26		21.2		1.09		15		11.6		0.80	
22	**CFS 21**	27	99	19.5	22.4	0.74	0.50	17	70	10.5	13.8	0.85	0.58
23	**CFS 24**	13		20.7		1.78							

23	**CFS 24**	6		24.8		3.91	
23	**CFS 24**	6		25.2		3.11	
23	**CFS 24**	14	39	23.1	23.4	1.32	1.06
24	**N39 6**	19		24.3		0.69	
24	**N39 6**	22		26.9		0.96	
24	**N39 6**	17		25.5		0.77	
24	**N39 6**	17	75	26.0	25.6	1.86	0.56
25	**N56 5**	3		19.3		3.67	
25	**N56 5**	5		22.0		2.70	
25	**N56 5**	1		28.0			
25	**N56 5**	14	23	23.5	23.2	0.89	0.94
26	**N56 5 II**	17		22.6		1.40	
26	**N56 5 II**	14		25.4		2.46	
26	**N56 5 II**	19		25.2		1.04	
26	**N56 5 II**	17	67	25.8	24.7	1.41	0.77
27	**N57 6**	8		25.4		1.84	
27	**N57 6**	9		23.8		1.78	
27	**N57 6**	8		21.9		1.49	
27	**N57 6**	7	32	28.7	24.9	3.54	1.12
28	**AZ2 TC2**	40		48.3		0.66	
28	**AZ2 TC2**	40		48.5		1.03	
28	**AZ2 TC2**	38		49.3		0.82	
28	**AZ2 TC2**	38	156	46.0	48.0	1.04	0.46
29	**PAR L 914**	4		13.0		1.00	
29	**PAR L 914**	8		18.5		1.28	
29	**PAR L 914**	4		13.5		2.22	
29	**PAR L 914**	13	29	15.5	15.1	1.04	0.74

4		13.8		1.11	
2		7.0		1.00	
3		16.0		0.58	
5	14	9.6	11.8	0.87	0.97
23		21.9		1.14	
6		14.0		1.69	
10		15.3		1.26	
6	45	7.5	17.5	0.67	1.02

30	**PARL 915**	12		18.9		0.45	
30	**PARL 915**	7		16.4		1.46	
30	**PARL 915**	8		14.4		1.39	
30	**PARL 915**	11	38	18.0	16.9	0.36	0.50
31	**PARL 916**	29		22.3		1.20	
31	**PARL 916**	31		22.8		0.73	
31	**PARL 916**	29		20.6		0.71	
31	**PARL 916**	22	111	21.0	21.7	0.66	0.44
32	**PARL 917**	18		23.6		0.94	
32	**PARL 917**	26		21.8		0.45	
32	**PARL 917**	27		22.0		0.80	
32	**PARL 917**	19	90	21.8	22.3	0.92	0.38
33	**PARL 919**	24		26.0		0.98	
33	**PARL 919**	21		20.0		1.10	
33	**PARL 919**	24		22.6		0.94	
33	**PARL 919**	21	90	22.3	22.8	1.51	0.60
34	**PARL 920**	15		20.9		0.84	
34	**PARL 920**	11		22.4		0.87	
34	**PARL 920**	19		25.2		1.46	
34	**PARL 920**	16	61	22.8	22.8	1.25	0.64

24		12.9		0.63	
19		10.9		0.73	
28		14.4		0.80	
29	100	15.9	13.8	0.55	0.38
13		12.1		0.46	
20		12.3		0.56	
16		13.7		0.67	
17	66	9.7	11.9	0.67	0.35
29		16.4		1.05	
17		12.8		1.04	
24		13.0		0.74	
20	90	12.2	13.9	0.75	0.50
10		10.8		1.29	
24		15.7		1.01	
12		28.3		1.36	
20	66	13.2	16.5	0.86	0.58

35	**PARL 921**	6		35.3		3.86	
35	**PARL 921**	3		19.3		0.33	
35	**PARL 921**	5		14.4		1.36	
35	**PARL 921**	3	17	16.3	21.4	3.28	2.72
36	**PARL 922**	24		25.3		0.71	
36	**PARL 922**	16		25.3		1.79	
36	**PARL 922**	28		25.7		1.22	
36	**PARL 922**	18	86	27.1	25.8	1.51	0.63
37	**PARL 923**	11		23.2		1.73	
37	**PARL 923**	16		25.2		1.41	
37	**PARL 923**	16		26.0		1.81	
37	**PARL 923**	16	59	29.6	26.0	1.39	0.83
38	**PARL 924**	20		20.5		0.66	
38	**PARL 924**	16		20.3		1.05	
38	**PARL 924**	15		21.4		0.53	
38	**PARL 924**	14	65	20.5	20.7	1.16	0.42
39	**PARL 929**	8		29.3		1.00	
39	**PARL 929**	10		25.1		2.00	
39	**PARL 929**	17		27.8		0.96	
39	**PARL 929**	15	50	28.5	27.7	2.17	0.85

8		7.8		1.08	
5		9.4		1.03	
15		15.6		0.82	
9	37	8.8	11.4	0.40	0.72

40	**PARL 930**	5		27.0		3.00		30		23.3		0.70			
40	**PARL 930**	12		32.4		2.32		22		17.7					
40	**PARL 930**	9		28.3		0.67		22		17.1		0.79			
40	**PARL 930**	9	35	31.7	29.9	0.91	0.98	34	108	19.8	19.8	0.68			
41	**PARL 931**	6		28.0		1.65		30		18.2		1.18			
41	**PARL 931**	11		24.3		1.09		30		16.7		0.78			
41	**PARL 931**	9		26.3		1.72		32		20.3		0.57			
41	**PARL 931**	10	36	30.2	27.2	0.94	0.74	28	120	16.3	18.0	0.56	0.43		
42	**PARL 932**	7		10.6		1.66		19		9.5		0.68			
42	**PARL 932**	4		24.0		3.03		36		13.4		0.54			
42	**PARL 932**	6		11.5		3.02		21		9.7		0.39			
42	**PARL 932**	11	28	12.7	14.7	1.04	1.23	26	102	10.1	11.1	0.47	0.32		
43	**PARL 934**	6		44.3		2.01		1		22.0					
43	**PARL 934**	8		29.3		3.10		1		20.0					
43	**PARL 934**	15		43.7		1.51		0							
43	**PARL 934**	1	30	18.0	33.8		1.81	3	5	19.0	19.8	5.29	2.96		
44	**PARL 935**	4		22.0		1.00		2		7.5		1.50			
44	**PARL 935**	1		18.0				4		19.5		2.02			
44	**PARL 935**	4		16.0		1.08		0							
44	**PARL 935**	4	13	17.5	18.4	0.65	0.84	0	6		15.5		2.86		

45	**R10 37**	9		26.7		1.28	
45	**R10 37**	4		31.0		1.58	
45	**R10 37**	4		28.5		1.26	
45	**R10 37**	6	23	25.8	28.0	4.84	1.37
46	**R10 40**	9		25.8		1.13	
46	**R10 40**	15		26.2		1.84	
46	**R10 40**	13		27.5		1.56	
46	**R10 40**	11	48	29.6	27.3	1.74	0.85
47	**AZ2 TC5**	38		51.4		0.70	
47	**1203 209. 005**	40		25.4		0.35	
47	**AZ2**	32		41.6		1.64	
47	**AZ2**	34	144	45.6	41.0	0.98	0.97
48	**R10 44**	22		25.5		0.53	
48	**R10 44**	10		26.5		1.21	
48	**R10 44**	14		23.8		1.21	
48	**R10 44**	13	59	24.5	25.1	1.13	0.48
49	**R10 92**	9		15.7		0.65	
49	**R10 92**	17		15.9		0.66	
49	**R10 92**	8		16.0		0.96	
49	**R10 92**	19	53	22.4	17.5	0.64	0.56
50	**R10 93**	9		14.0		0.33	
50	**R10 93**	13		15.1		0.52	
50	**R10 93**	14		16.5		0.75	
50	**R10 93**	12	48	16.5	15.5	1.00	0.38
51	**R10 96**	17		27.0		0.69	
51	**R10 96**	21		27.7		1.04	
51	**R10 96**	18		28.4		1.08	
51	**R10 96**	22	78	33.1	29.0	1.12	0.58
52	**R11 03**	4		23.5		2.84	

18		17.8		1.89	
8		14.6		1.98	
16		15.3		1.76	
13	55	15.0	16.0	1.12	0.89

18		13.1		0.63	
14		12.3		0.62	
7		10.1		0.70	
14	53	10.3	11.7	0.63	0.37

52	**R11 03**	9		23.2		1.68	
52	**R11 03**	10		22.4		0.78	
52	**R11 03**	9	32	21.7	22.7	1.61	0.75
53	**R11 08**	8		19.3		1.37	
53	**R11 08**	6		17.0		1.06	
53	**R11 08**	9		19.0		0.96	
53	**R11 08**	8	31	19.8	18.8	1.62	0.64
54	**R11 09**	26		40.1		2.46	
54	**R11 09**	14		45.0		2.32	
54	**R11 09**	26		38.3		1.56	
54	**R11 09**	17	83	38.5	40.5	2.29	1.11
55	**R11 10**	12		31.8		2.69	
55	**R11 10**	7		23.3		2.67	
55	**R11 10**	6		21.0		2.85	
55	**R11 10**	7	32	35.3	27.9	3.29	1.72

30		28.9		1.76	
15		23.7		3.12	
33		25.7		1.93	
25	103	28.6	27.0	1.24	0.98

Thermogradient Table Analysis:

Twenty-seven (27) USDA guayule accessions and 2 other *Parthenium* species were tested for germination rates at 14 days at 10 alternating temperatures on a thermogradient table at Bridgestone Americas – Guayule Research Farm, Eloy, AZ (Table 3). Six replications of 25 seeds per petri dish were used for the study. Temperatures alternated to mimic day/night temperatures. These data help to decide the optimum temperature for direct seeding and an estimate of loss when planting at suboptimal temperatures.

Table 3. *Germination rates at 14 days at 10 variable (Day, Night) temperatures on a thermogradient table at Bridgestone Americas Inc. - Guayule Research Farm, Eloy AZ for 27 guayule accessions and 2 other Parthenium species.*

14 Day		1	2	3	4	5	6	7	8	9	10
	Day °C	13.5	16	18.1	20.8	23.2	25.9	27.8	30.4	33	35.4
	Night °C	10.4	12.6	14.4	16.2	18.2	20.4	21.8	23.6	25.5	27.1
	593	56.7%	76.7%	70.0%	69.3%	69.3%	60.0%	55.3%	52.7%	50.0%	26.0%
	11591	60.0%	62.7%	70.7%	69.3%	54.7%	54.7%	51.3%	60.7%	43.3%	34.0%
	11604	46.0%	83.3%	86.7%	83.3%	82.7%	83.3%	82.0%	79.3%	68.7%	53.3%
	11605	52.7%	63.3%	62.7%	62.7%	52.7%	48.7%	53.3%	54.0%	44.7%	35.3%
	11635	35.3%	69.3%	52.7%	53.3%	62.0%	57.3%	52.7%	56.7%	40.0%	35.3%
	AZ5	34.7%	56.0%	49.3%	56.0%	44.0%	64.0%	52.7%	50.7%	45.3%	40.0%
	AZ6	66.0%	91.3%	90.0%	90.7%	90.0%	80.7%	82.7%	72.7%	70.0%	54.7%
	CAL3	78.7%	80.0%	84.7%	81.3%	84.0%	82.7%	71.3%	66.7%	66.0%	50.7%
	CFS 24	62.7%	79.3%	94.0%	78.0%	70.7%	78.7%	70.7%	61.3%	55.3%	47.3%
	CFS21	27.3%	47.3%	53.3%	52.7%	56.7%	48.0%	43.3%	54.0%	36.7%	40.7%
	N396	37.3%	42.7%	52.7%	46.0%	42.7%	35.3%	50.0%	50.7%	52.0%	32.0%
	N565 II	30.7%	47.3%	47.3%	46.0%	46.7%	48.0%	36.7%	30.0%	32.7%	34.0%
	N576	24.7%	40.0%	39.3%	29.3%	34.7%	37.3%	34.7%	30.0%	27.3%	16.0%
	PARL 914	46.0%	66.0%	64.0%	66.7%	58.0%	57.3%	52.0%	56.7%	50.0%	40.7%
	PARL 916	58.0%	72.7%	80.0%	82.7%	75.3%	70.0%	70.7%	67.3%	72.7%	48.7%
	PARL 917	40.0%	47.3%	50.0%	40.7%	52.0%	46.0%	39.3%	40.7%	43.3%	30.7%
	PARL 919	60.0%	82.7%	82.0%	76.0%	79.3%	80.0%	74.7%	73.3%	68.7%	57.3%
	PARL 920	61.3%	63.3%	72.7%	60.7%	69.3%	57.3%	62.0%	62.0%	58.0%	56.0%
	PARL 922	44.0%	70.7%	74.7%	76.7%	74.0%	66.0%	72.7%	64.7%	58.0%	50.7%
	PARL 923	44.7%	76.7%	82.0%	75.3%	78.7%	84.0%	76.7%	77.3%	66.0%	61.3%
	PARL 929	40.0%	52.7%	68.7%	77.3%	71.3%	62.7%	58.7%	56.7%	51.3%	28.0%
	PARL 932	49.3%	77.3%	77.3%	75.3%	71.3%	75.3%	66.0%	58.7%	59.3%	43.3%
	PARL 935	49.3%	47.3%	62.0%	61.3%	47.3%	57.3%	49.3%	48.0%	42.0%	33.3%
	R1092	37.3%	64.0%	60.7%	60.7%	52.0%	52.0%	55.3%	47.3%	43.3%	30.0%
	R1103	46.7%	57.3%	62.0%	56.0%	64.7%	54.7%	49.3%	55.3%	48.0%	36.7%
	R1110	56.0%	59.3%	63.3%	68.7%	58.0%	56.7%	51.3%	55.3%	36.0%	32.0%
	W6-429	64.0%	48.0%	56.0%	64.0%	64.0%	40.0%	48.0%	40.0%	28.0%	20.0%
	Incanum	28.0%	36.0%	52.0%	72.0%	80.0%	76.0%	68.0%	52.0%	80.0%	72.0%
	tegrifolium	8.0%	24.0%	48.0%	24.0%	52.0%	64.0%	56.0%	48.0%	48.0%	20.0%

Biomass Drying Experiment:
Rubber and resin analyses of biomass samples were completed. Statistical analyses are ongoing.

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	31 Aug 19

		Summarize data after harvest; present at field day in Clovis, NM	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:

Neutron probe calibration was started before guar was planted in Clovis, NM. Replacing electron board on the neutron probe necessitated recalibration of the instrument. Separate neutron tubes were installed at different locations of the center. Some of them will be saturated, while some will be kept dry. Along with these neutron tubes, more tubes installed in different trials and different crops (annual crops as well as perennial grasses) will provide range of soil moisture conditions for ideal calibration of the instrument. Preliminary regression was developed using two set of observations and the regression look very good. We have planned to take third set of observation in two weeks and that is expected to improve the relationship.

The pre-irrigation and critical growth stage based irrigation trial was planted on June 6, 2018 using a plot planter. Row spacing of 30 inches was used. The large trial was planted on cultivated flat ground and irrigated with center pivot. Irrigation treatments were pre-irrigation (5 inch) and no-pre-irrigation, while in season irrigation treatments were 1). irrigation throughout the growing season (Irr), 2). no irrigation after establishment at vegetative stage (VStss), 3). no irrigation after flowering (RStss) and 4). no irrigation after establishment (Rainfed). With declining irrigation resources in High Plains, this study will provide us the much needed information on how to maximize water efficiency of guar crop. Two cultivars of different growth habit, branching (cv. Kinman) and non-branching (cv. Monument) are used for the study. Replanted trial is looking great, but cooler and shorter days are delaying the maturity (Therefore Yellow was put in self-evaluation). The delay is also adding to travel expenses because students have returned to main campus for their course work. They are traveling from Las Cruces to Clovis to collect data. We have made good progress in collecting all necessary data.

Drought physiology of guar crop will be studied using the pre-irrigation and critical growth stage based irrigation trial. The trial will provide guar crops stressed at different levels due to different irrigation practices. Replanting has delayed or affected some observations. The graduate student is trained in different physiological observations. Effect of drought on source and sink will be assessed. The ability of guar in using soil profile moisture for maintaining photosynthesis and yield formation at varying stress levels will be assessed. Seasonal soil moisture to a depth of 1.40m will be measured at different growth stages to assess role of soil moisture extraction on yield and yield components.

The task of developing crop coefficients for evapotranspiration of guar is using irrigation study. The delay due to replanting affected observations. The graduate students returned to main campuses and no additional technical help was available for neutron tube observations. Limited tubes were recorded weekly by Dr. Sultan Begna. Once neutron probe calibration is completed, this data will be used by Hadiqa Maqsood to develop Crop coefficients for guar. They can be used to model water requirement of guar in different agroclimates using local weather date.

During retreat, it was planned to include deficit irrigation study at Clovis, NM for remote sensing task. Dr. Diaa El-Shikha, UA travelled to Clovis during two different growth stages of guar. He used two separate drones to collect RGB and multispectral data of the study. The data will be processed, and indices will be developed to assess guar performance with different deficit irrigation management.

We have procured all guar cultivars from Guar Resources for guar germination and temperature study. We are working on quotes for buying incubators for the study. Working on protocol and on selecting model of the incubator for this study. This trial will provide much needed information on what cultivars can be used in northern latitudes or for delayed planting. This will help in increasing guar acreage in the US and local production of guar gum.

Guar Trials (Artesia, NM):

Tasks completed this quarter include planting the guar accession seed multiplication study; continued data collection; collaborations were developed for research/extension project. Hosted

a visiting scientist from USDA ARS, TX and other potential research collaborators from NMSU and Chihuahua, Mexico.

Guayule and Guar Yield Trials in Arizona:
Guayule plant heights measured August 17. Received bulk seed from USDA for transplanted guayule yield trial. Separation/cleaning is ongoing. Guar lines evaluated for flowering and maturity. Harvest is delayed.

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 Contribute data for developing guar crop coefficients (Kc) for irrigation management Present data at regional and national conferences	31 Aug 19 31 Aug 19 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 trial in Tucson	Establish trial with different densities in Tucson, AZ	31 Oct 18
4 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
5 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
6 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	31 Aug 19

		Prowl H2O (pendimethalin) and Aim (carfentazone) labels expire in 2018; work with BASF and FMC on renewals	31 Jan 19
7 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
8 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
9 Ogden	Literature review of field/plant level growth models	Complete literature review	31 Dec 18
10 Ogden	Phase 1 growth models developed	Preliminary models developed and shared with project team	1 Aug 19
11 Ray	Plant density trial	Fall trial established for comparison with spring-established trial	15 Sep 18
12 Ray	Biomass drying experiment	Biomass, resin, and rubber content analyzed	30 Sep 18
13 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
14 Waller	Install TDR, infrared camera and flowmeter system	Provide data on guayule irrigation experiments	15 Jan 19

		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 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 Develop educational videos and documents on use of WINDS	15 Apr 19 15 Apr 19 15 Apr 19
16 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 Document effects of irrigation treatment on plant growth, soil moisture, plant stress, plant chemical response, plant vegetative indices, and crop coefficient Generate a publication on guayule irrigation experiments	15 Jul 19 15 Jul 19 15 Jul 19

Plant Density Trial with 2 Varieties and 5 Densities: The densities are 30, 18, 12, 6, 3 inch in-row spacing for density 1, 2, 3, 4, 5 (Figures 7-9). The trial was established at Bridgestone Americas, Inc. – Guayule Research Farm, Eloy, AZ on April 11, 2018 with 5 densities of plants and 2 entries. Figures 7 and 8 shows all densities of AZ-2 with higher NDVI values and higher plant heights (measured by sonar sensors) than Sel 1. The 30 inch spacing (#1) of both varieties had the lowest NDVI value which is an indication of biomass. Figure 9 shows the Sel 1 variety with higher leaf temperatures than AZ-2 densities indicating higher transpiration rates for AZ-2.

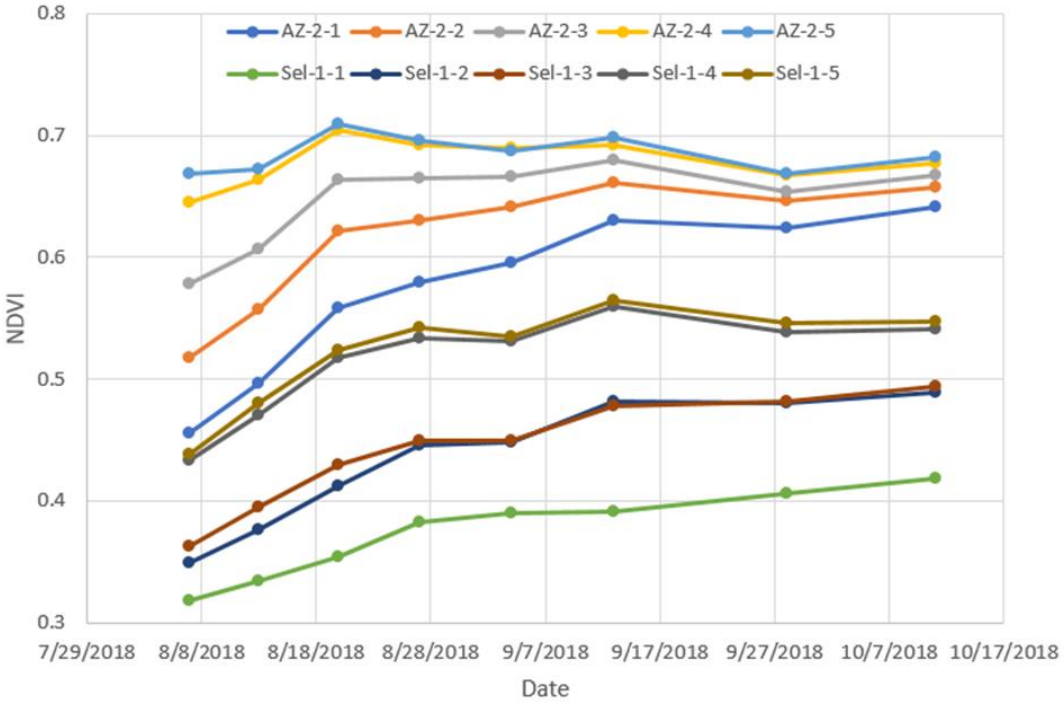

Figure 7. *Plant density trial NDVI readings taken from July - October 2018 on 2 varities of guayule.*

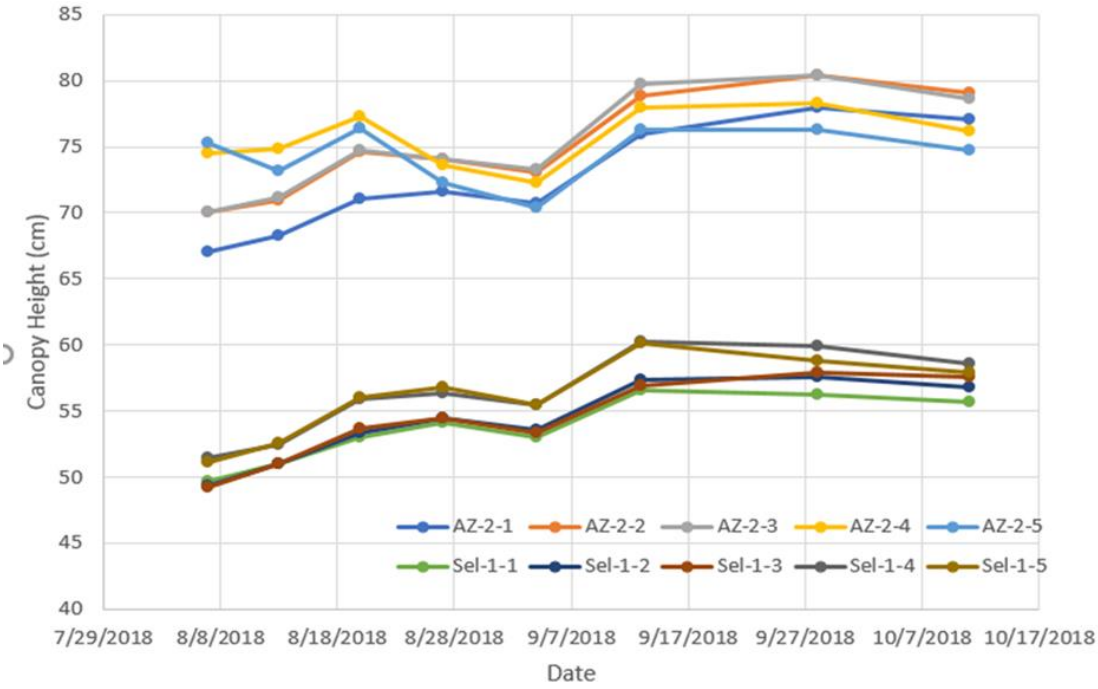

Figure 8. *Plant density trial canopy height results taken from July - October 2018 on 2 varieties of guayule.*

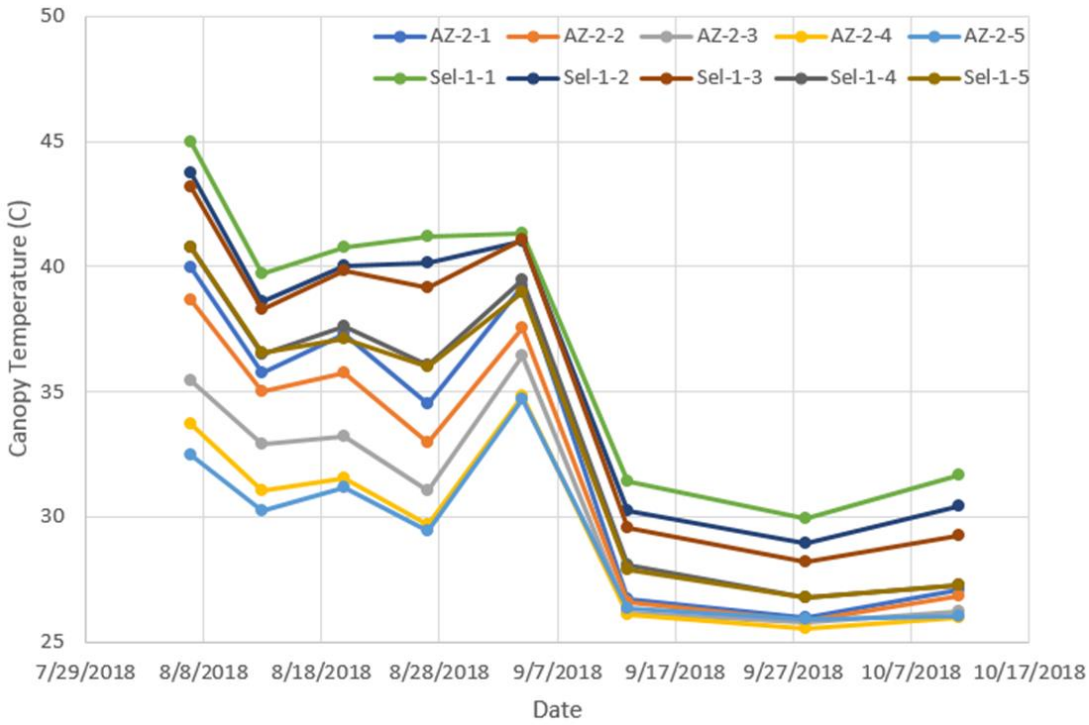

Figure 9. *Canopy temperature readings taken July - October 2018 on 2 varieties of guayule.*

Guar Response to Moisture and Density:
Presented a poster on guar work at International Soil and Water Conference; Presentations made to students and clientele in various forums: New Mexico State 4-H Conference; invited talks at undergraduate and graduate classes at NMSU; at several field days held at Agriculture Science Centers across NM; and at on-station demonstration trials.

Plant Density Trial, Biomass Drying Experiment, and Guayule Trials:
Preliminary data for four-month-old direct-seeded guayule shows that total root biomass is about 30% of the total above ground biomass; with 47% of the root found between 0-20 cm below the soil surface. Roots grew to 140 cm with 11% of the root mass found between 120 cm and 140 cm.

Collaboration with Herbicide Manufacturers:
The experimental designs and treatment lists for the Marana, Maricopa and Eloy Fall 2018 experiments were ready to implement at the end of the third quarter. This was the result of consultation with industry scientists (Gowan, FMC, Syngenta, and BASF) regarding data needs (herbicide rates and application methods) and discussions with Bridgestone scientists regarding planting and other agronomic practices. The Marana preemergence herbicide experiments are in a field with a coarse soil texture and were added to the fall schedule of experiments due the loss of the spring 2018 Maricopa studies in a field with a coarse soil texture. I obtained an Arizona Experimental Use Permit (EUP Permit# AZ 18-003) in order to conduct the Marana experiments.

Renew Existing 24c SLN Herbicide Registrations:
I reached out to BASF and FMC scientists regarding the 24c SLN renewals for Prowl and Aim, respectively. I will be interacting with them as the fall 2018 experiments progress and will tour the field experiments with them at appropriate times.

Guayule Herbicide Tolerance Studies:
The postemergence tolerance of guayule to Aim (carfentrazone) at 4 growth stages and 6 rates was initiated and completed at the Bridgestone farm in Eloy during the spring and early summer of 2018 (Table 4). A research report on this experiment is in progress. This experiment will be repeated in fall 2018 so that I have 2 site-years of data to support the renewal of the 24c SLN for Aim on guayule transplants and expand the label to seedlings larger than 4 to 6 true leaves.

Table 4. *Guayule experiment detail (herbicide broadcast-sprayed topically after guayule seedlings were established).*

Spray Date	Chemicals Applied	Location/Field	Method of Incorporation	ARM File Name / Data Tables?	Data Collected to Date
5-25-2018 6-1-2018 6-8-2018 6-20-2018	Aim	Bridgestone / A5	Sprinkler	Aim Guayule Spring 2018 EPOST Eloy	5/25/2018 – Guayule Pre-spray Stand Counts 6/1 – Guayule Pre-spray Stand Counts 6/8 – Guayule Pre-spray Stand Counts - Nadir Pictures 6/20 – Guayule Pre-spray Stand Counts 7/1 – Guayule Stand Counts 7/19 – Guayule Stand Counts

The second set of spring, sprinkler-incorporated, preemergence herbicide studies with acetochlor (Warrant), bensulide (Prefar), ethalfluralin (Sonalan) metolachlor (Dual), pendimethalin (Prowl), and sulfentrazone (Spartan) were completed in field 4 at the Maricopa Ag. Center. We were able to collect data on both guayule emergence and prostrate pigweed control in response to different herbicides each applied at various rates in a sandy loam soil. The data entry and preliminary analysis of variance is complete for these studies. A research report on the experiments is in progress.

The first of three sets of fall 2018 preemergence herbicide studies was initiated Gary Deen's farm in Marana at the end of September (Table 5). Initiation of the remaining two sets of preemergence herbicide studies and the postemergence Aim study have been delayed by a series of late September-October storms that resulted in significant rainfall and cooler temperatures at our study sites

Table 5. *Guayule preemergence herbicide experiment detail (herbicide applied at planting).*

Spray Date	Chemicals Applied	Location/ Field	Method of Incorporation	ARM File Name / Data Tables?	Data Collected to Date
9/25/2018	Prefar 4-E Prowl H2O	Marana	Sprinkler	PRE-Prowl Prefar Fall2018 Marana	10/8/2018 – Guayule Stand Counts
9/25/2018	Dual Magnum Spartan 4F	Marana	Sprinkler	PREE Dual-Spartan Fall2018 Marana	10/8/2018 – Guayule Stand Counts
9/25/2018	Warrant Sonalan	Marana	Sprinkler	PREE-Fall2018-Warrant-Sonalan Marana	10/8/2018 – Guayule Stand Counts
	Dual Magnum Spartan 4F	MAC / F1 / B36	Sprinkler	Guayule PREE Fall2018 Maricopa Ag Center Dual Spartan	Start of experiment is pending dryer and warmer weather
	Prefar 4-E Prowl H2O	MAC / F1 / B37	Sprinkler	Guayule PREE Prowl Prefar_Maricopa_Ag_Center Fall2018	Start of experiment is pending dryer and warmer weather
	Warrant Sonalan	MAC / F1 / B38	Sprinkler	Guayule PREE Fall2018 Warrant Sonalan	Start of experiment is pending dryer and warmer weather
	Dual Magnum Spartan 4F	MAC / F1 / B39	Incorporvator	Guayule PPI Fall2018 Maricopa Ag Center Dual Spartan	Start of experiment is pending dryer and warmer weather
	Prefar 4-E Prowl H2O	MAC / F1 / B40	Incorporvator	Guayule PPI-bedtop Prowl Prefar MAC Fall2018	Start of experiment is pending dryer and warmer weather
	Warrant Sonalan	MAC / F1 / B41	Incorporvator	Guayule PPI-Bedtop Warrant Sonalan MAC FALL2018	Start of experiment is pending dryer and warmer weather

Research technicians Bryan Pastor was largely responsible for setting up the experiments, spraying the herbicide treatments, and collecting the data with some help from me and a temporary research technician, Sam Pernu. 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.

Plant Growth Models:
A new post-doc has been hired (Sarocha "Mimi" Pradyawong) and she joined the team in mid-September. She will begin working on a comprehensive literature review to identify best practices and methods, as well as questions that may still need to be addressed with this research. Preliminary growth models under development are on track to be completed by August 2019.

Irrigation Experiments and WINDS Model:
Waller has made the WINDS model run with the MySQL database on the server. He is working on the website presentation of data with a python library called Flask. A faculty member in Biosystems Engineering, Haiquan Li, is helping with website development and phone app development. He has a PhD in computer science and has expertise in database management.

Diaa El-Shikha traveled to New Mexico twice and collected drone images of the Dr. Angadi and Dr. Grover experiments on guar irrigation. We are continuing to develop irrigation models based on the New Mexico guar experiments. Hadiqa Maqsood is working on developing a crop coefficient calibration method in python. She developed an Excel spreadsheet and python code that calculate reference evapotranspiration based on the Clovis weather data. She is developing a crop coefficient calibration method in python that will employ the same logic pattern used by Dr. El-Shikha and Dr. Hunsaker in their spreadsheets. She will then connect this to the WINDS model on the server. The method will use an iterative method in which crop coefficients are adjusted until the WINDS model agrees with neutron probe measurements

Danielle Murdoch-Hoare has finished the sensor connections to the Raspberry Pi and Arduino. She is waiting for the server port to be activated, which we requested.

Diaa El-Shikha continues to supervise the guayule irrigation experiments at Eloi and Maricopa. The experiments have healthy plants and irrigation treatments are proceeding as planned. Bridgestone sampled from different irrigation treatments in late August. Drone flights are taking place once each week. Neutron probe measurements are collected once each week by Matthew Katterman.

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	31 Dec 18 31 Dec 18
2 Maier/ Neilson	DNA extraction of soil samples for microbiome analysis	Quantify available biomass for 108 samples for amplicon sequencing	31 Dec 18
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	1 Apr 19

		Coordinate chemical analysis of samples with NMSU	1 Apr 19

Dr. Holguin's lab is in the process of analyzing the baseline soil samples from the MAC and Eloy fields for pH, EC, OrgM, NO_3-N, P, K, cations and SAR. The work is on schedule and data will be available during Quarter 4.

Soil texture analysis was completed in Q3 for 50% of the MAC soils (Figure 10). All soils analyzed to this point are a sandy loam texture. The clay content average was 15.4% (± 1.8%) with a range of 10.5 %-18.3%. Clay values were highest in P11, corresponding to Drip100 treatment, replicate 2. Lower clay content values were observed for P4 and P8, corresponding to Drip 50 treatment, replicates 1 and 2, respectively. Field statistics will be done when all MAC samples have been analyzed.

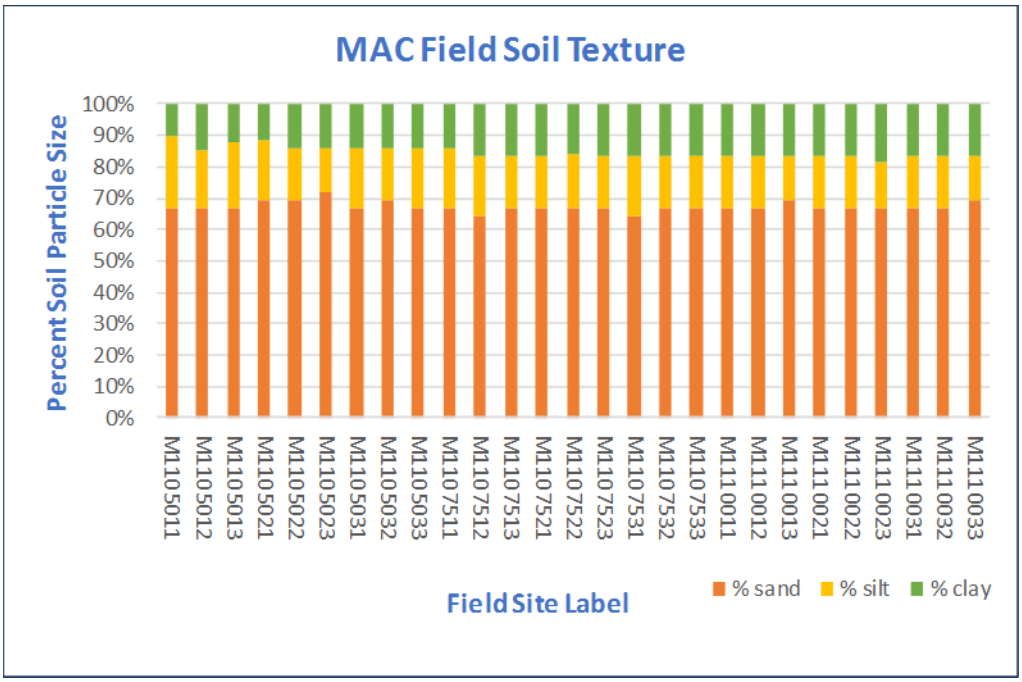

Figure 10. *Soil texture data collected at the Maricopa Agricultural Center in Maricopa, Arizona.*

Soil DNA extractions were completed during Q3 for 50% of the samples from the Eloy field. The DNA extracts will be amplified and sequenced to generate microbial community composition profiles. All samples contain robust DNA concentrations. DNA concentration can be used as a proxy for microbial biomass. No significant differences have been observed in microbial biomass for the areas of the Eloy field that have been analyzed thus far.

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:
Biomass characterization results have been delayed by about 3 months due to challenges with student availability for training/laboratory time. We have been coordinating with Dr. Holguin's group to arrange for students to be trained and to be assigned tasks to get through the analysis backlog. Graduate students have also been communicating with other biomass conversion groups to troubleshoot analytical methods applied to our samples.

One of our graduate students Stephanie Willette, has taken a postdoc position with Los Alamos National Labs /New Mexico Consortium. This has caused a delay in processing of guayule leaf material for both metabolomics and pesticide residue analysis. However, we have recently made adjustments to our undergraduate researchers to help provide additional support in this area.

We continue to implement the National Renewable Energy Laboratory (NREL) biomass characterization methods with Dr. Brewer's group on bagasse material. However there has been an issue with the bagasse material to have recalcitrant biochemicals to the acid digestion for total carbs and lignin analysis. The research assistants are trouble shooting the process to improve the digestion efficiency.

Regarding the task "data collection for feedstock logistics" (Fan's Group), we did complete the information and data for the GIS data collection part. But there is still a gap of data related to biomass availability and productivity, as well as the cost factors for each component and activity. The cost factors we collected from literature do not match our biomass type and there is little information for guayule from open resource.

To address this, we plan to: (1) talk to Bridgestone for more detailed data during the trip to Bridgestone with other groups in early November 2018; (2) continue searching for useful information from related literatures, for example, the cost factors for lignocellulosic biomass such as switchgrass and corn stover.

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 Composition information and sample extracts completed	31 Aug 19 31 Aug 19

		Generate manuscript on cold tolerance in guayule	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:
In September, eight NMSU researchers visit Guar Resources in Brownfield, TX to better understand the guar gum production process, to meet with Guar Resources/Texas A& M agronomists, and to acquire samples for education and outreach activities. That visit provided much needed information on the amounts and composition of guar co-products and opportunities for development. We also visited the NMSU farm in Clovis to see Dr. Angadi's guar field trials.

Five new students (four undergrad and one grad) were trained in biomass characterization methods. Guar and guayule bagasse samples were characterized reliably for lignin content, proximate analysis, and CHNS elemental analysis. Work is continuing on increasing the reliability of analysis for structural carbohydrates and water/hexane/DCM extractives for lignocellulose.

Guayule Biochemical Composition Analysis:
We have also continued our work with Dr. Von Mark V. Cruz and Dr. David Dierig on characterization of guayule leaf material. From our previous report to Drs. Cruz and Dierig we reanalyzed some samples to address inconsistences found in the data. The analysis is now complete and ready to prepare the tables and figures for a manuscript on the cold adaptation and acclimation of guayule varieties.

Guar Bagasse Biochemical Composition Analysis:
We continue to perform biomass characterization methods with Dr. Brewer's group on bagasse material. We have begun aqueous size exclusion analysis of carbohydrates as well as galactomannans from guar seeds. In addition all samples from Bridgestone have been characterized by GC/MS and chemical analysis report is currently being drafted. And is to be shared with the logistics group.

Analytical Evaluation of Thermochemical Conversion Products:
We have started collaboration with Dr. Jack Jarvis at NMSU, who is an expert at high-resolution mass spectrometer to increase our support in evaluation thermochemical conversion products from the logistics group.

Other SBAR Collaborative Work:
Soil samples received from Dr. Julie Neilson are greater than 50% complete and we anticipate the full completion of the soil samples prior to a Nov 5th deadline

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:
For the data collection for feedstock logistics, the work is partially done. We collected the Geographic information system (GIS) data (including land cover type for each field, road networks and railway roads, water supplies) from online database, some cost factors (including harvest and hauling cost for biomass, transportation cost for biomass and different products) from published literature. We also sent the request of data related to fields and yields of guayule to our industry partner, and we received some response and we are working on more details as our model input.

Economic Benefits and Environmental Influences:
Based on the feedbacks from annual retreat, we modified our optimization model in the following aspects:

(a) Each candidate location is surrounded by at least 100000 acres of available crop lands.

(b) We are going to find only one proper facility location in the end considering the current scale of the model.
(c) We include the railroad transportation into our consideration for long distance transportation of the products.
(d) We assume the products as rubber, resin and bagasse rather than the rubber only.

Hybrid Optimization Models for Operations:
Decomposition-based algorithms were developed to solve the optimization model. We also started to write code for the optimization model with implementation of the algorithm. We plan to write code in C++ programming language and call the commercial solver CPLEX to solve the problem.

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

Cheng and Bayat continued work on the lignocellulose waste material-conversion method review paper; they expect to finish the feedstock and conversion method sections by December and to submit in March. Audu has begun the methods section drafts for the guayule and guar bagasse characterization sections, which we intend to include in a manuscript on guayule bagasse/algae HTL study and a joint paper with Dr. Grover's group on guar growth.

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 compounds in commercially relevant quantities	Define research questions for guayule resin separation methods Preliminary experimental designs defined for guayule resin separation methods	31 Aug 19 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	31 Aug 19

		Develop chemical and/or microbial methods for the conversion of guayule by-products into value-added products	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	30 June 19 30 Jun 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

Dehghanizadeh began literature review manuscript on guayule resin extraction and characterization to guide his work on resin separation, which was requested by Bridgestone last quarter.

Biological evaluation of argentatin H: We have previously found that argentatin H isolated from guayule resin to be cytotoxic to a number of cancer cell lines. However, further biological evaluation of argentatin H suggested that it is not sufficiently potent and/or selective to be pursued as a potential anticancer agent.

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 team began meeting weekly in August to support model integration. This meeting time has been instrumental in supporting the team coming together to achieve the goal of model integration. All notes and presentation materials are maintained in a community workspace available to all partners for future reference.

Issues/Risks:
Potential acreage must accurately represent producers in New Mexico using crop mixes that guar and guayule can easily fit into whole farm rotations. The needs assessment survey will help in decision making on questions that producers desire to have answered using the systems model as well as identify accurate potential for adoption of biofuel crops.

Gathering the current cost and price data is difficult to collect across the region. 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.

Model integration represents a significant risk for the sustainability team. CSU has been diligently working to identify this as a risk with the team. In an effort to minimize this risk the team has been meeting on a weekly basis. The concept is for team members to come together and identify issues on a weekly basis such that the team can deliver on the timeline agreed upon at the workshop in August.

CSM has fallen behind on the work based on personnel issues. CSU has been directly working with CSM in an effort to get work back on track. Concerns in regard to the quality of previous modeling work done by CSM based on current results and model fidelity are an issue. The validity of this concern will be evaluated through the integration effort.

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	31 Mar 19
		Re-run model with new information	31 Mar 19
5 Landis	Clarify social sustainability metrics	Develop overview of sustainability tools and list of potential metrics	30 Jun 19
			30 Jun 19

		Generate publication/presentation for conference proceedings	
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 (Q3), 2018 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. All farm level data is currently in the process of being integrated into the model using crop budgets developed for production of guar and guayule in New Mexico and Arizona. Harvesting practices and data for guar were successfully collected to be used in the integrated model at the farm level analysis and life cycle analysis.
- **Potential Acreage for Crop Adoption in New Mexico:** The team is in the process of identifying potential acreage and crop mix for producers in New Mexico. The data is being collected from USDA NASS CropScape for southern New Mexico counties to

identify potential acreage for adoption of producing guar and guayule. Adoption will be identified using 10%, 15%, and 20% levels.

- **Guar Needs Assessment Survey – New Mexico Producers:** The team has successfully connected with county extension agents in 7 southern New Mexico counties in order to meet with producers and distribute the needs assessment survey to producers

First Order LCA Model:
Existing guayule data and knowledge was used to setup a preliminary guayule excel model as well as outline a guar excel model. A LCA mini-workshop/tutorial was also lead by Dr. Eranki to assist with the setup of the model. Additional research on general agricultural models was completed to explore simple to complex model options that may benefit this project, specific to field emission simulations. Preliminary results were produced for guar agricultural impacts from the excel based model. Refinement of model inputs was completed, and new results were produced (see figure)

LCA First Order Model Integration:
Inputs to both LCA and cost models are very similar; as such the teams are collaborating to ensure that the models are harmonized with one streamlined inputs location. For the cost model, costs and breakeven prices are based on whole-farm, long-term scenarios that include changes to labor, fuel, repairs and maintenance costs for tractors and equipment as crops are planted or adopted. Some outputs from the cost model can be used as inputs for the LCA, and include hours of labor, amounts of fertilizer and chemical inputs, irrigation water usage, and tractor and equipment fuel requirements, and replacement costs. The LCA model estimates environmental impacts by creating process models and coupling them with life cycle inventory databases, with environmental impacts calculated via the EPA TRACI model. Full team model integration is still in progress

Clarify Social Sustainability Metrics:
Initial social sustainability literature review is in progress

Other Highlights this Quarter:
VeeAnder Mealing, a graduate student at Colorado School of Mines, presented a winning poster at the LCA XVIII Conference hosted in Fort Collins, Colorado in October.

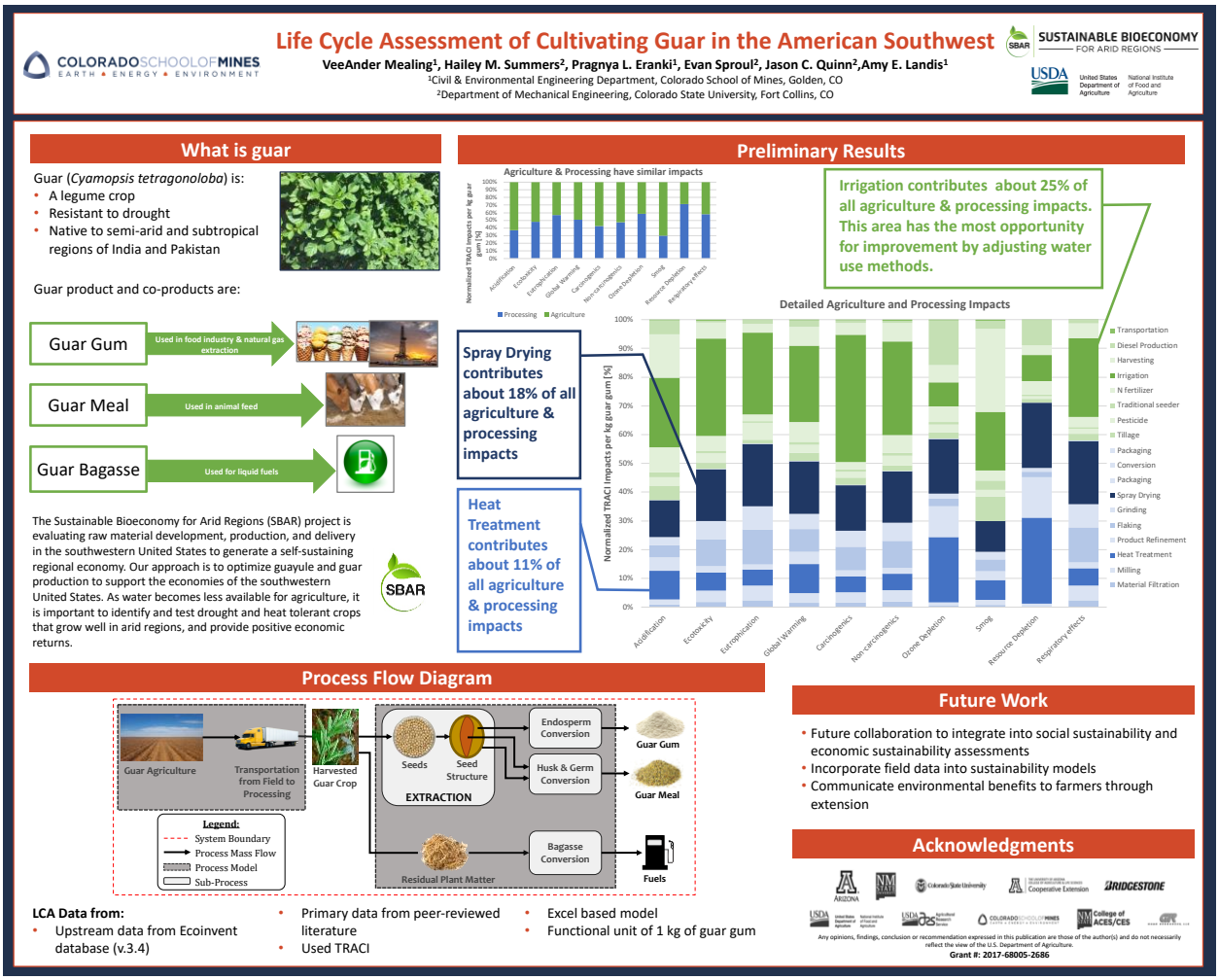

Figure 11. *Winning poster presentation at the LCA XVIII Conference hosted in Fort Collins, Colorado in October 2018.*

Enterprise Budget Development:

Added a significant portion to the agricultural economics section of the integrated model to be linked with other Sustainability Team efforts. The agricultural team decided to build a machine cost generator into the integrated model for crops associated with the project. This will make the economics section more dynamic and robust but anticipate more effort towards this task.

Guayule Harvest Cost Estimates:

The current status of project in meeting defined milestones for the recent quarter (Q3) is on schedule. There has been a series of bi-weekly meetings as well as in person with projects partners to facilitate the achievement set targets.

- Continue to meet with Clark Seavert to refine scenarios and create additional budgets for upload to the team box file
- Preparing information to be used with the extension outreach group.

- Further 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.
- Assist in securing experimental plots on tribal farms.

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

The focus of this quarter has been focused in following primary areas:

- Model integration with a focus on integrating with other modeling team members on economics and environmental impact
- Model integration across the sustainability team
- The continued development and validation of individual sub-process models for the processing of guar and guayule from agricultural biomass to final products
- Development of LCA results in support of presentation of results at the ACLCA conference
- Development of a sustainability team meetings on a weekly basis in support of model integration

Model Integration:

A critical aspect moving forward is the integration of modeling efforts across the teams. CSU has lead the integration effort with the development of a modeling framework to support the integration of the research across all research groups. Specifically, CSU is coordinating the economic and environmental modeling integration. The economic integration is focused on connecting with UofA, NMSU, OSU, and CSU. UofA, NMSU, and OSU are leading the economic modeling effort on the agricultural aspects of the process. CSU is leading the economic modeling on the downstream processing aspects of the process. CSU has met multiple times with the upstream modeling team members in support of model integration.

On the environmental impact front the integration has focused on working with CSM. CSU has met with CSM multiple times to support integrating existing CSM models with the modeling framework and downstream process models which have been developed by CSU.

Engineering Process modeling:
Sub-process modeling work has focused on improved model fidelity. Current work has focused on improving fidelity with heat integration across downstream processing. Preliminary results have highlighted the importance of raw energy input in terms of environmental impact and economic viability. The focus of this work continues to be accurately tracking energy and mass of each sub-process.

LCA results:
The foundational engineering process models have been integrated with life cycle methodology to evaluate the environmental impact of downstream processing. This quarter has focused on expanding the LCA work to include TRACI impacts. This has required the use of EcoINVENT software. The expansion of scope is in support of presenting results at the ACLCA conference held in Fort Collins, CO.

Guar:
This quarter we have focused on updating the LCA work to include TRACI impacts and support the presentation of the work at the ACLCA conference. The abstract for the work is:
Guar (*Cyamopsis tetragonoloba*) is harvested to produce guar gum, a thickening and stabilizing agent used in oil and gas recovery, the production of paper, cosmetics, paints, and detergents. The rise of hydraulic fracturing for shale oil production has increased the world market demand for guar by 250% in the past decade. The United States currently imports the majority (>80%) of its guar demands from India, with increasing annual demands further escalating a continual reliance on imports. This reliance has led to the investigation of cultivating guar in the United States in an effort to generate a more reliable domestic supply chain.

Guar's high water use efficiency, and low moisture storage requirements make it a drought resistant crop ideal for arid regions of the American Southwest. Initial work to determine the feasibility of integrating guar into the American Southwest has focused on developing models to quantify the resources required to cultivate guar as well as downstream bioprocessing to obtain guar gum. These models were leveraged to develop a life cycle assessment (LCA) which uses the TRACI 2.1 lifecycle impact assessment (LCIA) method to evaluate environmental impacts. Preliminary results of agricultural modeling show that irrigation and harvesting practices have the highest impact among all TRACI categories. A preliminary sensitivity analysis shows that decreasing the irrigation rate to a minimum value found in literature results in a decrease across all impact categories by over 50%. Results from bioprocessing models have shown that the heating requirements used for guar gum extraction represent the highest energy demand. Modeling results will be used to optimize the overall production of guar gum with experimental work validating models throughout development. Furthermore, the integration of co-products will be investigated, namely the feasibility of obtaining biofuels from residual plant matter. Co-products have the potential to reduce environmental impact and economic costs. Through our analyses, we will determine the environmental impact of cultivating guar in the American Southwest, while considering both the regional and rural economies.

Guayule:
The focus this quarter was on upgrading the downstream LCA to support TRACI impacts and the presentation of results at the ACLCA conference. The abstract for the talk is:
Guayule (*Parthenium argentatum*) is a drought resistant shrub native to the arid regions of the southwestern United States, and has long been considered a potential domestic source of natural rubber. As a result, previous research has assessed the environmental impact associated with Guayule agriculture, bioprocessing, and subsequent use in the tire industry. Building upon this research, a new effort seeks to improve previous assessments and lower environmental impacts through process optimization to ensure sustainable rubber and co-product production.

This work presents high-fidelity process models and a cradle-to-grave life cycle assessment of Guayule rubber and co-products (bagasse and resin). The process models track energy and mass associated with cultivation, harvest, transport, and product extraction. These mass and energy balances inform and supplement life cycle inventory data; subsequently environmental impacts are compiled using the TRACI impact assessment method to determine the environmental impacts of producing Guayule rubber and associated co-products. Using these results, areas of high impact are identified. Potential areas for improving the environmental impact include improved irrigation, heat integration in product processing, and investigation of co-product pathways for residual biomass. Viable options for co-product pathways include the development of biofuels via pyrolysis, hydrothermal liquefaction, or gasification to Fischer-Tropsch.

Cradle-to-rubber processing gate results indicate that irrigation is the most environmentally impactful process in agriculture- water use for irrigation, followed by electricity to pump water and chemicals to maintain drip tape when using drip irrigation cause highest impacts. In the processing phase, results show that energy used during the extraction of rubber from Guayule is a major contributor to environmental impacts; therefore, optimization through heat integration has potential to reduce energy use and the corresponding environmental impacts. Preliminary analysis of co-product pathways shows pyrolysis to be the leading process for converting biomass to fuels with an energy efficiency of 38%. Ongoing work will build upon these findings to fully define optimized agriculture and bioprocessing pathways on the metric of environmental impact. The optimized pathway will then be evaluated and benchmarked against other crops to determine the sustainability of Guayule cultivation and processing in arid regions.

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.

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:
Near the middle of September 2018, Treftz experienced a serious health issue and had to withdraw from the program. Mostafa Dehghanizadeh, a new PhD student in chemical engineering who will be doing research on guayule resin separation has expressed interest in stepping in for Treftz this school year to support Ms. Bradley (teacher). He has begun the needed paperwork and will try to be up to speed by the end of October.

One of the SBAR Teacher Mentors had a medical emergency in September 2018, and will be out of the classroom for the remainder of the Fall semester. We are exploring options for the SBAR Fellow that was paired with this teacher and are mitigating the situation

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 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
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

Website Content: In July and August, Lopez and Taylor assisted with the collection and development of materials for the SBAR website, and the NMSU research group websites related to the research and education components.

NM SBAR Fellows: Audu and Treftz, participated with their matched teachers, Cathy Bradley (Lynn Middle School) and Tracie Mikesell (Mesilla Valley Leadership Academy), began offering activities within their classrooms with the fellows assisting one day per week. They conducted the first few weeks of a new afterschool STEM club on the shared Lynn/MVLA campus called Guardians of the Biosphere that incorporates SBAR-related concepts and activities. Both fellows attended and participated (virtually) in the Fellows' course at UA, and with the SBAR group meetings at NMSU.

Fellow Seminar: The SBAR Fellow seminar was planned by the team: Knox, Anderson, Duncan. It is going well and has been helpful for students. Per the seminar we realized we missed some additional training that needs to be addressed for new Fellows pertaining to reporting child abuse and other reporting protocols (not related to child abuse). The seminar covers topics such as lesson design, approaches, how to handle diverse student needs, working collaboratively with the teacher, culturally relevant science, teaching approaches, and handling 'interruptions' to their plans.

Teacher PD design: We are working slowly at documenting our best practices pertaining to PD design and execution. This is an element of the project that was not budgeted by the project. S. Chavarria has taken on this task for her college and will post final materials on the CoEd website but the materials will be linked to from the SBAR Education page.

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

In September, Audu participated in a group visit to Guar Resources in Brownfield, TX and to the NMSU research farm in Clovis to better understand guar growth and guar seed processing. The group picked up “show and tell” biomass and processing samples to use in the education and outreach events. Audu is working with the teachers to incorporate guar gum super bubbles and guar gum viscosity/stability demonstrations into the afterschool and classroom activities

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

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) continues to serve as the lead for the Extension & Outreach working team; and he continues to serve as the lead for when the Education and Extension & Outreach teams come together for monthly discussions.

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. During the ramping up toward the summer camp season, the 4-H Camp team met on a weekly basis to address issues and meet timelines. 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:

All field demonstrations in Clovis, NM were damaged by herbicide drift from a neighboring farm in the second half of June. They were replanted, the establishment was good, and the crop is doing very well. But maturity of the crop seems to be delayed. We hope the crop will be ready for harvest by middle of November.

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	31 Aug 19
		Visit guar farmers' fields to identify future research needs	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	31 Aug 19
		Train graduate students in guar agronomic management	31 Aug 19
3 Angadi	Guar deficit irrigation study	Gather/analyze data; develop peer-reviewed paper on guar deficit irrigation management	31 Aug 19
		Analyze/present results at regional and national meetings	31 Aug 19
4 Fields	Design/schedule evaluation tools, protocols, and metrics for all Extension & Outreach activities	Fall tools developed/refined; evaluation data gathered	31 Dec 18
		Spring tools developed/refined; evaluation data gathered	31 May 19
		Summer tools developed/ refined; evaluation data gathered	31 Jul 19
		Data synthesized; evaluation report generated	31 Aug 19
5 Grover	Establish guar trial and showcase guar as potential crop in NM	Host field day	31 Aug 19
		Collect data; results synthesized	31 Aug 19

		Generate peer-reviewed Extension publication	31 Aug 19
6 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
7 Idowu	Travel to conferences	Present SBAR info/materials at 4-5 grower commodity conferences	31 Aug 19
8 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
9 Idowu	Establish guayule and guar trials in Las Cruces, NM and Los Lunas, NM	Showcase trial experiments at field days Gather data/synthesize results (toward generating an Extension bulletin) Generate first year trial summary (published on SBAR website)	31 Aug 19 31 Aug 19 31 Aug 19
10 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
11 Rock	Deploy stakeholder needs assessment survey in AZ	Survey results collected from grower stakeholders in AZ	31 Dec 18
12 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
13 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
14 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
15 Teeg	Generate updated cost-production budgets for current cropping systems (guayule and guar)	Develop 5 enterprise budgets showcasing different scenarios	30 Jun 19

		Generate summary; publish results (SBAR website)	30 Jun 19
16 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
17 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:

A presentation was made by Dr. Angadi, Dr. Idowu and Mr. Singh at the Annual Field Day at Clovis Science Center on August 9th. More than 80 people attended the event. A graduate student presented his deficit irrigation project, while Dr. Idowu talked about SBAR and Dr. Angadi summarized research efforts to develop guar as a low input, low irrigation requiring alternative crop for the region.

A group of graduate students from NMSU lead by Dr. Brewer visited Clovis research fields on September 7th, 2018 and learned about guar plant, guar agronomy and different aspects of growing guar in the region.

Photo 4. *Field day presentation focused on guar production in New Mexico.*

Use of guar gum for fracking, food and other industries has made news in recent years. Many farmers are interested in knowing more about the guar crop and what are the products from it. Want to develop a display consisting seeds of different cultivars and some of the products including guar gum, guar splits, hull, protein and forage. This will be useful to educate farmers. Have collected some products from Guar Resources.

Planning exploratory research visit to Rajastan, India during October second half of 2018 to learn more about guar industry in the region. The region is the major producer and exporter of guar gum in the world. First, I will present invited talk in the Indian Society of Agronomy and interact with guar researchers in the country at Udaipur, Rajastan. Then I travel to Jodhpur to visit some guar fields and processing plants. This will help in assessing recent developments in guar industry.

Guar Phosphorus Rhizobium Study:
Guar is a legume crop and can fix nitrogen. The crop can benefit from P availability. The P benefit on guar productivity may vary with and without Rhizobium. This is a replicated trial and planted at multiple locations. A plant growth promoting microbes/rhizobium mix (Micronoc) from Sono Ag (Brownfield Texas) was obtained for the trial. It is the only commercially available product for guar. This trial will evaluate the efficacy of that product for formers in the region. Later in the growing season gaur plants will be randomly dug to check for nodulation.

Guar Deficit Irrigation Study:
Six guar cultivars available for planting (Kinman, Monument, Judd, Santa Cruz, Lewis, Metador) were planted at Clovis to demonstrate them to area farmers. These cultivars are grown in buffer areas at different irrigation levels and will help in assessing their productivity under different irrigation levels. It is not a replicated project. All released guar cultivars were presented to area farmers during annual filed day at Clovis.

Finding an optimum row spacing for guar is important for adoption. A demonstration using row planter and seed drill with different cultivars is planted. We have used 20- and 30-inch row spacing as well as 6-inch row spacing with similar populations. Part of this unreplicated trial was planted using large field scale row planter. Plot sizes are large. The results will identify the optimum planting method for guar in the region.

Photo 5. *Demonstrating the value of proper spacing in guar production, New Mexico.*

Showcase Guar as Potential Crop in New Mexico:

- Participated in monthly SBAR Guar focus group, SBAR EEO group, and SBAR NMSU group meetings with colleagues on the project
- Served on advisory committee of Western Sustainable Agricultural Research and Education (WSARE) and planned for a Sustainable Agriculture Conference.
- Conducted on-station demonstrations on guar.
- Presented talks on guar at Field Days held at the NMSU Agriculture Science Center, Clovis, NM and Artesia, NM.
- Presented a workshop on alternative crops and guar at 4-H NM State Conference, Las Cruces, NM.
- Provided information and answered queries of growers/clientele about guar cultivation and related topics.

Travel to Conferences:
During this quarter, the SBAR project was presented at two field days in New Mexico. The first field day was held on August 9, 2018 at NMSU Clovis Agricultural Science Center in Clovis, NM. Idowu gave a presentation to about 150 field day attendees in the SBAR guar demonstration field plots on the goals and objectives of the SBAR project, highlighting the importance of the project for long-term economic development of farming in New Mexico. In addition, SBAR informational table was set up and project brochure and extension publications were distributed. The second field day was held at the Artesia Science Center in Artesia NM on August 23, 2018. SBAR information table was set up and project materials distributed to attendees. About 125 people attended the Artesia field day.

Photo 6. *Dr. John Idowu staffing an informational table at the Field Day in Artesia, New Mexico.*

Distribute Needs Assessment to farmers in New Mexico:
We have launched the needs assessment for guar in New Mexico. We have contacted extension agents in major agricultural counties to help identify suitable farmers that we could survey. This process is on-going.

Establish Guayule and Guar Trials in New Mexico:
Guar field demonstration trial is still on-going in Los Lunas and Clovis, NM

Stakeholder Needs Assessment in Arizona:
Over the last reporting period, the research-driven extension team has focused on the completion of the Arizona needs assessment survey to better understand grower stakeholders and aid in UA Cooperative Extension's ability to develop useful tools and resources to meet their needs. Recently, the Extension team in Arizona has worked with the Extension team in New Mexico and has initiated the New Mexico survey deployment on Guar.

The extension team has surveyed over 100 growers in the state of Arizona using the online platform Qualtrix. Example stakeholder needs assessment questions focus on awareness of the crops Guayule and Guar, common terminology, how stakeholders prefer information, questions/concerns, willingness to support biofuels, and alternative crop research. Additionally, questions targeting growers sustainability "ethics" as well as changes in growing practices as a result of the impacts of variable climates and changing weather patterns were asked.

The following text provides an overview of select stakeholder needs assessment questions and responses to-date. Note that responses have been updated to reflect new grower stakeholder survey responses

Question 1: Have you heard of the crop Guayule (pronounced why-YOU-lee)? (Red=Yes, Purple=No, and Blue=Not sure.)

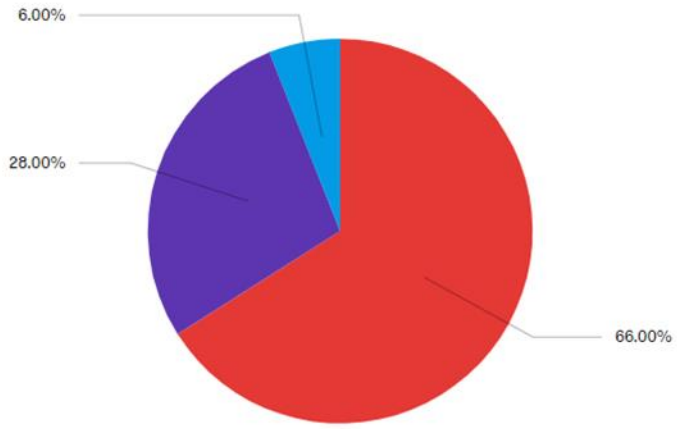

Figure 12. *Guayule Awareness in Arizona.*

Question 2: Are you aware that Arizona Cooperative Extension is supporting new biofuel and bio-product research on Guayule?

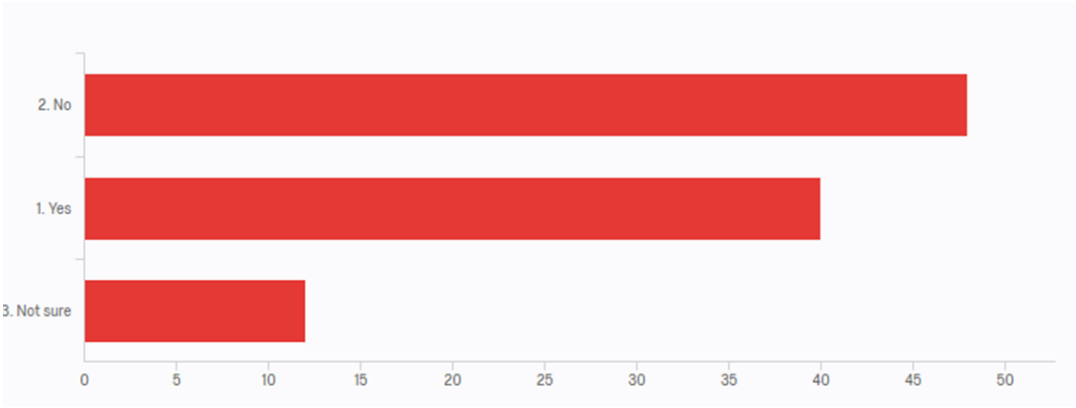

Figure 13. *University of Arizona Support of Guayule Research.*

Question 3: Some suggested benefits of the production of biofuel and bio-product crops include promoting America's energy security, reduction in greenhouse gas emissions, protection of the environment, and financial benefits for farmers and agricultural businesses. Taking that into consideration, are you interested in the production of biofuel and bio-product crops as a sustainable resource?

- 67.00% responded "Yes",
- 22.00% responded "Not sure", and
- 11.00% responded "No".

While generally respondents were supportive, when asked "*What are some of the questions that you will likely have, if converting some of your current farm land into Guayule?"*, top responses included

(1) crop growth cycle;
(2) cultural practices (fertilizer, soil health, herbicide/pesticide management);

(3) market demand and access;
(4) Equipment availability (e.g. harvesting equipment) and
(5) irrigation management (quantity and salinity).

Additional opened ended responses included comments related to pest management and economic viability.

Needs assessment questions were also tailored to help Cooperative Extension learn best ways to communicate findings to these select grower stakeholders. When asked to rank resources related to the following question, *What would help answer your questions regarding biofuel or bio-product crops such as Guayule?,* the top responses are as follows:

1. Crop production information (pamphlets, factsheets, reports, etc.)
2. Informational workshops
3. Field demonstration sites
4. One-on-one farm advice

Nearly 73.00% of respondents noted that they have seen changes or changed their farming practices, techniques or methods in the last 5 years with 34.00% responding that they had adopted new or different management practices to better manage climate variability. This was a shift in previous survey results where respondents indicated a higher adoption rate of new technology or management practices as a result of climate variability.

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 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

See Objective 1 narrative for detail.

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	31 Aug 19

		youth in Southern and Northern NM	
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

Order Camp Supplies:

4-H Team meetings have met 3 times with members from UA and NMSU; there is a consensus to integrate the research components: Feedstock Development & Production, Post-Harvest Logistics & Co-Products and System Performance & Sustainability into the biofuel summer camp in 2019; 4-H Team members Gerardo and Cara has begun attending UA-Research Team meetings to gain a better understanding of project research and to speak with PI's on how to best incorporate the research and their undergraduate and graduate students into the summer camp.

Provide 4-H Biofuel Activities to Youth:
Gerardo and UA undergraduate students Jasmine Lopez – AmeriCorp member and Shiara Perez who are part of Gerardo's outreach and research team have begun collaborating with High School Chemistry Teacher at Pueblo High School, who participated in the STEM RISE Arizona 5-wk summer program with Gerardo. We have met the students and now plan to have our first activity with the chemistry club.

Expand 4-H Biofuel Camp:
We plan to have Pueblo students either attend the biofuel summer camp or potentially help deliver the program. Students seem very interested in doing the biofuel activities and participating in the biofuel during the summer.

Refine Evaluation Instrument for the BYOE Program:
Gerardo and Daniela have begun to review the Bioenergy Youth Outreach and Engagement (BYOE) evaluation responses.

Project Puente Internships:
During the end of this reporting period a total of four *Project Puente* student interns were recruited to participate in the SBAR program. Student interns were located at the Maricopa Agricultural Center or the USDA Arid Land Agricultural Research Center in Maricopa, as well as on campus at the University of Arizona in Tucson.

Photo 7. *Project Puente interns actively engaged in research, Maricopa, Arizona.*

Student interns worked on 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 will share their findings at a culmination event on July 26th at the Maricopa Agricultural Center with the faculty mentors, teachers, and families.

Photo 3 shows *Project Puente* student interns learning environmental monitoring techniques as well as interacting with grower stakeholders in Maricopa, Arizona. As part of the *Project Puente* program, student interns are invited to participate in University research and Extension beyond their individual project to learn additional field and laboratory and well as team building skills to aid in their success.

PRODUCTS GENERATED.
September 2017 – September 2018

PUBLICATIONS, CONFERENCE PAPERS AND PRESENTATIONS

Publications

None this reporting period.

Conference Papers

None this reporting period.

Scholarly Presentations

1. **Angadi, S. 2018.** *Sustainable Bio-economy for Arid Regions: Growing Guar.* Extension Field Day. Clovis, New Mexico. 9 August.
2. 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.
3. **Brewer, C.E. 2018**. *Pairing biomass residues with conversion technologies*. Advanced Bioeconomy Leadership Conference, Washington, D.C. 28 February.
4. **Brewer, C.E. 2018**. *Polymerization and guar gum bubbles*. Outreach event activity. New Mexico 4-H State Conference. 11 July.
5. **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.
6. **Brown, K.S., Neilson, J.W. 2018.** *Microbial contributions*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. April.
7. **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.
8. **El-Shikha, D. 2018.** *Update – Guayule irrigation experiments at Maricopa Agricultural Center*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 12 September.
9. **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]
10. **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.
11. **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.

12. **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.
13. **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]
14. **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.
15. **Godfrey, D., Willmon, J., Teetor, V.H., Schmalzel, C., and Ray, D.T. 2018.** *Vegetative propagation of guayule*. 2018 Annual Conference, American Society for Horticultural Science, Washington D.C. 30 July – 3 August 2018.
16. **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.
17. **Grover, K. 2018.** *Sustainable agriculture and guar production in New Mexico*. New Mexico State 4-H Conference, Las Cruces, New Mexico. 10 July.
18. **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.
19. **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.
20. **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.
21. **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.
22. **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.
23. **Grover, K. and 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.
24. **Hoare, D.M. 2018.** *Irrigation Sensors and the WINDS Model.* SBAR UA Research Team Seminar Series, Tucson, Arizona. 26 September.
25. **Idowu, O.J. 2018.** *Introduction to the SBAR Project*. Las Cruces, New Mexico. 6 Feb.
26. **Idowu, O.J. 2018.** *Sustainable Bio-economy for Arid Regions: Update*. Extension Field Day, Clovis, New Mexico. 9 August.
27. **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.
28. **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.
29. **McMahan, C. 2018.** *Flowering Reduction in Guayule*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 19 September.

30. **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.
31. **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.
32. **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]
33. 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]
34. **Niu, D., 2018.** *Partial cloning of APETALA1 (AP1) gene from guayule*. cDNA Lab Seminar, USDA-ARS Western Regional Research Laboratory. 28 March.
35. **Ogden, K. 2017**. *Introducing new USDA NIFA CAP grant awardees – Developing regional AJF supply chains: Sustainable Bioeconomy for Arid Regions*. Invited Panel Speaker at the CAAFI-SOAP Jet Webinar. Hosted online. 13 October.
36. **Ogden, K. 2017.** *Sustainable Bioeconomy for Arid Regions*. Invited Speaker at the Biomass Research and Development Technical Advisory Board Meeting. 15 November.
37. **Ogden, K. 2018.** *Sustainable Bio-economy for Arid Regions*. Southwest Indian Agricultural Association. Laughlin, Nevada. 16-18 January.
38. **Ogden, K., White, R., Brewer, C.E. 2018.** *Public Private Partnerships*. ABLC Conference. Washington, D.C. 27-28 February.
39. **Rock, C., and Brassill, N. 2018.** *Importance of Cooperative Extension in University Research*. University of Arizona, Tucson, Arizona. 14 March.
40. **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]
41. **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.
42. **Sun, O., and Fan, N. 2018.** *Harvest scheduling*. SBAR Logistics Team Group Meeting. (webinar) New Mexico State University. Las Cruces, New Mexico. 5 February.
43. **Sun, O., and Fan, N. 2018.** *Optimization of feedstock logistics*. SBAR UA Research Seminar. University of Arizona. Tucson, Arizona. 14 February.
44. **Sun, O., and Fan, N. 2018.** *Optimally locating biorefineries*. SBAR Sustainability Working Group Seminar. (webinar) Colorado State University. Lakewood, Colorado. 8 March.
45. **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, CO, October.
46. **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, CO, November.
47. **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.

48. **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.
49. **Waller, P.** 2018. *WINDS Model: A status report and connection to SBAR research*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 10 October.
50. **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.

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

Audience Demographic Parameter	Previous Total (Cumulative)	This Quarter Total	Cumulative Project Total
Gender			
Males	338	291	***629***
Females	186	156	***342***
Race/Ethnicity			
Hispanic	69	96	***165***
Asian	45	39	***84***
Native American	106	68	***174***
African American	25	13	***38***
Anglo/White	279	231	***510***

Audience Cumulative Total *(when captured)****: 971ppl***

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. **Grover, K. 2018**. Guar – A potential alternative crop in New Mexico. Two page informational handout. January.
6. **Kiela, C. 2018.** Guayule. SBAR Project two-page fact sheet. March.
7. **Kiela, C. 2018.** Guar. SBAR Project two-page fact sheet. April.
8. **Kiela, C. 2018.** History of Guayule. SBAR Project two-page fact sheet. April.
9. **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.

→*Total Reach via Tabling Events and Workshops (when captured):* ***1,457 participants***

PARTICIPANTS AND COLLABORATING ORGANIZATIONS. September 2017 – September 2018

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
Amber Lynch	Professional	Feedstock Development & Production
Theresa Sullivan	Professional	Feedstock Development & Production
Sam Wang	Professional	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		
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*
Sangu Angadi	Key Collaborator	Extension & Outreach Feedstock Development & Production
Matt Armijo	Undergrad Student	Post-Harvest Logistics & Co-Products
Meshack Audu	Graduate Student	Education Post-Harvest Logistics & Co-Products
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
Catherine E. Brewer	Key Collaborator	Education Post-Harvest Logistics & Co-Products
Feng Cheng	Graduate Student	Post-Harvest Logistics & Co-Products
Mostafa Dehghanizadeh	Graduate Student	Post-Harvest Logistics & Co-Products
Barry Dungan	Professional	Post-Harvest Logistics & Co-Products
Sarah Fox	Undergrad Student	Post-Harvest Logistics & Co-Products
Kulbhushan Grover	Key Collaborator	Extension & Outreach Feedstock Development & Production
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
Travis Le-Doux	Undergrad Student	Post-Harvest Logistics & Co-Products
Esai Lopez	Undergrad Student	Education
Sicilee Macklin	*Undergrad Student*	*Education* *Post-Harvest Logistics & Co-Products*
Sa'Rae Montoya	Graduate Student	Post-Harvest Logistics & Co-Products
Kaavya Polisetti	Graduate Student	Post-Harvest Logistics & Co-Products
Darien Pruitt	Professional	Extension & Outreach
Joram Robbs	Graduate Student	Extension & Outreach System Performance & Sustainability
Tarah Schuman	Undergrad Student	Post-Harvest Logistics & Co-Products
Jagdeep Singh	Graduate Student	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	Undergrad Student	Post-Harvest Logistics & Co-Products
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*
Megan Bennett	Undergrad Student	Feedstock Development & Production
Natalie Brassill	Professional	Extension & Outreach
Kyle Brown	Graduate Student	Feedstock Development & Production
Daniela Cabrera	Professional	EO (3)
Madasu Chandrashekar	Professional	Post-Harvest Logistics & Co-Products
Sara Chavarria	Key Collaborator	E (1,2) EO (3)
German Coronado	Undergrad Student	Feedstock Development & Production
Cara Duncan	Professional	Education Extension & Outreach
Diaa El-Shikha	Post-doc	Feedstock Development & Production
Blase Evancho	Graduate Student	Extension & Outreach Feedstock Development & Production
Neng Fan	Key Collaborator	Post-Harvest Logistics & Co-Products
Krista Farmer	*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
Danielle Hoare	Graduate Student	Feedstock Development & Production
Pujan Kafle	Graduate Student	System Performance & Sustainability

Matthew Katterman	Graduate Student	Education Extension & Outreach Feedstock Development & Production
C. Kasia Kiela	*Undergrad Student*	*ALL AREAS*
Corey Knox	Graduate Student	Education
Maping Liu	Professional	Post-Harvest Logistics & Co-Products
Gerardo Lopez	Key Collaborator	Extension & Outreach
Raina Maier	Key Collaborator	Feedstock Development & Production
Hadiqa Maqsood	Graduate Student	Feedstock Development & Production
William McCloskey	Key Collaborator	Feedstock Development & Production
Istvan Molnar	Key Collaborator	Education
Julie Neilson	Professional	Feedstock Development & Production
Andrew Nelson	Post-doc	Feedstock Development & Production
Kim Ogden	Key Collaborator	ALL AREAS
Bryan Pastor	Professional	Feedstock Development & Production
Duke Pauli	Key Collaborator	Feedstock Development & Production
Sam Pernu	Undergrad Student	Feedstock Development & Production
Dennis Ray	Key Collaborator	Feedstock Development & Production
Channah Rock	Key Collaborator	Extension & Outreach
Alix Rogstad	Professional	ALL AREAS
Carl Schmalzel	Professional	Feedstock Development & Production
Stephanie Sikora	Professional	Education
Ou Sun	Graduate Student	System Performance & Sustainability
Trent Teegerstrom	Key Collaborator	Extension & Outreach System Performance & Sustainability
Valerie Teetor	Professional	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
Stevi Zozaya	Undergrad Student	Extension & Outreach
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
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		
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	Professional	Feedstock Development & Production

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

Total Key Collaborators: ***24***
Total Professional Staff: ***33***
Total Postdoctoral Researchers: ***5***

Total Graduate Students: ***23***
Total Undergraduate Students: ***25***

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 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 Education - 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 - Natural Products Center - School of Natural Resources and the Environment - School of Plant Sciences
Nonprofits:	
Industrial or Commercial Firms:	BASF Bridgestone Americas, Inc. FMC Guar Resources Syngenta
Federal Government	USDA – Agricultural Research Service, Western Regional Research Center - Chemistry (Bioproducts) - Plant Genetics
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
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
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:	