2019 Summary of Accomplishments

FEEDSTOCK DEVELOPMENT & PRODUCTION

Lead: Dennis T. Ray
Team: H. Abdel-Haleem, S. Angadi, K. Brown, Y. Chen, V.M. Cruz, D. Dierig, S. Dittmar, D. El-Shikha, B. Evancho, A. Garcia, K. Grover, D. Hunsaker, M. Lewis, P. Lohr, B. McCloskey, C. McMahan, J. Neilson, K. Ogden, L. Ossanna, M. Pradyawong, A.Rogstad, C. Schmaltzel, V. Teetor, P. Waller, S. Wang

Feedstock Development: Ray Lab

- Developed grading system for salt tolerance experiment (Fig. 1)

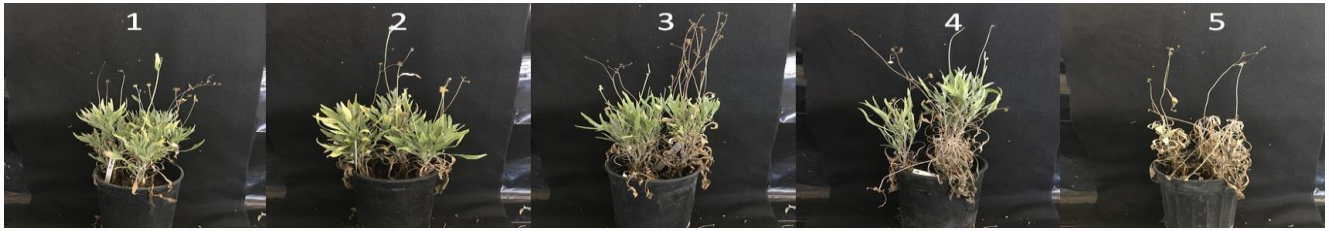

Figure 1: Guayule salt tolerant grading **scale:** 1 = No effect; 2 = Yellow leaves (~10 – 25%), brown leaves (~10 – 25%); 3 = Yellow leaves (~10 – 25%), brown leaves (~25 – 50%); 4 = Yellow leaves (~10 – 25%), brown leaves (~50 – 75%); 5 = Mortality, complete or imminent (brown leaves >90%).

- Harvested guayule density trial (Fig. 2)
- Harvested guar 16-18 December (183-184 days after planting) (Figs. 3-4)

Fig. 2: Guayule harvest 9 Oct.

Fig. 3 (left): harvesting; Fig.4 (right): threshing

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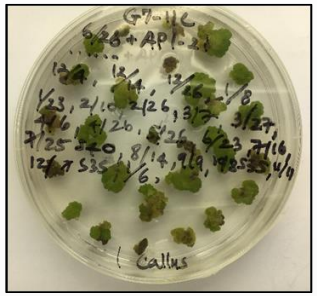
FEEDSTOCK DEVELOPMENT & PRODUCTION
USDA-ARS Rubber Lab– Colleen McMahan

Obj 1: Improve biomass quantity and quality through genetics and traditional breeding
Sub Obj: 2) Downregulate flowering to improve yield - guayule

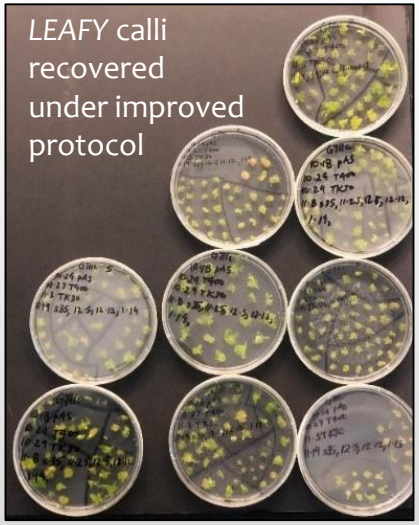
- Key Accomplishments Oct-Dec 2019
  - *As of January 2020 we have performed several thousand guayule transformations featuring 4 constructs, plus one 2-gene construct. All genes are transcription factors related to flowering which are downregulated by RNA interference:*
    - *APETALA1* AP1 : Calli growing under selection pressure
    - *SEPATTALA* SEP3 : Plant transformation confirmed by PCR for 6 events, moved to rooting media
    - *FLOWERING LOCUS T* FT2: Calli growing under selection pressure
    - LEAFY: Calli growing and forming leaves under selection pressure
    - pND6 – AP1 – SEP3 (pAS).: initial calli obtained, transformations continuing.

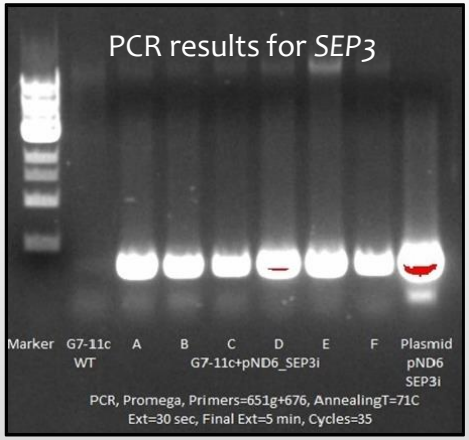
AP1 calli



FT2 calli

SEP3 shoots





Team: Niu Dong, Trinh Huynh, Mariano Resendiz, Dante Placido, Chen Dong, Grisel Ponciano

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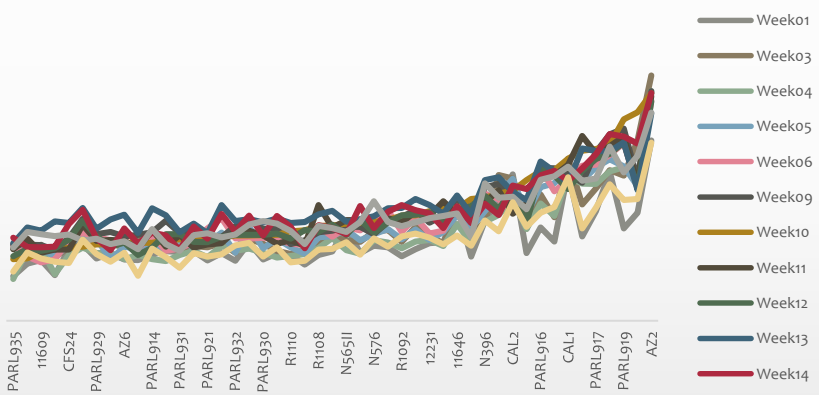
Q4 major accomplishment (Maricopa)

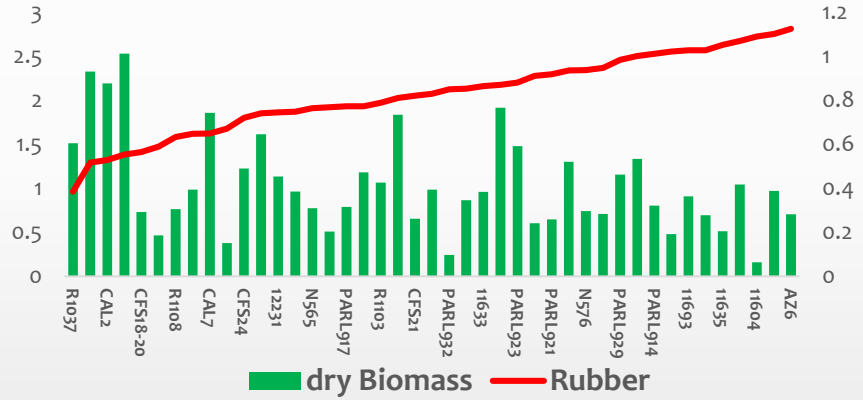
Hussein Abdel-Haleem (co-PI), Lily Luo (Postdoc), Aaron Szczepanek and Tristan Dunton (Biological Science technicians), Harmony Glover, Avery Luna and Brandon Vera (students)

Variations in NDRE, a vegetation index, among guayule genotypes and weeks



- Remote sensing could be used to detect the phenotypic variations among guayules
- Improved germplasm tend to be greener (healthier) compare to wild

Rubber and resin % in one-year old plants guayule genotypes



- There are phenotypic variations within guayules for rubber and biomass
- Improved germplasm tend to be high in rubber with heavy biomass
- Negative correlation between biomass and rubber

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Feedstock Development at Bridgestone

Dierig, Cruz, Wang, Dittmer, Sullivan, Lynch, Prock

Key accomplishment: Quarter 4, 2019

- Analyzed data from harvest of 18 month-old plants of 2 varieties planted at 5 densities. Biomass was highest in AZ-2 overall. The plants spacings were 30, 18, 12, 6, 3-inch and biomass for AZ-2 was lowest at the 30" density. We found no difference in biomass production between the other densities. Rubber % was unaffected by densities.

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Guayule Herbicide Tolerance
Bill McCloskey

- Postemergence herbicide tolerance studies were completed at Maricopa and Eloy.
  - *Measured guayule seedling tolerance to carfentrazone (Aim) at different growth stages.*
  - *Found that guayule is completely tolerant to the grass herbicides clethodim, fluazifop, and sethoxydim.*
  - *Determined that paraquat kills guayule seedlings.*

Aim @ 2 fl. oz./A on 3.5 leaf guayule – 7 DAT

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Spatial and Temporal Variability in Soil Microbiome Associated with Guayule Dormancy

Lia Ossanna, Yongjian Chen, Julie Neilson
In collaboration with
McMahan Research group and Diaa El Shikha

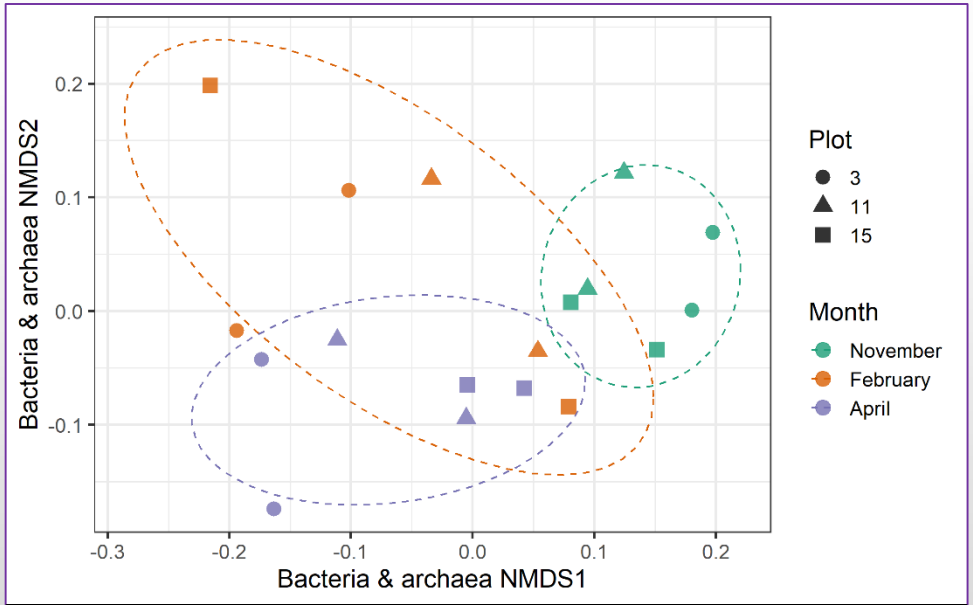
Research Aim: characterize soil microbiome variability for 3 guayule growth stages

November: cold induced rubber biosynthesis

February: winter dormancy with active rubber biosynthesis

April: Spring active growth

- Soil microbiome varies with guayule growth stage: 25% of bacterial/archaeal community variability is explained by sampling time (20% for fungi)
- Spatial variability greatest in February (most active rubber production time): plants across field may experience different plant/microbe interactions
- Results will be combined with plant growth and rubber production data to evaluate correlations



Two locations sampled per plot at each time point

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SBAR

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

Guayule and guar irrigation experiments

- **The following presentations on guayule and guar irrigation were made at the AAIC conference in September 2019.**
- **Growing direct-seeded guayule with furrow and subsurface drip irrigation in Arizona**
  - *D. Elshikha, P. Waller, D. Hunsaker, D. Dierig, S. Wang, M. Cruz, K. Thorp, M. Katterman, K. Bronson, G. Wall*
- **Development of a remote crop condition sensing system utilizing Internet of Things**
  - *D. Hoare, M. Katterman, P. Waller*
- **Evaluating crop water status for guar using WINDS model**
  - *H. Maqsood, S. Angadi, D. Elshikha, P. Waller, J. Singh, D. Hunsaker, B. Barua.*
- **Assessment of irrigation requirement for guayule using WINDS model**
  - *H. Maqsood, P. Waller, D. Elshikha, D. Hunsaker, M. Katterman, D. Dierig, S. Wang, K. Ogden.*

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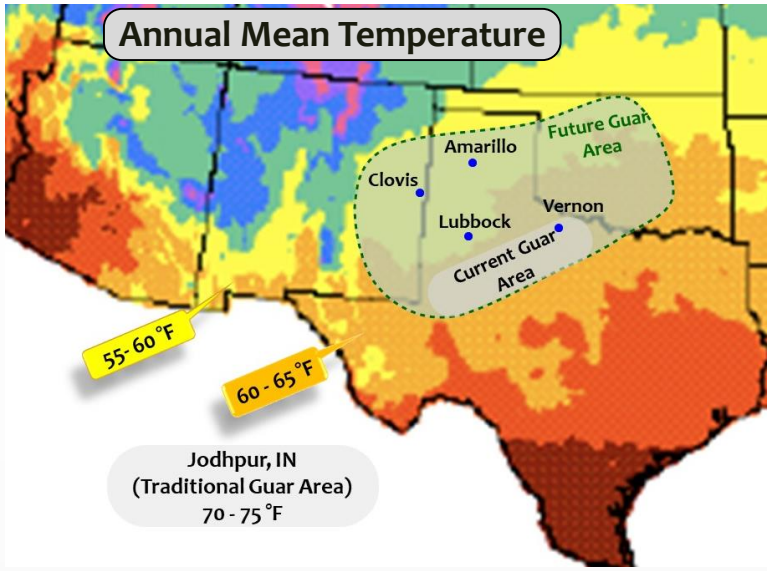
NMSU: Sangu Angadi

Title: Temperature and Guar Germination Study

- Guar cultivars showed lots of variation in germination.
- Cultivar differences were more prominent under lower temperatures.
- Kinman was different and tolerated lower temperatures better compared to other cultivars.
- It is possible to expand guar acreages to cooler locations, if we find cold tolerant cultivars.



Cultivars	Temperature °F					
	13	16	19	22	25	28
Kinman	77	99	99	97	96	95
Monument	19	45	85	93	91	92
Judd 69	29	80	97	98	94	96
Matador	11	39	68	92	96	95
Lewis	29	55	87	85	82	81
Santa Cruz	43	73	76	81	86	77

Fig.1. Potential guar area expansion by identifying cold tolerance germplasm

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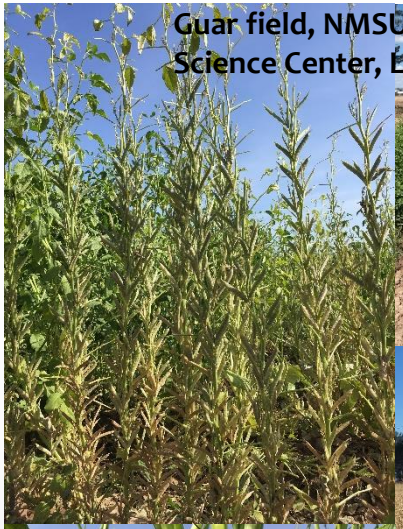
Guar research – Kulbhushan Grover

- Feedstock Development
  - *Evaluated field performance of Guar genotypes.*
- Production technology
  - *Evaluated response of guar to planting densities.*
- Scientific interactions
  - *Delivered presentations at scientific meetings.*



Guar field, NMSU Fabian Garcia Plant Science Center, Las Cruces, NM.

Guar harvest, Las Cruces, NM.

Guar pods

Guar nodules

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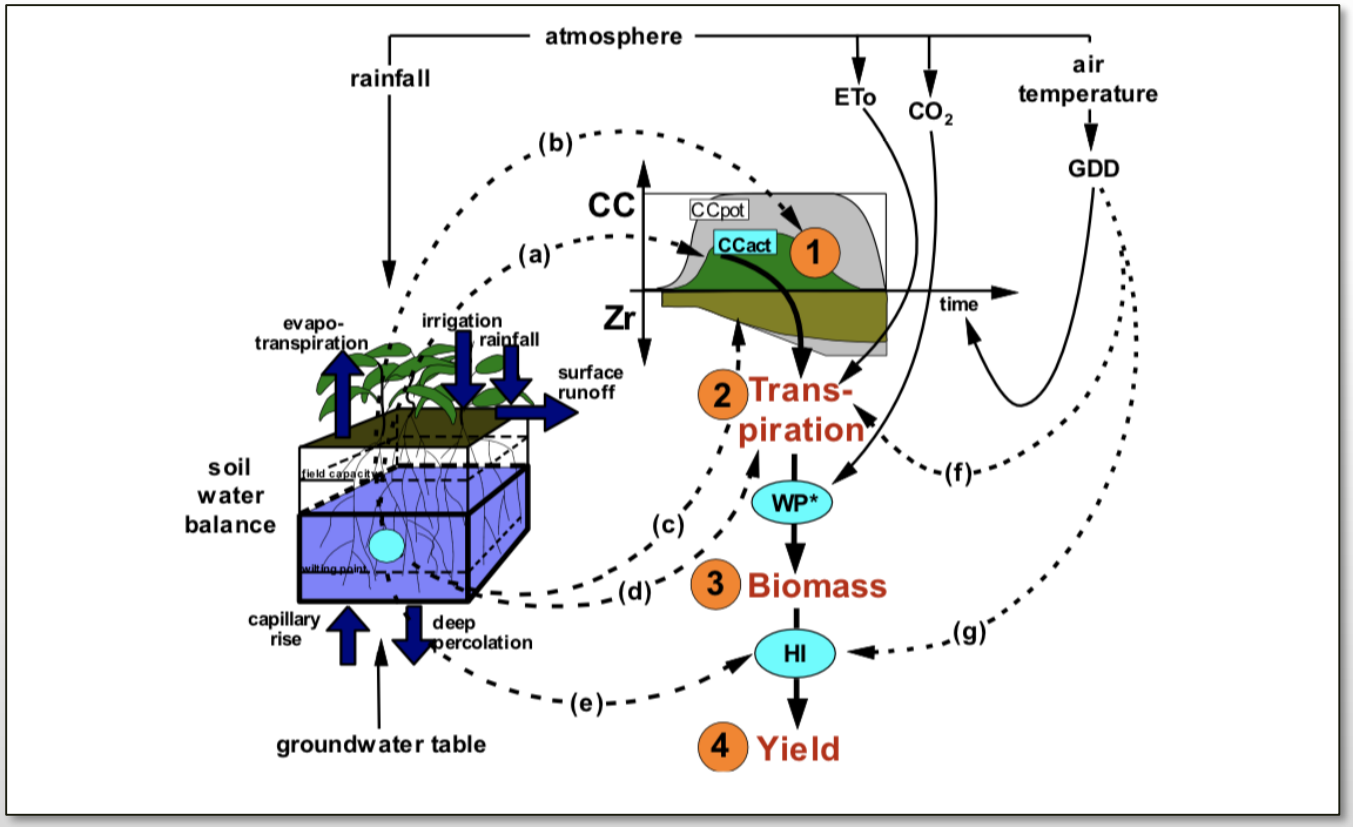
AquaCrop Modeling of Guayule

Patrick Lohr, Sarocha Pradyawong, Kim Ogden



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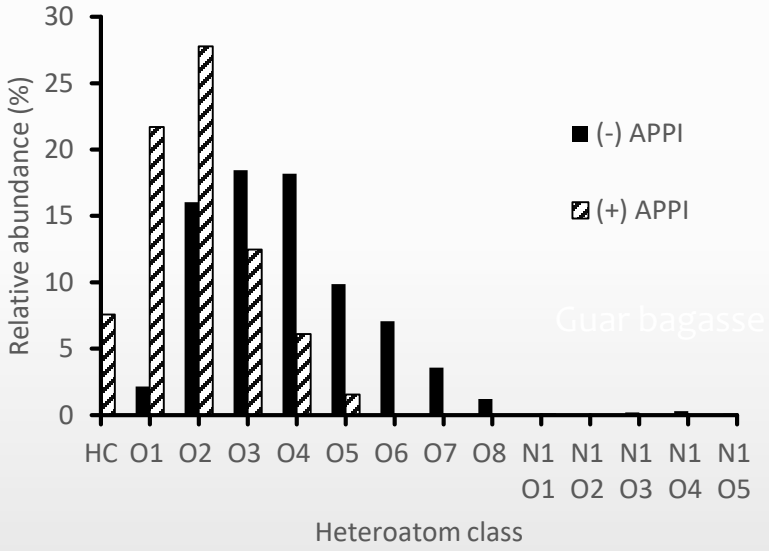
POST-HARVEST LOGISTICS & CO-PRODUCTS

Lead: Catie Brewer
Team: M. Armijo, H. Bayat, M. DeDecker, M. DehghanizadehL. Gunatilaka, E. Gutierrez, O. Holguin, J. Jarvis, U. Jena, A. Knagg, M. Liu, C. Madasu, H. Mozaffari, A. Muravijov, K. Ogden, M. Pradyawong, R. Rosalez, L. Rodriguez-Uribe, A. Rogstad, U. Sehar, A. Smith, N. Soliz, Y.-M. Xu, B. White, A. Wright

Co-Products from Bagasse and Resin (Brewer/Jena Groups)

- Preparing manuscripts on guayule bagasse/resin characteristics, conversion of low-cost protein- and lignin-rich biomass wastes into fuels, and guayule resin composition and applications
- Conducting guayule bagasse and algae co-hydrothermal liquefaction tests
- Initiating experiments into guayule resin applications as polymer tackifiers and urban insect repellents
- Supporting lab analysis for guar gum and biomass, guayule metabolites and resin, and sustainability modeling efforts
- Four graduate fellows working with middle school teachers on afterschool program and in-class SBAR-related activities



Heteroatom chemical compound class distribution for guayule resin observed using negative- and positive- ion atmospheric pressure photoionization Fourier-transform ion cyclotron resonance mass spectroscopy (APPI FT-ICR MS).

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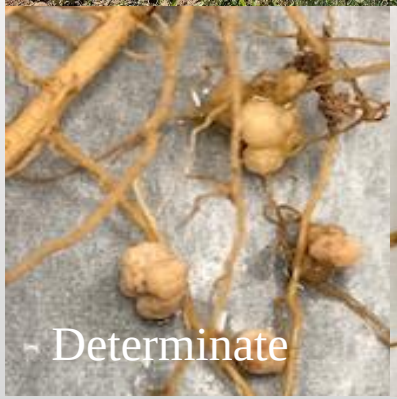
Guayule metabolomics studies on freeze tolerance and identification of *Rhizobia* in nodules of guar plants grown in NM

- Sixty-eight guayule leaf and stem samples were harvested from Cold Germination, Freeze tolerant, and Survivor plants grown at the Leyendecker Plant Science Center NM
- Five Rhizobia species were identified within the guar plants grown in Fabian Garcia : *Rhizobium azibense* 23C2, *Rhizobium* sp. AC93c, *Rhizobium* sp. T1Gsb2, *Rhizobium* sp. Cap_B1, and *Rhizobium pakistanense* BN-19.
- Three species of nodule associated bacteria identified: Pseudomonas, Bordetella, and Agrobacterium.



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SYSTEM PERFORMANCE & SUSTAINABILITY

Lead: Jason Quinn

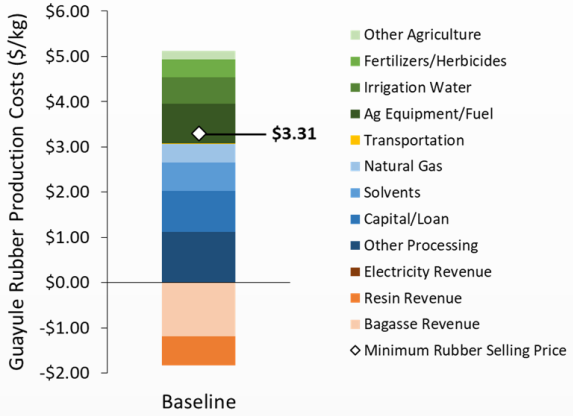
Team: C. Brewer, N. Fan, P. Gutierrez, S. Khanal, A. Landis, V. Mealing, P. Moreno, K. Ogden, A. Rogstad, T. Teegerstrom, C. Seavert, E. Sproul, H. Summers, D. Zuniga-Vazquez

Sustainability-CSU

Jason Quinn, Hailey Summers, Evan Sproul, Paula Moreno

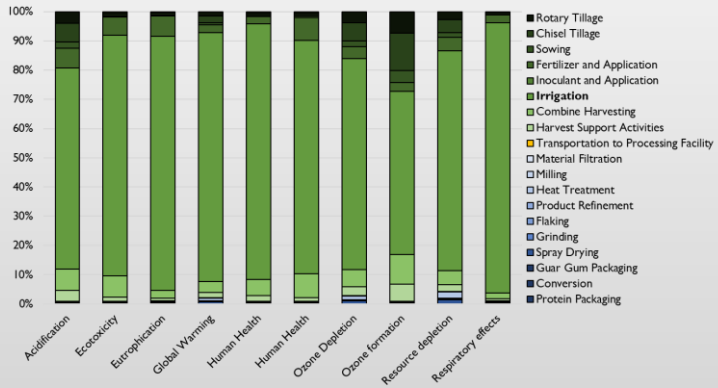
- Leading integrated modeling
- Baseline and scenario results for Guayule
- Baseline and scenario results for Guar
- Generation and submission of team wide publications
- Presentations of results at ACLCA, all hands meeting, SUS team working session

Guayule Economic Results

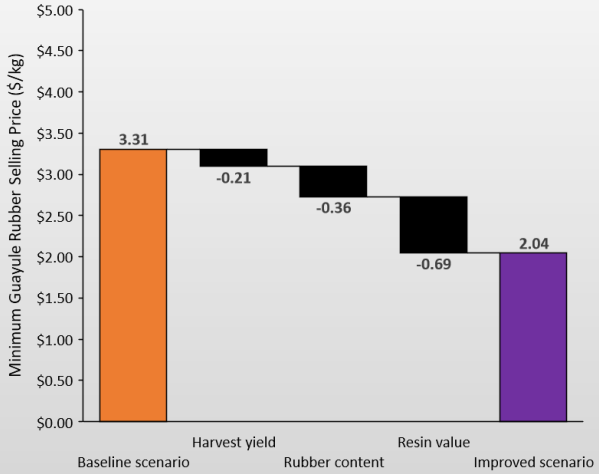


A few examples of updated results:

Guar Environmental impact Results



Guayule Economic Scenario Results



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Farm-Level Economics: Sita Khanal, Clark Seavert, Trent Teegerstrom & Paul Gutierrez

- Signed agreements between at least two Tribal Farms in AZ for Establishment of experimental plots on Tribal lands
- Budgets are included in the Sustainability Team's integrated model
- Five enterprise budgets to be published on university websites.
- Whole-farm case studies are linked into a sensitivity model that can be adjusted as desired for breakeven analysis.

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Optimization for Feedstock Logistics (Fan, Zuniga-Vazquez@UA) 1/15/2020

- Data collection process:
  - *Geographic information system (GIS) data from the USDA CropScape is collected for the most likely crops to switch to Guayule*
  - *Detailed farm information for the past 10 years is analyzed to identify additional potential facility locations (please refer to Fig. 1)*
  - *Parameters for the irrigation water used per crop were determined based on the feedback from the Research Meeting Group presentation*
- The multi-objective optimization model and algorithm are updated to consider:
  - *Multi-objective defined for economic, environmental, and social impacts with a weighted factor*
- Decomposition-based coding and algorithm updates:
  - *The model is coded using the programming language C++, the solver CPLEX, and the UoA's high performance computing (HPC).*
  - *The decomposition code is updated to include labor per location and construction permits within the model.*

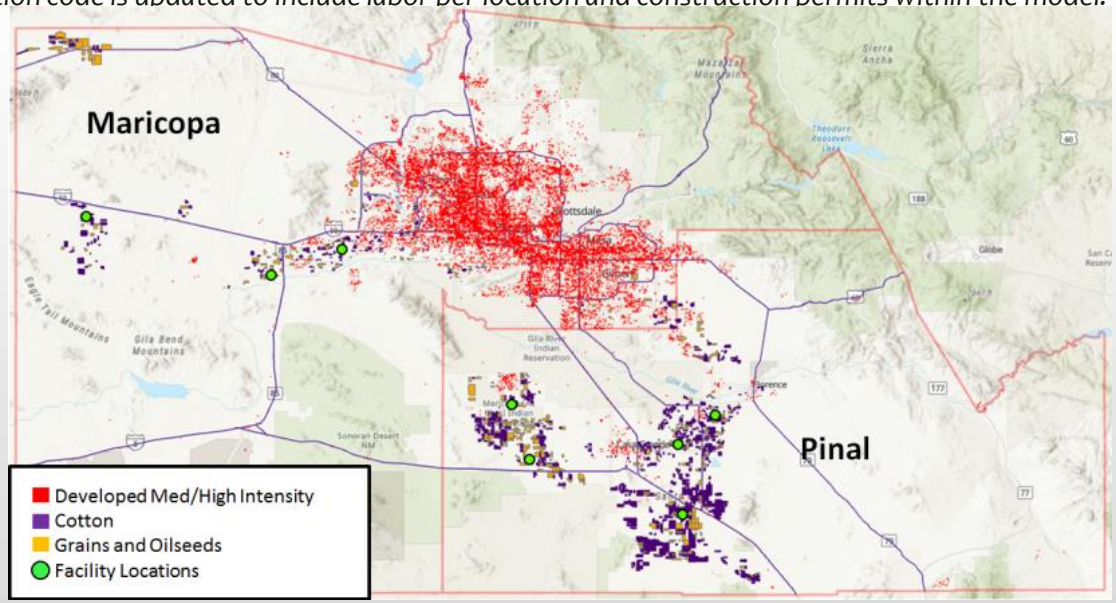

Fig 1. Identified facility locations based on most likely crops to switch to Guayule – Maricopa and Pinal

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Mines – Sustainability Team

Dr. Amy Landis, VeeAnder Mealing

- Data Integration
  - *Developed guar and guayule field trial summary tables, displaying all field trials, associated PIs and their purpose in one location*
  - *Lead field data collection effort proposed approaches for utilizing data in integrated model*
- Social Sustainability
  - *Initial literature and matrix mapping of social sustainability tools relevant for emerging feedstocks is complete*
  - *Reviewed and summarized data from social sustainability break out session at SBAR retreat & developed framework using United Nations' sustainable development goals*

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EDUCATION

Lead: Sara Chavarria

Curriculum & Instruction: C. Knox, T. Anderson, C. Brewer, G. Fritz

Support & Evaluation: C. Duncan, S. Sikora, J. Fields

Oversite: K. Ogden, A. Rogstad

Education Team

Team: Dr. Sara Chavarria, Dr. Corey Knox, Dr. Catie Brewer, Torran Anderson, Cara Duncan, Stephanie Sikora

- July 2019: Summer Train the Trainer at NMSU and Professional Development Week at UA
- Fall Seminar with SBAR Fellows working in their SBAR Teachers classroom focused on lesson plan development
- Development of an SBAR lesson plan template. Two lesson plans submitted for the Educational Resource page on the SBAR website.
- Classroom visits to SBAR teacher/fellow schools. Including a trip to Sells, AZ where two new SBAR teacher/fellow pairs are working on Tohono O'odham Nation.

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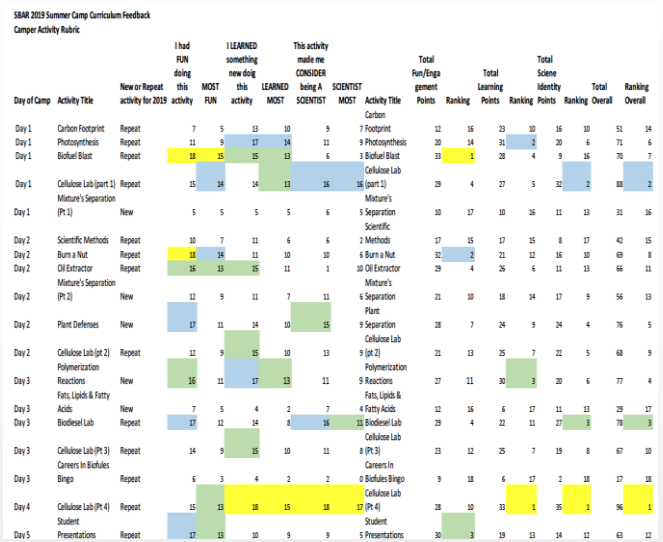
Evaluation of EEO, Jen Fields

- Implemented evaluation tools and protocols for summer EEO activities, including AZ 4-H summer camp and AZ/NM SBAR teacher/fellow PD
- Analyzed data from evaluation tools implemented with campers, teachers, and fellows including observations, surveys, concept mapping and focus group interviews. Received ongoing input from EEO staff via individual interviews and meetings.



SBAR 2019 Summer Camp Curriculum Feedback
Camper Activity Rubric

Day of Camp	Activity Title	New or Repeat activity for 2019	I had FUN doing this activity	MOST FUN	I LEARNED something new doig this activity	LEARNED MOST	This activity made me CONSIDER being A SCIENTIST	SCIENTIST MOST	Activity Title	Total Fun/Engagement Points	Ranking	Total Learning Points	Ranking	Total Scienc Identity Points	Ranking	Total Overall	Ranking Overall
Day 1	Carbon Footprint	Repeat	7	5	13	10	9	7	Carbon Footprint	12	16	23	10	16	10	51	14
Day 1	Photosynthesis	Repeat	11	9	17	14	11	9	Photosynthesis	20	14	31	2	20	6	71	6
Day 1	Biofuel Blast	Repeat	18	15	15	13	6	3	Biofuel Blast	33	1	28	4	9	16	70	7
Day 1	Cellulose Lab (part 1)	Repeat	15	14	14	13	16	16	Cellulose Lab (part 1)	29	4	27	5	32	2	88	2
Day 1	Mixture's Separation (Pt 1)	New	5	5	5	5	6	5	Mixture's Separation	10	17	10	16	11	13	31	16
Day 2	Scientific Methods	Repeat	10	7	11	6	6	2	Scientific Methods	17	15	17	15	8	17	42	15
Day 2	Burn a Nut	Repeat	18	14	11	10	10	6	Burn a Nut	32	2	21	12	16	10	69	8
Day 2	Oil Extractor	Repeat	16	13	15	11	1	10	Oil Extractor	29	4	26	6	11	13	66	11
Day 2	Mixture's Separation (Pt 2)	New	12	9	11	7	11	6	Mixture's Separation	21	10	18	14	17	9	56	13
Day 2	Plant Defenses	New	17	11	14	10	15	9	Plant Separation	28	7	24	9	24	4	76	5
Day 2	Cellulose Lab (pt 2)	Repeat	12	9	15	10	13	9	Cellulose Lab (pt 2)	21	13	25	7	22	5	68	9
Day 3	Polymerization Reactions	New	16	11	17	13	11	9	Polymerization Reactions	27	11	30	3	20	6	77	4
Day 3	Fats, Lipids & Fatty Acids	New	7	5	4	2	7	4	Fats, Lipids & Fatty Acids	12	16	6	17	11	13	29	17
Day 3	Biodiesel Lab	Repeat	17	12	14	8	16	11	Biodiesel Lab	29	4	22	11	27	3	78	3
Day 3	Cellulose Lab (Pt 3)	Repeat	14	9	15	10	11	8	Cellulose Lab (Pt 3)	13	12	25	7	19	8	67	10
Day 3	Careers In Biofules Bingo	Repeat	6	3	4	2	2	0	Careers In Biofules Bingo	9	18	6	17	2	18	17	18
Day 4	Cellulose Lab (Pt 4)	Repeat	15	13	18	15	18	17	Cellulose Lab (Pt 4)	28	10	33	1	35	1	96	1
Day 5	Student Presentations	Repeat	17	13	10	9	9	5	Student Presentations	30	3	19	13	14	12	63	12

- Provided summarized evaluation findings and data analysis spreadsheets to EEO groups so that they could review full evaluation data from each stakeholder group.
- Provided suggestions to EEO teams, based on evaluation findings, for program modifications moving forward into year 3 EEO activities
- Developed Year 2 annual evaluation report

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EXTENSION & OUTREACH

Leads: John Idowu & Blase Evancho

Team: S. Angadi, S. Begna, P. Bhandari, N. Brassill, M. Darapuneri, D. Dierig, C. Duncan, J. Fields, A. Garcia, A. Gellis, K. Grover, P. Gutierrez, S. Khanal, J. Miller, K. Ogden, D. Pruitt, C. Rock, A. Rogstad, J. Singh, P. Singh, T. Teegerstrom, S. Wang

Extension & Outreach

Arizona

- Weed management trials were presented at the Central Arizona Farmer Field Day to 43 growers grower and ag professionals.
- The needs assessment survey was deployed to Native American communities in Arizona, and we received input on 13,700 agriculture production acres.
- The SBAR Newsletter was completed and delivered to 319 subscribers to the "Crop Rotator" Central Arizona Extension Newsletter.

Dr. Bill McCloskey discusses guayule weed management trials.

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Guar extension and outreach- Kulbhushan Grover

- Farmer field demonstrations on guar
  - *Anthony, NM*
- SBAR Train-the-Trainer workshop on guar
  - *NMSU, Las Cruces, NM*
- Future Farmers of America (FFA) Conference presentation on guar
  - *NMSU, Las Cruces, NM*
- NMSU Agric. College Open House- community event on guar products
  - *NMSU, Las Cruces, NM*
- Field tours of guar trials to students, growers and researchers.
  - *NMSU, Las Cruces, NM*

Farmer field demonstration on Guar, Anthony, NM.

College Open House, Las Cruces, NM.

Train-the-trainer workshop on Guar, Las Cruces, NM.

FFA workshop on guar

Tour of Guar field, Las Cruces, NM.

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SBAR – Grower Extension

John Idowu

- Guar and guayule information were presented at:
  - *SBAR Train the Trainers Workshop, Las Cruces*
  - *Clovis Ag. Science Center Field Day*
  - *Tucumcari Ag. Science Center Field Day*
  - *Los Lunas Ag, Science Center Field Day*
  - *Program Review Event at NMSU*
- Guar on-station trials were completed in Las Cruces, Los Lunas, Tucumcari and Clovis, NM.
- Farmers were able to see the guar demonstration trials during the field days at various locations.
- First SBAR Grower Extension Newsletter was released in December 2019.
- At least 550 people were reached with SBAR information in New Mexico.

Guar fertility trial in Clovis, NM

SBAR Grower Newsletter

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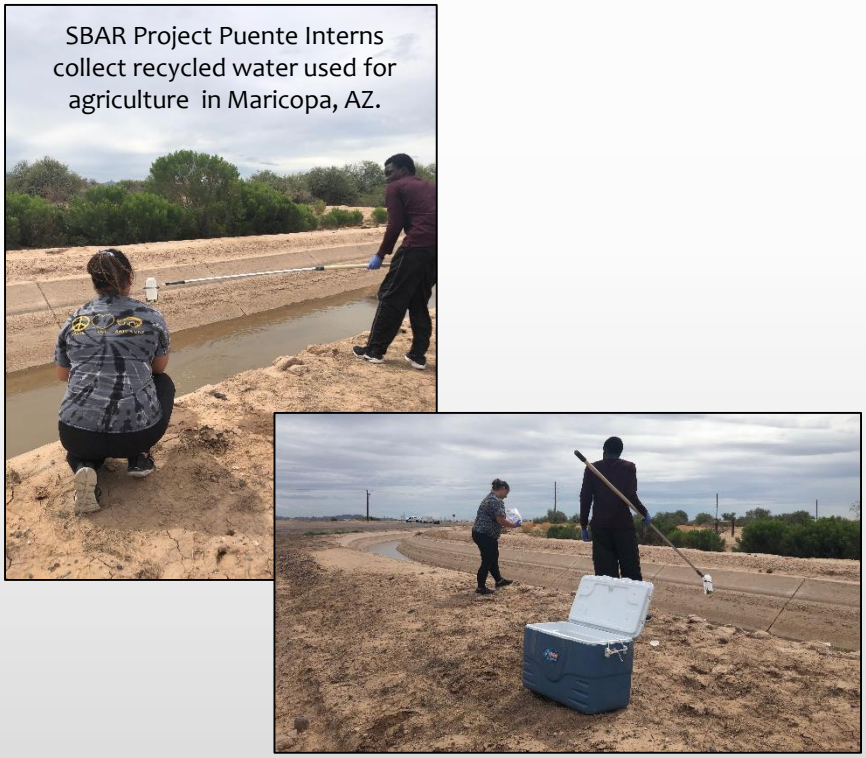
Arizona Cooperative Extension -

Channah Rock, Natalie Brassill, & Stevi Zozaya

- Collected feedback from SBAR 'Project Puente' 2019 mentors
- Started the development of new 'Project Puente' mentor materials
- Started the development of new 'Project Puente' intern materials
- Begin recruitment of SBAR 2020 Summer Interns and Mentors



SBAR Project Puente Interns collect recycled water used for agriculture in Maricopa, AZ.

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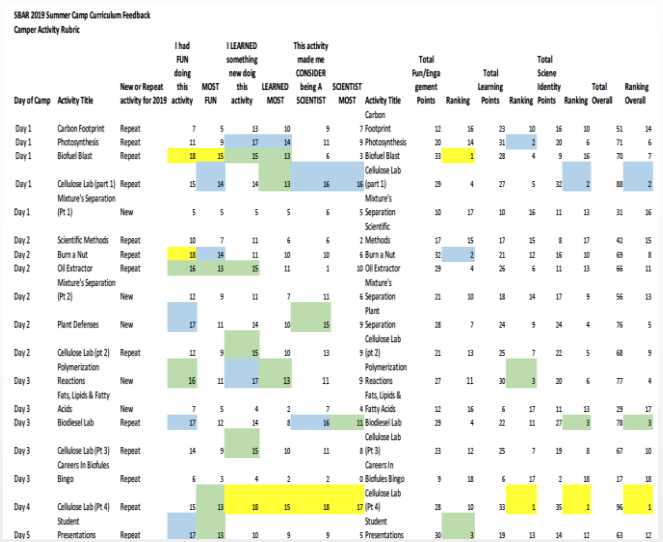
Evaluation of EEO, Jen Fields

- Implemented evaluation tools and protocols for summer EEO activities, including AZ 4-H summer camp and AZ/NM SBAR teacher/fellow PD
- Analyzed data from evaluation tools implemented with campers, teachers, and fellows including observations, surveys, concept mapping and focus group interviews. Received ongoing input from EEO staff via individual interviews and meetings.



SBAR 2019 Summer Camp Curriculum Feedback
Camper Activity Rubric

Day of Camp	Activity Title	New or Repeat activity for 2019	I had FUN doing this activity	MOST FUN	I LEARNED something new doig this activity	LEARNED MOST	This activity made me CONSIDER being A SCIENTIST	SCIENTIST MOST	Activity Title	Total Fun/Engagement Points	Ranking	Total Learning Points	Ranking	Total Scienc Identity Points	Ranking	Total Overall	Ranking Overall
Day 1	Carbon Footprint	Repeat	7	5	13	10	9	7	Carbon Footprint	12	16	23	10	16	10	51	14
Day 1	Photosynthesis	Repeat	11	9	17	14	11	9	Photosynthesis	20	14	31	2	20	6	71	6
Day 1	Biofuel Blast	Repeat	18	15	15	13	6	3	Biofuel Blast	33	1	28	4	9	16	70	7
Day 1	Cellulose Lab (part 1)	Repeat	15	14	14	13	16	16	Cellulose Lab (part 1)	29	4	27	5	32	2	88	2
Day 1	Mixture's Separation (Pt 1)	New	5	5	5	5	6	5	Mixture's Separation	10	17	10	16	11	13	31	16
Day 2	Scientific Methods	Repeat	10	7	11	6	6	2	Scientific Methods	17	15	17	15	8	17	42	15
Day 2	Burn a Nut	Repeat	18	14	11	10	10	6	Burn a Nut	32	2	21	12	16	10	69	8
Day 2	Oil Extractor	Repeat	16	13	15	11	1	10	Oil Extractor	29	4	26	6	11	13	66	11
Day 2	Mixture's Separation (Pt 2)	New	12	9	11	7	11	6	Mixture's Separation	21	10	18	14	17	9	56	13
Day 2	Plant Defenses	New	17	11	14	10	15	9	Plant Separation	28	7	24	9	24	4	76	5
Day 2	Cellulose Lab (pt 2)	Repeat	12	9	15	10	13	9	Cellulose Lab (pt 2)	21	13	25	7	22	5	68	9
Day 3	Polymerization Reactions	New	16	11	17	13	11	9	Polymerization Reactions	27	11	30	3	20	6	77	4
Day 3	Fats, Lipids & Fatty Acids	New	7	5	4	2	7	4	Fats, Lipids & Fatty Acids	12	16	6	17	11	13	29	17
Day 3	Biodiesel Lab	Repeat	17	12	14	8	16	11	Biodiesel Lab	29	4	22	11	27	3	78	3
Day 3	Cellulose Lab (Pt 3)	Repeat	14	9	15	10	11	8	Cellulose Lab (Pt 3)	13	12	25	7	19	8	67	10
Day 3	Careers In Biofules Bingo	Repeat	6	3	4	2	2	0	Careers In Biofules Bingo	9	18	6	17	2	18	17	18
Day 4	Cellulose Lab (Pt 4)	Repeat	15	13	18	15	18	17	Cellulose Lab (Pt 4)	28	10	33	1	35	1	96	1
Day 5	Student Presentations	Repeat	17	13	10	9	9	5	Student Presentations	30	3	19	13	14	12	63	12

- Provided summarized evaluation findings and data analysis spreadsheets to EEO groups so that they could review full evaluation data from each stakeholder group.
- Provided suggestions to EEO teams, based on evaluation findings, for program modifications moving forward into year 3 EEO activities
- Developed Year 2 annual evaluation report

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