



Association for the Advancement  
of Industrial Crops



AAIC  
2019 ANNUAL MEETING



*Advancing the adoption of industrial crops  
through innovation and technology*

El Conquistador Hilton Resort  
Tucson, Arizona USA  
September 8-11, 2019



SUSTAINABLE BIOECONOMY  
FOR ARID REGIONS



RESEARCH, DISCOVERY & INNOVATION  
Institute for Energy Solutions



*Cover art (in collaboration with 4-H Youth  
Development, University of Arizona Cooperative  
Extension)*

**PLANT MATTER MAKES THE WORLD GO ROUND**  
Alexis Peck, Grade 11, Duncan High School, Duncan, AZ



**ASSOCIATION FOR THE ADVANCEMENT  
OF INDUSTRIAL CROPS**

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“ADVANCING THE ADOPTION OF INDUSTRIAL CROPS  
THROUGH INNOVATION AND TECHNOLOGY”

31<sup>st</sup> Annual Meeting

September 8-11, 2019

Tucson, Arizona USA

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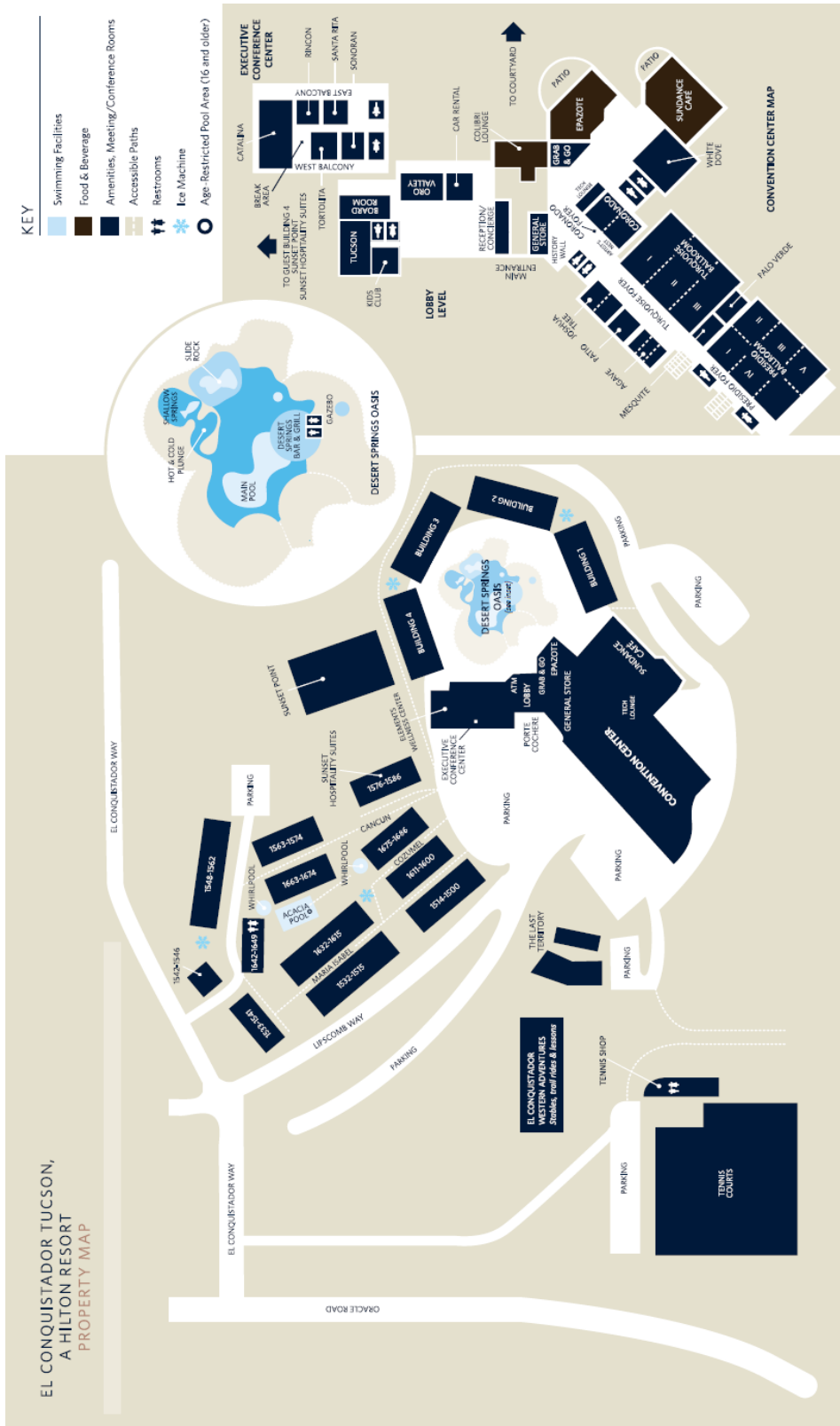
## **Division Chairs**

Fibers & Cellulosics:	Efthymia Alexopoulou, Centre for Renewable Energy Sources and Saving (CRESS), Pikermi, Greece
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Medicinal & Nutraceutical Plants:	Diana Jasso De Rodríguez, Universidad Autónoma Agraria Antonio Narro, Saltillo, Coahuila, México
Natural Rubber & Resins:	Guangyao (Sam) Wang, Bridgestone Americas, Inc., Eloy, AZ, USA
Oilseeds:	Hussein Abdel-Haleem, USDA-ARS ALARC, Maricopa, AZ, USA

To cite this publication: Cruz, V.M.V. and M. Berti. (eds.) 2019. Advancing the Adoption of Industrial Crops through Innovation and Technology. 31<sup>st</sup> Annual Meeting of the Association for the Advancement of Industrial Crops (AAIC). Program and Abstracts. September 8-11, 2019, Tucson, Arizona, USA.

# El Conquistador Hilton Resort

## Tucson, Arizona



# Conference Program

## Sunday, September 08

2:00 - 4:00 PM	New Crops Crop Germplasm Committee Meeting	Board Room
4:00 - 5:00 PM	AAIC Board Meeting	Board Room
4:00 - 6:00 PM	Registration	Coronado Foyer
4:00 - 6:00 PM	Poster Set-up	Coronado
6:00 - 9:00 PM	Opening Reception <i>Navigating the Sonoran Skies with Guest Astronomer</i>	The Last Territory

## Monday, September 09

### Plenary Session

**Moderator: Von Mark Cruz**

**Room: Coronado**

8:00-10:00 AM	Registration Desk Open and Poster set up	Coronado Foyer
8:00 AM	<u>Von Mark Cruz</u> , Bridgestone Americas, Inc.	Introduction
8:05 AM	<u>Barbra Coffee</u> , Economic Initiatives Director, City of Tucson, AZ	Welcome
8:15 AM	<u>Thomas O'Halleran</u> , Congressman (AZ-01), Member, House Committee on Agriculture	Keynote address
8:30 AM	<u>Alix Rogstad</u> , Project Director, SBAR, Univ. of Arizona, Tucson, AZ	Sustainable Bioeconomy for Arid Regions (SBAR)
8:45 AM	<u>Kamel Didan</u> , Associate Professor and Head, Vegetation Index and Phenology Lab, Univ. of Arizona, Tucson AZ	From UAS to spaceborne observation: Challenges and opportunities
<b>9:45-10:00 AM</b>	<b>Coffee Break</b>	
10:00 AM	<u>Joyce Van Eck</u> , Director, Boyce Thompson Institute Center for Plant Biotechnology Research, Ithaca, NY	Application of gene editing to accelerate improvement of underutilized crops
11:00 AM	<u>Kelly Thorp</u> , Agricultural Engineer, USDA-ARS Arid-Land Agricultural Research Center, Maricopa, AZ	UAS technologies for HTP and irrigation management

**Lunch on Your Own**

## Plenary Session (*continued*)

1:30 PM	<u>Fei Jia (Jeff)</u> , Technical Solutions Manager, Heliospectra, Guthenburg, Sweden	Lighting applications in Controlled Environment Agriculture (CEA) Systems
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## TECHNICAL SESSIONS

### 1. Oilseeds Division

**Moderator: Hussein Abdel-Haleem**

**Room: Coronado**

2:30 PM	<u>Sheeja George</u> , R. Seepaul, I. Small, G. Johnston, and D. Wright	Renewables from <i>Brassica carinata</i> -opportunities for a domestic fuel and coproduct supply chain
2:50 PM	<u>Winthrop B. Phippen</u> , J.C. Sedbrook, M.D. Marks, and M.S. Wells	Program to commercialize pennycress ( <i>Thlaspi arvense</i> L.)
3:10 PM	J. Costa, L. Gomes, C. Graça, M. Ferreira, F. Germanà, M. Abias, C. Rodrigues, F. Zanetti, A. Monti, and <u>Ana Luisa Fernando</u>	Screening of different oil crops for phytoremediation of heavy metals contaminated soils
3:30 PM	<b>Coffee Break</b>	
3:40 PM	<u>Federica Zanetti</u> , B. Alberghini, A. Borghesi, A. Vecchi, T. Isbell, R.V. Loo, and A. Monti	Sowing date effects on crambe EMS mutants with improved oil composition
4:00 PM	<u>Katherine Frels</u> , R. Chopra, K.M. Dorn, D.L. Wyse, M.D. Marks, and J.A. Anderson	Genetic diversity of field pennycress ( <i>Thlaspi arvense</i> ) reveals untapped variability and paths toward selection for domestication
4:20 PM	<u>Alex Wittenberg</u> , M.T. Berti, A. Peterson, D.P. Samarappuli, A. Greenberg, K. Mozea, S. Cabello, S. Podder, and J.V. Anderson	Fall sowing dates in camelina affected plant density
4:40 PM	<u>Zinan (Lily) Luo</u> , T. Kutchan, M. Augustin, N. Fehlgren, D.P. Schachtman, Y. Ge, J. Dyer, and H. Abdel-Haleem	Genome-wide association study (GWAS) helps unveil the genomic regions controlling yield components and fatty acids in <i>Camelina sativa</i>
5:00 PM	<u>Yesuf Assen Mohammed</u> , H.L. Matthees, R. Gesch, S. Patel, F. Forcella, B. Johnson, M.S. Wells, and A.W. Lenssen	Seed and oil yields of winter annual oilseed crops interseeded into maize ( <i>Zea mays</i> L.), and soybean [( <i>Glycine max</i> (L.) Merr.)]
5:20 PM	<u>Efthymia Alexopoulou</u>	Selected oilseed crops to be grown on marginal lands in Europe
5:40-6:00 PM	<b>Oilseeds Division Meeting - Division Chair: Hussein Abdel-Haleem</b>	

**Dinner on Your Own**

## Tuesday, September 10

8:00-11:45 AM	<b>Tour- Biosphere 2, Oracle, AZ</b>
8:00 AM	Board bus – Hotel entrance
8:30 AM	Bus departs
9:15 AM	Biosphere 2 Tour
11:15 AM	Board bus
11:45 AM	Arrive hotel

### Lunch on Your Own

## TECHNICAL SESSIONS

### 2. Medicinal and Nutraceutical Plants Division

**Moderator: Diana Jasso de Rodríguez**

**Room: Coronado**

1:30 PM	<i>Invited speaker:</i> <u>Mahesh Pattabiraman</u> and D.K. Santra	Mint ( <i>Mentha</i> sp.) varieties for commercial production in western Nebraska
1:50 PM	<u>Diana Jasso de Rodríguez</u> , C.F. Alonso-Cuevas, R. Rodríguez-García, H. Ramírez, M.L.V. Díaz-Jiménez, J.A. Villarreal-Quintanilla, and A. Juárez-Maldonado, and F.M.Peña-Ramos	Extracts of <i>Rhus</i> spp., <i>Flourensia</i> spp., and <i>Cucurbita foetidissima</i> as biostimulants of growth and yield of tomato
<b>2:10-2:30 PM</b>	<b>Medicinal and Nutraceuticals Plants Division Meeting</b> <b>Division Chair: Diana Jasso de Rodriguez</b>	
<b>2:30 PM</b>	<b>Coffee Break</b>	



### 3. Fibers and Cellulosics Division

**Moderator: Efthymia Alexopoulou**

**Room: Coronado**

3:00 PM	J. Liaw, <u>Dilpreet S. Bajwa</u> , L. Jiang, and S.G. Bajwa	Corn distillers dried grains with solubles (DDGS) – a functional material for manufacturing binderless particleboards
3:20 PM	B. Cumbane, L. Gomes, J. Costa, C. Rodrigues, F. Zanetti, A. Monti, E. Alexopoulou, and <u>Ana Luisa Fernando</u>	Kenaf ( <i>Hibiscus cannabinus</i> L.): a valuable fiber crop for heavy metals contaminated soils?
3:40 PM	<u>Efthymia Alexopoulou</u> , and E. G. Papazoglou	Industrial hemp: an old-new fiber crop
4:00 PM	<u>Efthymia Alexopoulou</u> , and F. Zanetti	Long-term yields for switchgrass lowland and upland ecotypes grown in the in the Mediterranean region
<b>4:20-4:40 PM</b>	<b>Fiber and Cellulosics Division Meeting- Division Chair: Efthymia Alexopoulou</b>	
<b>5:00-6:00 PM</b>	<b>Poster Session: Coronado</b>	

**Dinner on Your Own**

## Wednesday, September 11

TECHNICAL SESSIONS

**Concurrent Sessions**

### 4. Natural Rubber and Resins Division

**Moderator: Guangyao (Sam) Wang**

**Room: Coronado**

8:00 AM	<b>Invited speaker:</b> <u>Liqun Zhang</u> , R. Wang, J. Zhang, and Z. Wang	Progress of alternative elastomers with high performance
8:30 AM	<u>Serge Palu</u> , E.Tardan, D. Pioch, L. Brancheriau, N. Boutahar, and M. Dorget	Development of guayule ( <i>Parthenium argentatum</i> A. Gray) in the south of France after the EU-Pearls project
8:50 AM	<u>Muhammad Akbar Abdul Ghaffar</u> and K. Cornish	Discovery of rubber particle ontogeny pathways during <i>Taraxacum kok-saghyz</i> rubber formation
9:10 AM	<u>Diaa Eldin M. Elshikha</u> , P.M. Waller, D.J. Hunsaker, D. Dierig, G. (Sam) Wang, V.M.V. Cruz, K.R. Thorp, K.F. Bronson, and M.E. Katterman	Growth and yield of direct seeded guayule under SDI and furrow irrigation

9:30 AM	<b>Coffee break</b>	
10:00 AM	<u>David A. Dierig</u> , G. (Sam) Wang, D. E. Elshikha, T. Sullivan, S. Dittmar, and V.M.V. Cruz	Guayule growth and yield over time at two locations at high and low irrigation treatments
10:20 AM	H. Maqsood, <u>Peter Waller</u> , D.E. Elshikha, D. Hunsaker, M. Katterman, D. Dierig, S. Wang, and K. Ogden	Assessment of irrigation requirement for guayule using winds model
10:40 AM	X. Ren, C.S. Barrera, J.L. Tardiff, and <u>Katrina Cornish</u>	Liquid guayule natural rubber, a renewable processing aid for high-performance natural and synthetic rubber composites
11:00 AM	<u>William B. McCloskey</u> and G. (Sam) Wang	Guayule ( <i>Parthenium argentatum</i> A. Gray) seedling tolerance to topically applied carfentrazine-ethyl herbicide
11:20 AM	<u>Chen Dong</u> , G. Ponciano, Y. Wang, N. Huo, D. Hunsaker, D.E. Shikha, Y.Q. Gu, and C. McMahan	Gene expression of guayule field plants under drought stress: a comparative RNA-SEQ study
11:40 AM	V.M.V. Cruz, G. (Sam) Wang, A. Lynch, S. Dittmar, T. Sullivan, R. Prock, W. Niaura, and <u>David A. Dierig</u>	Guayule germplasm characterization for variation in ploidy and biomass production
<b>12:00-1:30 PM</b>	<b>General Membership Luncheon Meeting (Coronado II)</b>	
1:30 PM	<u>Dante F. Placido</u> , N. Dong, T. Pham, T. Huynh, B. Amer, E. Baidoo, and C. McMahan	Down-regulation of squalene synthase in guayule ( <i>Parthenium argentatum</i> )
1:50 PM	<u>Guangyao (Sam) Wang</u> , D. Dierig, and D.T. Ray	Guayule response to plant population
2:10 PM	<u>Mostafa Dehghanizadeh</u> , F. Cheng, J.M. Jarvis, F.O. Holguin, and C.E. Brewer	High resolution mass spectroscopy for characterization of resin from guayule ( <i>Parthenium argentatum</i> )
2:30 PM	<u>Claire Heinitz</u> , H. Abdel-Haleem, G. Ponciano, and S. Dohle	Results of the August 2019 Texas guayule exploration trip
2:50 PM	C. Seavert, <u>Trent Teegerstrom</u> , P. Gutierrez, and S. Khanal	Whole farm analysis tool for evaluating the adoption of guayule and guar into southwest producers current operation
<b>3:10-3:30 PM</b>	<b>Rubber and Resins Division Meeting, Division Chair: Sam Wang</b>	

<b>4:00-5:00 PM</b>	<b>AAIC board meeting: El Conquistador Board Room</b>	
<b>5:30-8:30 PM</b>	<b>AAIC Awards Banquet: Catalina Guest Speaker: John Adams, Deputy Director, Biosphere 2, University of Arizona, Tucson, AZ</b>	

## Concurrent Sessions

### 5. General Crops & Products Division

**Moderator: Ana Luisa Fernando**

**Room: Oro Valley**

8:20 AM	<u>Hadiqa Maqsood</u> , S. Angadi, D.E. Elshikha, P. Waller, J. Singh, D. Hunsaker, and B. Barau	Evaluating crop water status for guar using winds model
8:40 AM	<u>Sita Khanal</u> , J. Robbs, R. Acharya, and P. Gutierrez	Import demand and potential for domestic production of guar
9:00 AM	<u>Kutay Yilmaz</u> and B.L. Johnson	Seeding date effect on grain sorghum performance in North Dakota
9:30 AM	<b>Coffee Break – Oro Valley</b>	
10:00 AM	<u>Burton L. Johnson</u> , K. Yilmaz, and A.G. Taylor	Seeding date and seed treatment effect on industrial hemp stand establishment
10:20 AM	<u>Maria M. Jenderek</u> , B.D. Ambruzs, G.E. Holman, D.J. Carstens, D.D. Ellis, and M.P. Widrlechner	Using dormant buds for preservation of industrial woody species. the <i>Salix</i> case
10:40 AM	L. Gomes, J. Costa, C. Rodrigues, F. Santos, F. Zanetti, A. Monti, and <u>Ana Luisa Fernando</u>	Yield potential and biomass characteristics of the perennial crops giant reed ( <i>Arundo donax</i> L.) and switchgrass ( <i>Panicum virgatum</i> L.) in soils contaminated with heavy metals
11:00-11:30 AM	<b>General Crops Division Meeting - Division Chair: Ana Luisa Fernando</b>	
12:00-1:30 PM	<b>General Membership Luncheon Meeting (Coronado II)</b>	

4:00-5:00 PM	<b>AAIC board meeting: Board Room</b>	
5:30-8:30 PM	<b>AAIC Awards Banquet: Catalina Guest Speaker: John Adams, Deputy Director, Biosphere 2, University of Arizona, Tucson, AZ</b>	

## Poster Presentations

### Room: Coronado

GENERAL CROPS & PRODUCTS		
1	<u>Curtis Adams</u> , S. Thapa, and C. Trostle	Root nodulation in guar ( <i>Cyamopsis tetragonolobus</i> L. Taub.): effects of soils, rhizobium inoculants, and guar varieties
2	<u>Jagdeep Singh</u> , S. Angadi, S. Begna, O.J. Idowu, and I. Guzman	Seasonal water extraction patterns of guar under different irrigation strategies in the Southern High Plains
3	<u>VeeAnder S. Mealing</u> , and A. E. Landis	Life cycle assessment of guar agriculture in the southwest USA
4	<u>J. Bradley Morris</u>	Seed viability from 30 roselle ( <i>Hibiscus sabdariffa</i> L.) accessions regenerated at USDA, ARS, PGRCU in Georgia, USA
5	<u>Efthymia Alexopoulou</u>	PANACEA - A thematic network to design the penetration path of non-food crops into European agriculture
6	<u>Efthymia Alexopoulou</u>	Which industrial crops can be grown on marginal lands?
7	<u>Candice Gardner</u> , J. Perrett, A. LeRoy, U. Frei, and D.M. Peters	Use of optical seed sorters for optimizing plant genetic resource seeds lots
MEDICINAL AND NUTRACEUTICALS		
8	<u>Ana V. Charles-Rodríguez</u> , L.L. Rivera-Solís, A.A. Vicente, J.T. Martins, Z. Genisheva, A. Robledo-Olivo, S. González-Morales, G. López-Guarin, D.G. Martínez-Vázquez, and M.L. Flores-López	Extracts of agrito ( <i>Rhus microphylla</i> ) for the control of plant pathogenic fungi
9	<u>Diana Jasso de Rodríguez</u> , R. Rodríguez-García, M.L.V. Díaz-Jiménez, J.A. Villarreal-Quintanilla, M.L. Flores-López, and F.M. Peña-Ramos	<i>Flourensia cernua</i> , an outstanding plant in the arid and semi-arid zones of Mexico
10	D.J. de Rodríguez, R. Rodríguez-García, <u>José A. Villarreal-Quintanilla</u> , M.L.V. Díaz-Jiménez, and F.M. Peña-Ramos	Antifungal activity of secondary metabolites of extracts of stems and rhizomes of <i>Jatropha dioica</i> and its control of <i>Fusarium oxysporum</i> in tomato.
11	M.I.M. Flores-Verástegui, A. Robledo-Olivo, A.V. Charles-Rodríguez, S.C. Rangel-Ortega, M. Hernández-González, A. Jiménez-Herrera, and D.G. Martínez-Vázquez	Effect of the temperature on the antioxidant quality and shelf life of concentrate of pitahaya ( <i>Pachycereus grandis</i> )
RUBBER AND RESINS		
12	Sita Khanal, C. Seavert, P. Gutierrez, and <u>T. Teegerstrom</u>	The economic potential of producing guayule in the southwest
13	Chloe Gonzalez, D.A. Dierig, and <u>V.M.V. Cruz</u>	Pollen studies in guayule: comparison of staining and sampling procedures and survey of pollen size variation
14	<u>Grisel Ponciano</u> , N. Dong, D. Placido, K.	Bioengineering of guayule ( <i>Parthenium argentatum</i> )

	Borg, L. Fonseca, C. Howard, D. Shintani, and C. McMahan	A. Gray) to enhance tocopherols content
<b>RUBBER AND RESINS (<i>continued</i>)</b>		
15	<u>Danielle Hoare</u> , M. Katterman, and P. Waller	Development of a remote crop condition sensing system utilizing internet of things technology & cloud computing
16	<u>Colleen McMahan</u> , D. Placido, D.E. Elshikha, C. Dong, G. Ponciano, and J. Neilson	Dormancy and the guayule ( <i>Parthenium argentatum</i> A. Gray) soil microbiome
17	<u>Guangyao (Sam) Wang</u> , A. Lynch, V.M.V. Cruz, and D. Dierig	Temperature requirements for guayule seed germination
<b>OILSEEDS</b>		
18	<u>Mark A. Smith</u>	Targeting improvement of seed quality in <i>camelina sativa</i> through development of a fast neutron (FN) mutagenesis population
19	<u>Marco Acciai</u> , F. Zanetti, and A. Monti	The potential of camelina ( <i>Camelina sativa</i> L. Crantz) and crambe ( <i>Crambe abyssinica</i> Hochst. ex R.E. Fries) in marginal slopy land of the Mediterranean region
20	<u>Roque L. Evangelista</u> , M.P. Hojilla-Evangelista, R.W. Gesch, S.C. Cermak, and T.A. Isbell	Aqueous fractionation of mucilage and protein from camelina seeds
21	<u>Katherine Frels</u> , R. Chopra, Z. Tandukar, K. Dorn, D. Wyse, M.D. Marks, and J.A. Anderson	Unlocking pennycress potential: rapid domestication through breeding and bioinformatics at the university of Minnesota
22	<u>Gerald J. Seiler</u> , R. Adams, and M. Lavin	Variation of hexane extractable hydrocarbons in native populations of wild <i>Helianthus annuus</i>
23	<u>Federica Zanetti</u> , A. Vecchi, E. Alexopoulou, M. Christou, A. Borghesi, T. Isbell, and A. Monti	How much is sole-cropping system sustainable for camelina and crambe?
24	<u>Steven C. Cermak</u> , G.H. Roh, J.A. Kenar, and J. Zhu	Spatial and contact repellency of coconut materials Against biting flies
<b>FIBERS AND CELLULOSICS</b>		
25	<u>Efthymia Alexopoulou</u> , D. Li, and F. Zanetti	Kenaf ( <i>Hibiscus cannabinus</i> L.): a high yielding bast fiber crop for the Mediterranean region
26	<u>Efthymia Alexopoulou</u> , W. Zegada, M. Christou, and A. Monti	Sorghum, industrial hemp, sunn hemp, and kenaf can produce feedstock for advanced biofuels in the Mediterranean region

**PROGRAM ABSTRACTS**  
**KEYNOTE SPEAKERS AND PLENARY SESSION**

## FROM UAS TO SPACEBORNE OBSERVATION: CHALLENGES AND OPPORTUNITIES

Kamel Didan, Truman P. Combs, and Armando Barreto Munoz

The University of Arizona, Tucson, AZ, USA

With the global population edging towards the 10 billion mark by 2050 (7.7 billion in early 2019), the urgency and relevance of creative management of our limited natural resources remains critical. Two key questions arise: 1) how to improve food and crop production, and 2) which technologies to consider. The usual settings remain: limited water, limited agricultural land, and lack of labor. Mechanization and highly efficient water delivery are stretched to their limits, which necessitates other pathways to improving crop production and meeting the demand: 1) breeding and genetic manipulation which hold the most promise yet elicits the most controversy, 2) concerted reallocation of resources and optimization of crop production at a global scale (requiring some sort of central planning), and/or 3) envisioning an economical and operational ‘plant-level’ management, a sort of ‘super-precision agriculture which is part of the larger still insubstantial digital and smart agriculture vision. Low-cost and easy-to-operate Unmanned Aerial Systems (UAS) equipped with miniature sensors for measuring at high resolution (high fidelity remains tenuous) the physical and biogeochemical characteristics of the individual plant present a great opportunity to farming and resources management. Their goal remains to improve our monitoring and management capabilities. Whereas there are workarounds to their limited spatial footprint which is related to the UAS flight endurance, the technology continues to face the challenges of moving from the qualitative image-based visual assessments to the rigorous decision support systems capable of facilitating quantitative analysis. Furthermore, coarse- to medium-resolution synoptic spaceborne remote sensing data from sensors like Terra/Aqua MODIS, S-NPP VIIRS, and Landsat OLI offer rich and no-cost observation that can support monitoring and managing crops from the district to the global level. This suggests a framework where UAS provide the high-spatial-resolution and rich proximal data necessary to understand and characterize each plant, while the synoptic coarse-resolution spaceborne sensors provide the broader view required for a meaningful regional to global management of crops and natural resources. Here, we explore how such a framework can be designed to take advantage of field observations coupled with UAS-mounted miniature sensors for collecting super-high-resolution data, and finally how the two can inform and calibrate spaceborne remotely-sensed data. We present two examples: 1) characterizing the vegetation index of a natural landscape in a semiarid environment using multispectral UAS imagery, hyperspectral and high-resolution imagery from a low-flying, fixed-wing plane, and coarse- and medium-resolution MODIS/VIIRS and OLI data, and 2) deriving and characterizing field crop biomass with Structure-from-Motion techniques using an HD RGB camera mounted on an autonomous UAS as well as field and lab measurements. Both examples demonstrate great potentials at extremely low cost with reasonable and potentially operational results. While the UAS platforms, sensors, and required data science and algorithms continue to evolve, become more reliable, and easier to operate in a meaningful, economical and quantitative fashion, there are still some major challenges. We point to the lack of spectral standardization and critical calibration protocols for most miniature multispectral and other sensors/cameras which continue to pose a challenge to repeatable and scalable science, and the still very limited spatial footprint of these platforms.

*Contact: Kamel Didan, Biosystems Engineering Dept., The University of Arizona. 1177 E. 4th Street, Shantz Building, Room 403, Tucson, AZ, USA 85721-0038. Tel: 1 (520)-621-8514. E-mail: [didan@email.arizona.edu](mailto:didan@email.arizona.edu)*

# APPLICATION OF GENE EDITING TO ACCELERATE IMPROVEMENT OF UNDERUTILIZED CROPS

Joyce Van Eck

The Boyce Thompson Institute, Ithaca, NY, USA

The availability of gene editing technologies, especially CRISPR/Cas, has greatly advanced gene function studies and provides the long-term benefit of approaches to precisely manipulate phenotypes to advance crop improvement. These improvements have the potential to secure agricultural productivity by enhancement of characteristics such as yield and resilience to stresses imposed by climate extremes. Traits of interest to us are those that when modified can transform a plant species that is underutilized because of undesirable agronomic characteristics into one with potential to diversify options for agricultural production. Our early work with the *Solanaceae* family member tomato (*Solanum lycopersicum* L.) as a model centered on investigation of gene function as it relates to plant architecture, productivity, and fruit-related characteristics. Results from this work led us to believe that gene editing could be exploited to fast-track improvement, in a sense fast-track domestication of underutilized plant species. Our subsequent work has transitioned to other *solanaceous* species, including the closest tomato wild relative, *Solanum pimpinellifolium* L., and members of the distantly related *Physalis* genus to determine if what we learned from our earlier work with tomato is translatable to improvement or domestication of these species. Within the *Physalis* we are working with two different species, *Physalis pruinosa* L. (groundcherry), which is a diploid and *Physalis peruviana* L. (goldenberry) a tetraploid. Through application of CRISPR/Cas-mediated gene editing, we have observed timely improvements of undesirable phenotypes that cements our belief that this technology can indeed be exploited to turn an underutilized species into one with desirable agronomic characteristics within a realistic timeframe. To date, we have targeted a number of genes to affect characteristics such as plant growth habit and fruit size. We observed a more compact growth habit in both tomato and groundcherry by targeting the *Self Pruning* gene (*SP*, homolog of *Arabidopsis TFL1*) and its homolog *SP5G*. Related to fruit characteristics, we have recovered groundcherry fruit with a 24% increase in weight by editing the *CLAVATA1* (*CLV1*) gene as compared to the wild type, non-edited control. As our research has progressed, we have identified additional traits to improve in *Physalis* that would be considered undesirable from an agricultural productivity perspective. Through this work we intend to establish editing strategies for key genes that most affect traits such as growth habit, productivity, harvestability and others that if improved would increase the likelihood of underutilized plant species being part of a solution to strengthen food and agricultural security.

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## UAS TECHNOLOGIES FOR HTP AND IRRIGATION MANAGEMENT

Kelly Thorp

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Data-driven techniques to estimate crop water use will be advantageous in the development of drought-tolerant crop varieties. The objective of this research was to develop an approach to estimate daily water use for cotton varieties using multispectral drone imagery to estimate basal crop coefficients for a geospatial implementation of FAO-56. Two cotton field experiments were conducted in the same field during 2016 and 2017 in central Arizona: 1) a test of one cotton variety (DP 1549) responding to 16 irrigation strategies with water use estimated from weekly neutron soil water content measurements and 2) a test of 10 cotton varieties responding to 4 irrigation strategies and two planting dates with small plot size and large plot numbers prohibiting comprehensive soil water content measurements. Analytical methods were evaluated with water use data from the former study and applied to estimate cotton water use for all treatments in the latter study. Weekly multispectral images were collected with a MicaSense RedEdge camera mounted on a hexacopter drone and orthomosaicked using commercial Pix4D software. Images were calibrated by comparing digital numbers to measured spectral reflectance of targets deployed at the field edge during overflight. A supervised maximum likelihood classification was used to identify vegetation and bare soil image pixels for calculation of percent canopy cover within the area of each experimental plot. Soil texture measurements at 150 locations across the field provided data for calculating soil water holding and hydraulic conductivity characteristics via Rosetta pedotransfer functions and for analyzing spatial soil variation via ordinary kriging interpolation. Using drone-based canopy cover to estimate FAO-56 basal crop coefficients and with soil water limits defined geospatially, a Python-based FAO-56 algorithm was used to calculate cotton water use uniquely for each experimental plot. When combined with yield measurements, the methodology can be used to estimate crop water use efficiency for individual treatment plots in breeding trials.

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## LIGHTING APPLICATIONS IN CONTROLLED ENVIRONMENT AGRICULTURE SYSTEMS

Fei Jia (Jeff)

Heliospectra AB, Gothenburg, Sweden

This presentation is an introduction to state-of-the-art electrical lighting technology for controlled environment agriculture applications. Topics include general knowledge of light properties and the metrics to consider when evaluating lighting options for indoor farms and greenhouses. Our discussion will cover the measurement of light quality and common lighting control strategies for CEA applications. And we will review the effects of light spectrum and light quantity on various crops during the growth cycle and how to use both supplemental lighting and natural daylight to our advantage.

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# **ABSTRACTS**

**OILSEED DIVISION  
ORAL PRESENTATIONS**

**CHAIR  
HUSSEIN ABDEL-HALEEM, USDA-ARS, MARICOPA, AZ, USA**

## RENEWABLES FROM BRASSICA CARINATA- OPPORTUNITIES FOR A DOMESTIC FUEL AND COPRODUCT SUPPLY CHAIN

Sheeja George<sup>1</sup>, Ramdeo Seepaul<sup>1</sup>, Ian Small<sup>1</sup>, Glenn Johnston<sup>2</sup>, and David Wright<sup>1</sup>

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*Brassica carinata* (carinata) is a non-food oilseed crop that produces seed that can be processed into a premium quality industrial oil. There are proven and certified technologies to process carinata oil into renewable jet, renewable diesel, naphtha and a suite of other valuable coproducts. It is possible to grow carinata in the winter season in the Southeast US, which provides many unique advantages for this crop such as providing additional farm income, cover crop benefits, and several soil health and ecosystem services. It is estimated that carinata could be grown on over 1.2 million hectares in the SE US providing over \$1.2 billion in farm revenues in addition to income from traditional summer crops. The Southeast Partnership for Advanced Renewables from Carinata (SPARC) is a public-private consortium funded by the USDA National Institute of Food and Agriculture (NIFA) and led by the University of Florida. SPARC's objective is to commercialize sustainably produced carinata as a source of low carbon renewable jet and diesel fuel, high protein animal feed, and other renewable co products in the SE US. This talk will present an overview of carinata, research on best management practices for carinata production in the Southeast US, rotation fit of carinata with summer crops, and opportunities for establishing a viable supply chain in the SE US through research, extension and education.

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PROGRAM TO COMMERCIALIZE PENNYCRESS (*THLASPI ARVENSE L.*)

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A reliable, sustainable, and secure biofuels industry in the U.S. requires a diverse portfolio of feedstocks. Dedicated industrial crops which can be easily converted to drop-in fuels are limited in the Midwest region. To address this, our program will develop the oilseed plant pennycress (*Thlaspi arvense L.*) to be grown as a winter-annual cash cover crop throughout the U.S. Midwest Corn Belt and in other temperate-region cropping systems. Pennycress is a unique high-yielding oilseed crop that can be grown to: (1) provide environmental benefits including reducing nitrogen runoff and soil erosion from farm fields while providing early-season food sources for pollinating insects, (2) generate income thereby encouraging adoption and strengthening rural communities, (3) integrate seamlessly into existing corn-soybean rotations, and (4) yield up to 2 billion gallons of oil annually that can be easily converted to biofuels. Our program will specifically focus on pennycress variety improvement, agronomic management, environmental impacts assessment, and supply chain seed management. We will develop education and extension networks that enhance pennycress adoption and profitability by providing science-based guidance to producers and other stakeholders, training farmers, workers, and scientists, and highlighting new career opportunities. We fully expect that by the end of this five-year project to have established a set of management criteria to successfully commercialize pennycress as a dedicated oilseed biofuel feedstock grown in multiple Midwestern states. This will include tools and documented knowledge to (1) aid the seed industry in developing a reliable seed-source for planting, (2) provide extension educators and crop consultants with information needed to help farmers manage pennycress production, (3) provide farmers, oil processors, and livestock producers with necessary information to successfully produce and process pennycress seed oil for the biodiesel and aviation fuel industry, and (4) use the spent seed meal as a livestock feed ingredient. Since we recognize the need for regionally-adjusted agronomic practices, a strong emphasis will be placed on working directly with producers and industry. The use of pennycress as a cash cover crop will positively impact the profitability of production agriculture, decrease soil erosion and nutrient runoff thereby protecting water systems, support pollinator health and biodiversity, increase energy security by diversifying the nation's energy portfolio, help mitigate greenhouse gas emissions and related climate change, and contribute to the economic health of rural communities. The details of this program including; advances in variety development, production protocols, ecosystem services, supply chain development, and extension/education efforts will be discussed.

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## SCREENING OF DIFFERENT OIL CROPS FOR PHYTOREMEDIATION OF HEAVY METALS CONTAMINATED SOILS

J. Costa<sup>1,2</sup>, L. Gomes<sup>1</sup>, C. Graça<sup>1</sup>, M. Ferreira<sup>1</sup>, F. Germanà<sup>1,3</sup>, M. Abias<sup>1,4</sup>, C. Rodrigues<sup>1</sup>, F. Zanetti<sup>3</sup>, A. Monti<sup>3</sup>, and Ana Luisa Fernando<sup>1</sup>

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Cultivation of energy crops in heavy metals contaminated soils is an option once it contributes to reduce land use competition with food crops and the development of a vegetative cover contributes to reduce soil loss and degradation by erosion processes and water surface runoff. Therefore, the aim of this work was to study the effects of different heavy metals (Ni, Pb, Zn and Cd) on growth and yield of different oil crops, namely the oil crops *Camelina sativa* (L.) Crantz, *Brassica carinata* A. Braun and *Thlaspi arvense* L. The soils were artificially contaminated and the concentrations chosen were equivalent to twice the limits established by the Decree Law 276 of 2009 (Portuguese regulation that establishes the regime for the use of sewage sludge in agricultural soils) - Zn: 900 mg/kg; Pb: 900 mg/kg; Cd: 8 mg/kg and Ni: 220 mg/kg. Preliminary results indicate that *Brassica carinata* and *Camelina sativa* growth was not significantly affected by heavy metals contamination. By opposition, all the heavy metals affected the growth of *Thlaspi arvense*. However, *Thlaspi arvense* was the crop that presented the highest seed yield, either in non-contaminated and in contaminated soils. Overall, contamination reduced significantly the silique production, especially Ni and Cd contamination, which may hinder the economic viability of oil crops cultivation in heavy metals contaminated soils. Ni was the heavy metal that affected most the siliques yield of *Brassica carinata* and Cd was the heavy metal that affected most the silique yield of *Camelina sativa* and *Thlaspi arvense*. Biomass is being characterized to evaluate the effects of the contamination on the oil characteristics and the phytoremediation capacity of these oil crops to the heavy metals contaminated soils studied.

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## SOWING DATE EFFECTS ON CRAMBE EMS MUTANTS WITH IMPROVED OIL COMPOSITION

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Crambe (*Crambe abyssinica* R.E. Fries) is an interesting oilseed crop being extensively studied in Europe since the mid '80s in the framework of different European projects (i.e. DICRA, IENICA, ICON). The peculiar fatty acid composition (erucic acid >50%), the high content of glucosinolates, which excludes any food/feed applications of the cake, the very short growth cycle and the minimal input requirements, in terms of water and nitrogen, are the most attractive features of crambe for different bio-based applications. Despite the high content of erucic acid (C22:1), which is a monounsaturated fatty acid (MUFA), polyunsaturated fatty acids (PUFA) such as linoleic (C18:2) and linolenic (C18:3) acids still represent more than 15% of the total, thus partially reducing the oxidation stability of crambe oil. In the framework of the COSMOS project a set of five EMS mutants have been released by the Wageningen University and Research (The Netherland) characterized by a reduced PUFA content with respect with the wild type (Galactica) they originated from. A plot trial was set up at the experimental farm of Bologna University (Italy, 44°30' N, 11°21' E) in spring 2018, comparing Galactica with two mutants (MUT1 and MUT4) previously characterized as significantly different in terms of seed quality. Two sowing dates (SD5 = March 27 vs. SD6 = April 9) and two seeding rates (220 vs. 110 seeds m<sup>-2</sup>) were compared in a factorial experiment under a strip plot design, with sowing date in the main plots ( $n=3$ ). Crambe confirmed its good suitability to the Mediterranean climate, with seed yield > 2.3 Mg DM ha<sup>-1</sup> (grand mean of all cultivars, sowing dates and seeding rates). MUT4 reached significantly higher yield compared to MUT1 (2.54 vs. 2.06 Mg DM ha<sup>-1</sup>, MUT4 vs. MUT1, respectively), while Galactica showed intermediate values (2.40 Mg DM ha<sup>-1</sup>). While sowing date and seeding rate did not significantly affect seed yield. Seed weight was significantly ( $P\leq 0.05$ ) affected by both sowing date (SD5 > SD6) and cultivar (MUT1 = MUT4 > Galactica). Concerning oil composition, crambe mutants showed about half of the content of PUFA with respect to the wild type (7.6 vs. 15.7%, mean of MUT1 & MUT4 vs. Galactica). Interestingly while the PUFA content in the Galactica was not affected by sowing date, both crambe mutants significantly increased their content in response to earlier sowing (cv × sowing date effect,  $P\leq 0.05$ ). Galactica and MUT1 reported erucic acid content above 55% (i.e., Galactica 56.1% and MUT1 56.5%), otherwise MUT4 showed an erucic acid content of 52.1%, which was counterbalanced by an over accumulation of eicosenoic acid (C20:1) up to almost 6%, while normally this FA represents less than 3% of crambe oil. The availability of new crambe mutants with improved FA composition, enabling innovative chemical transformations, paves the way for a further development of this oilseed in Europe. The new mutants confirmed productive performance at least comparable or even higher than that of the wild type, but the effect of sowing date on their final oil composition should be carefully evaluated in order to meet the bio-based industry requirements.

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GENETIC DIVERSITY OF FIELD PENNYCRESS (*THLASPI ARVENSE*) REVEALS UNTAPPED  
VARIABILITY AND PATHS TOWARD SELECTION FOR DOMESTICATION

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Pennycress (*Thlaspi arvense* L.) has great potential to become a cash cover crop for the Upper Midwest that will provide ecosystem services as well as economic returns to farmers. Pennycress is planted in the fall, survives harsh winter conditions, and produces a harvestable oilseed in late spring, in time for planting a traditional summer crop such as soybeans. From fall to spring, pennycress reduces nutrient leaching and soil erosion and suppresses the growth of spring weeds. However, pennycress is a wild species that requires agronomic and seed quality improvements before it can be utilized in cropping systems. Evaluation of genetic diversity within wild pennycress is essential for breeding improved characteristics while avoiding genetic bottlenecks. This process involves evaluation of population structure and individual accessions based on genetic markers, growth habits, and geographic collection area. In this study, accessions of field pennycress were analyzed to identify population structure and variation in the germplasm available for breeding. A total of 9,157 genome-wide single nucleotide polymorphisms (SNPs) were identified among the 121 accessions analyzed, and linkage disequilibrium based pruning resulted in 3,497 SNPs. Bayesian cluster analysis was implemented in STRUCTURE to identify four population groups. These groups were then confirmed based on principal components analysis and geographic origins. Pairwise diversity among accessions was also evaluated and revealed considerable genetic variation. Notably, a subset of accessions from Armenia with exceptional genetic variation was identified. This survey is the first to report significant genetic diversity among pennycress accessions and explain some of the phenotypic differences previously observed in the germplasm. Understanding the genetic variation in pennycress accessions is a crucial step for designing effective selection programs for domesticating a new cash cover crop for cold climates.

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## FALL SOWING DATES IN CAMELINA AFFECTED PLANT DENSITY

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Camelina [*Camelina sativa* (L.) Crantz] is an emerging oilseed crop high in omega-3 fatty acids for biomaterial, bioproducts and food uses. Camelina has two distinctive biotypes, summer and winter, with the latter requiring vernalization to enter reproduction phase. There is increased producer interest in the northern Great Plains of the U.S. in complementing winter rye (*Secale cereale* L.) with winter camelina as a winter hardy cover crop that can routinely survive the winter in crop rotations involving maize (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr]. The objective of this research was to establish a range of sowing dates for winter camelina enabling producers to effectively produce seed locally for cover crop use as well in the future for industrial or food crop markets as they develop while providing ecosystem services. Sowing locations were at Fargo and Prosper, ND, in 2017-2018 and dates were targeted to start on 31 July and then every two weeks following for a total of six sowing dates. The experimental design was a RCBD with four replicates at each location. Fall and spring stand counts were taken along with aboveground biomass samples to analyze nitrogen content using near infrared spectroscopy. Fall and spring soil samples were also taken and analyzed for soil nitrate content. Fall stand counts ranged from 17 to 379 plants per m<sup>2</sup> both being less of the sowing rate of 799 viable seeds per m<sup>2</sup>, with more plants being present at later sowing dates. Fall biomass weight of collected samples did not significantly differ among sowing dates except in Prosper where the first sowing date, though few plants were present they were able to accumulate large aboveground mass up of 1136 kg ha<sup>-1</sup>. Samples that were analyzed for nitrogen content in above ground tissue were not significantly different among sowing dates. Having a high number of plants that are able to survive the winter can in turn be able to produced higher seed yield at harvest the following spring while providing increased flowers for pollinators. Comparison of both fall and spring soil test between sowing dates will also be presented.

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GENOME-WIDE ASSOCIATION STUDY (GWAS) HELPS UNVEIL THE GENOMIC REGIONS CONTROLLING YIELD COMPONENTS AND FATTY ACIDS IN *CAMELINA SATIVA* L. (CRANTZ)

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*Camelina sativa* L. (Crantz) is an oilseed crop newly introduced to the semi-arid regions of the Southwestern US. Recently, *C. sativa* gained attention as a biofuel feedstock crop due to its relatively high oil content, polyunsaturated fatty acids, short growing season with fairly good adaption to marginal lands, and low input requirements in agricultural systems. Few breeding efforts have been conducted on *C. sativa* so far. The traits that commonly raised interests in this species include biomass-related traits such as seed weight, seed yield, and plant height and metabolite-related traits such as fatty acids, oil and protein content. Our objective is to identify genomic regions controlling genes underlying these traits and apply them for future marker-assisted selection (MAS) in molecular breeding programs. In this study, a spring *C. sativa* diversity panel was grown under two contrasting water conditions in Maricopa, AZ with each genotype replicated three times. More than 20 phenotypic traits related to yield components and fatty acids were collected. Genome-wide association analysis using GAPIT was conducted to identify putative single-nucleotide polymorphism (SNP) markers that are significantly associated with these traits. This GWAS study will lay a foundation for future molecular breeding programs to help accelerate the selection of *C. sativa* varieties with superior traits of interests.

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SEED AND OIL YIELDS OF WINTER ANNUAL OILSEED CROPS INTERSEEDED INTO MAIZE  
(*ZEA MAYS* L.) AND SOYBEAN [(*GLYCINE MAX* (L.) MERR.)]

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Winter camelina [*Camelina sativa* (L.) Crantz] and field pennycress (*Thlaspi arvense* L.) are oilseed crops gaining attention to provide industrial feedstocks for biofuels, lubricants, and plastics, as well as to enhance agro-ecosystem services. Integrating these crops as winter annuals between main summer crops can provide additional economic benefits. Due to limited time to establish these crops after maize and soybean harvest and before winter freeze, interseeding into standing maize and soybean could be an option. The objective of this study was to determine seed and oil yields, and oil concentration of winter camelina and pennycress when interseeded into maize and soybean at Ames IA, Morris MN, and Prosper ND. There were three interseeding dates at different maize and soybean developmental stages over two years. Results showed that the different interseeding dates did not influence maize or soybean grain yields. Late interseeding generally increased seed yield, oil concentration and oil yield of winter camelina and pennycress. Overall mean seed yields of pennycress and winter camelina across all site years ranged from 306 to 476 kg ha<sup>-1</sup> and 142 to 319 kg ha<sup>-1</sup>, respectively, when interseeded into standing soybean. The seed yield was relatively low when interseeded into maize compared with soybean due to less light penetration. Similarly, the seed oil percent in pennycress and winter camelina ranged from 22% to 32% and 32% to 37%, respectively. Winter camelina seed typically had greater oil concentration than pennycress. Both oilseed crops produced comparable oil yield due to greater seed yield of pennycress compared with winter camelina. The results from this interseeding study showed that mean seed yields of winter camelina and pennycress were generally low compared with previous studies involving autumn seeding of these crops on spring-wheat stubble. Additional research is needed to develop better seeding practices to improve yields when used in maize-soybean system and to document additional rotational benefits of these crops to increase their adoption by growers.

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## SELECTED OILSEED CROPS TO BE GROWN ON MARGINAL LANDS IN EUROPE

Efthymia Alexopoulou

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Oilseeds are an important category of industrial crops since they offer feedstock for a large number of value-added products and biofuels. In Europe two oilseed crops are mainly been cultivated for first generation biofuels (rapeseed and sunflower). Flaxseed and industrial hemp are being grown in smaller areas in Europe for value-added applications. There is an increasing demand for oilseed crops that is been supported by the following facts: a) in EU up to 30% of the mineral oil-based chemicals and materials would be replaced with bio-based alternatives by 2030, b) the EU bio-plastics market was estimated at around 485 million € in 2013 with a potential increase to 900 million € in 2017 and to 1.4 billion in 2020, (55% increase), c) the bio-lubricants market, valued 410 million € in 2010, will reach to 640 million euros in 2020 (growth 56%) and d) the market for bio-based surfactants is expected to increase to about 1.3 billion € in 2030; while currently is 680 million euros (growth 91%). At the same time in Europe the marginal land facing natural constraints has been estimated as the 28% of the total agricultural land (MAGIC project). Part of this land is already been cultivated with food and feed crops, while part of it can be cultivated with several industrial crops such as oilseeds. In the framework of MAGIC project (HORIZON 2020; [www.magic-h2020.eu](http://www.magic-h2020.eu)) a total number of thirteen oilseed crops had been initially selected as candidate crops to be grow on marginal lands. By following a multi-criteria analysis eight oilseed crops have been selected as the most promising ones to be grown on marginal lands namely camelina, safflower, castor, crambe, pennycress, industrial hemp, cardoon and lupin. Camelina is annual short growing cycle (90-120 days), winter and spring crop, native of Europe. It is currently been tested in another two EU research projects namely COSMOS ([www.cosmos-h2020.eu](http://www.cosmos-h2020.eu)) & BIO4A ([www.bio4a.eu](http://www.bio4a.eu)), while in ITAKA project ([www.itaka-project.eu](http://www.itaka-project.eu)) camelina cultivated on marginal lands in Spain for aviation biofuels with seed yields varied from 0.5 to 2.5 t/ha. Crambe is annual spring crop with a growing cycle 85-105 days that had been domesticated to Mediterranean region. It is relatively drought tolerant and tolerates pH from 5.0 to 7.8. Castor bean is annual spring crop that needs 120-150 days to reach the harvesting time. It can be grown on marginal lands, which are not competitive with food (economic viable solution for non-productive lands). It can tolerate pH 5.5-6.5 and saline soils but not low temperatures. Ethiopian mustard is considered drought tolerance crop and thus it is a promising crop for the Mediterranean region and for areas with dryness problems. It tolerates soils with pH 5.5-8.0. Safflower (winter or spring crop) with 110-150 growing cycle. It can be grown successfully on dry lands. It has a strong taproot and thus thrives in dry climates. Pennycress (winter or spring crop) has shorter growing cycle than camelina. It has gained attention in USA as a short cycle crop that can be grown on unused land. It has low demand on soil nutrition and water demand. It is frost tolerant (up to -20°C). Industrial hemp (multipurpose spring crop) it is considered as candidate crop for phytoremediation. In GRACE project ([www.grace-bbi.eu](http://www.grace-bbi.eu)) it is grown on contaminated lands. Lupin is an annual crop with growing cycle around 150 days. It has been selected by LIBBIO project ([www.libbio.net](http://www.libbio.net)) as a crop that can be grown on poor and marginal lands. It tolerates the acid soils and it is considered drought tolerance.

Acknowledgements: MAGIC (Marginal lands for growing industrial crops: Turning a burden into an opportunity) has received funding from the European Union's Horizon 2020 Programme under Grant Agreement 727698.

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# **ABSTRACTS**

**MEDICINAL & NUTRACEUTICAL PLANTS DIVISION**

**ORAL PRESENTATIONS**

**CHAIR**

**DIANA JASSO DE RODRIGUEZ, UNIVERSIDAD AUTONOMA  
AGRARIA ANTONIO NARRO, SALTILLO, MEXICO**

## MINT (*MENTHA* SP.) VARIETIES FOR COMMERCIAL PRODUCTION IN WESTERN NEBRASKA

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Mint oil (peppermint and spearmint) is used in chewing gum, toothpaste, mouthwash, candy, liqueur, and medicine. Northwestern states of the US (OR, WA, and ID) accounts for 84 % of the U.S. mint production. Total value of U.S. mint is about \$200 million and 70% is peppermint. Western Nebraska climate is similar to major US mint producing areas and commercial production of high quality mint oil is possible. Objective of this study was to identify the best varieties of peppermint and spearmint for western Nebraska. Replicated field trial using six peppermint, six spearmint, and two 3<sup>rd</sup> type clones were planted on June 2, 2018 at Scottsbluff, NE. Flowering time, growth parameters data (e.g. vigor, plant height, pigmentation, branching), biomass yield, and leaf oil analysis were taken. Significant variation among the clones of both peppermint and spearmint was observed. Average plant height (vertical growth) and row width (horizontal growth) were 11 inches (ranged 7 to 13 inches), and 11 inches (ranged 7 to 13 inches). Peppermint had long vegetative stage, late flowering, and excellent vigor with profuse lateral suckers and stem and leaves are pigmented. Spearmint had short vegetative stage, early flowering, poor to medium vigor with no or little lateral suckers and branched stem and leaves are not pigmented. Average dry biomass yield was 4388 (peppermint) and 4362 (spearmint) lbs/acre indicating no yield differences between two them. Six different types with significant variation in proportion (%) were identified. Menthol and carvone were predominant in peppermint (av. 77%) and spearmint (82%), respectively. Third type mint (Arvensis II & III) had 26% menthol and 65% carvone.

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EXTRACTS OF *RHUS* SPP., *FLOURENSIA* SPP., AND *CUCURBITA FOETIDISSIMA* AS  
BIOSTIMULANTS OF GROWTH AND YIELD OF TOMATO

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In the semi-arid zones of northeastern Mexico, species with high polyphenols content and antioxidant activity have been identified, which can be used as growth and fruit yield biostimulants in tomato plants, this in the context of sustainable agriculture. The objective of this research was to evaluate the effect of five extracts of semi-desert plants: *Rhus trilobata*, *Rhus muelleri*, *Flourensia microphylla*, *F. retinophylla* and *Cucurbita foetidissima*, as growth and fruit yield biostimulants in tomato plants hybrid EL CID F1. The experiment was carried out in a greenhouse, under a completely randomized design with eight treatments: five extracts of the plants mentioned above and three bioregulators as controls (gibberellic acid, indole acetic acid, and 6 benzyl aminopurine), with twelve repetitions per treatment. The dose of extract and bioregulator was 75 mg L<sup>-1</sup>, at the transplant, at the 34 and 55 days after transplant. The variables evaluated were: longitudinal growth and diameter of stem, number of leaves, number of fruits, and dry weight of plant. In addition weight and fruit yield and its quality. In general, the extracts stimulated stem length and diameter, dry weight of leaves, as well as the number and weight of fruits and yield, having similar results to the 6-BAP bioregulator. It is concluded that the extract of *Rhus muelleri*, consistently showed high values in the growth and yield variables in tomato plants, and may represent an alternative for the formulation of a biostimulant.

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# **ABSTRACTS**

**FIBERS & CELLULOSICS DIVISION**

**ORAL PRESENTATIONS**

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## CORN DISTILLERS DRIED GRAINS WITH SOLUBLES (DDGS) – A FUNCTIONAL MATERIAL FOR MANUFACTURING BINDERLESS PARTICLEBOARDS

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In the U.S., the corn dry-grind process contributes to 70% of ethanol production. Nearly 1 kg of DDGS is produced per kg of ethanol. DDGS contain roughly 30% proteins, 13% fat and 39% fibers. DDGS proteins can be exploited for adhesive properties if their protein structure are uncoiled from existing globular structures into more linear chains. Currently DDGS is utilized locally as feed and protein supplement for ruminant animals. In 2017 DDGS production was 23.2 million tons with selling price of \$0.010-0.14 per kg which is below quality wood fiber price of \$0.18-0.20 per kg. As predicted by U.S. Grains Council, the availability of DDGS will jump from 10 million metric ton in 2006 to 70 million metric tons by 2020. With increasing DDGS volume, price fluctuations, geopolitical instability, and risk of tariffs it is paramount to identify new avenues to utilize DDGS locally for long term growth and viability of ethanol industry. The main objective of this project is to promote the use of DDGS as a novel functional filler for manufacturing binderless, formaldehyde free particleboards. The use of DDGS in wood composites will reduce the use of synthetic resin and wax and help to develop safe, reliable, and toxic chemical free composites for wood products industry. The two objectives of this project are: 1) Identify how DDGS proteins can be functionalized to act as natural adhesives in particleboards without compromising their physical and mechanical properties. 2) Determine the techno-economic analysis of using the DDGS in the particleboards. In this research several formulations of particleboard were hot pressed using various concentrations of acid and alkali treatments, DDGS filler contents of 10, 25 and 50 wt.%, and DDGS particle sizes of 120 and 250  $\mu\text{m}$ . Micronized DDGS were first treated with alkali (NaOH), and acetic acid to functionalize their proteins. The treated DDGS were blended with 50% pine wood flour and pressed into particleboards using hot press. The boards were tested for their physical and mechanical properties using ASTM D1037 standard. The test results showed that DDGS can be directly blended with wood particles in particleboards. Superior flexural strengths of particleboards occurred at press temperature of 190°C. The acetic acid treated particleboards at higher DDGS concentrations exhibited better water resistance properties. Test results showed that the mean internal bond strengths exceeded the minimum requirement of ANSI A208.1-2009. FTIR results showed that the decoupling of proteins was achieved by acid or alkali treatment. These positive outcomes suggest that DDGS has strong potential to act as a natural adhesive for manufacturing medium-density particleboards.

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## KENAF (*HIBISCUS CANNABINUS* L.): A VALUABLE FIBER CROP FOR HEAVY METALS CONTAMINATED SOILS?

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Heavy metals significantly contribute for the disruption, degradation, contamination, and pollution of the ecosystems, inducing a serious threat to the environment and public health. In particular, they might cause marginality of soils through the degradation of their quality—inducing the reduction of crop yields and the quality of agricultural products, desertification, and the loss of ecosystem services. In order to remove heavy metals from soils and prevent their risks to the environment, animals, and human health, different physical, chemical, and biological approaches have been employed. Phytoremediation, the use of plants and their associated microbes for soil decontamination, is a solar driven and environmentally suitable technology that can be employed for the restoration of soils contaminated with heavy metals, without compromising the other physical, structural, and chemical characteristics of the soil. Hence, the aim of this work was to study the effects of soils contaminated with heavy metals (Chromium, Copper, Lead and Zinc) on growth and productivity of kenaf (*Hibiscus cannabinus* L). The study was performed in a pot essay and the plants were tested in sandy soils and clay soils. The soils were artificially contaminated, and the concentrations chosen were twice the limits established by the Decree Law 276 of 2009 (Portuguese regulation that establishes the regime for the use of sewage sludge in agricultural soils) - Zn: 900 mg/kg; Cr: 600 mg/kg; Pb: 900 mg/kg and Cu: 400 mg/kg. Results indicate that all the contaminated soils affected the growth and yields of kenaf. Highest yield reduction was observed in sandy contaminated soils than in clay contaminated soils, although this trend was not statistically significant. Copper was the metal that affected most yields and growth of kenaf in clay soils. In sandy soils, it was chromium that affected most, yields and growth of kenaf. Overall, yield reduction due to heavy metals contamination was above 50%, which may hinder its economical exploitation. Mineral matter accumulation was also influenced by heavy metals soils contamination. Overall, kenaf is able to remove and to accumulate heavy metals from contaminated soils, especially zinc, and the highest proportion of the heavy metals taken up by plants is present in the shoots.

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## INDUSTRIAL HEMP: AN OLD-NEW FIBRE CROP

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Industrial hemp (*Cannabis sativa* L.) is a short-day bast-fibre crop with a rapid growth that can reach a height of 4 m in 100 days. It is considered a good fore crop for cereals cultivation. Hemp absorbs heavy metals (such as Cd, Pb, Zn, and Cu) and contributes to the phytoremediation of contaminated soils. Although it is traditionally considered as a fiber crop, currently it is characterized as a multi-purpose crop since a wide range of biobased products and bioenergy can be produced from all parts of the plant ([www.fibrafp7.net](http://www.fibrafp7.net), [www.multihemp.eu](http://www.multihemp.eu)) such as biocomposites, insulation mats, textiles and construction materials from its stems, CBD from its panicles, oil and proteins from its seeds ([www.eiha.org](http://www.eiha.org)). At European level the area of industrial hemp cultivation remains for a long period (more than 20 years) between 10,000 and 15,000 hectares and from 2013 started to increase. In 2017 the cultivation area of industrial hemp came up to 42,500 ha. The main producer in Europe is France providing more than half of the total production. The main reason for this increase in the cultivation area was the increasing demand for biocomposites and CBD. The cultivation area of industrial hemp was increased not only at EU level but at world level. In Canada there is an increasing demand for hemp in the food industry and thus its area of cultivation from 340,000 in 2016 a year later was 560,000 ha. In 2018 the cultivation of hemp started in USA and it is expected in a timeframe of ten years will come up to 560,000 ha. Industrial hemp is one of the traditional fiber crops with 470,000 ha in 2017. It has been estimated that the cultivation area in Europe, China and Canada is around 1.5 million ha and this is a great change taking into consideration the fact that during the 2<sup>nd</sup> world war the cultivation of industrial hemp had been almost disappeared. At EU level industrial hemp is being studied in a number of research projects namely BECOOL ([www.becoolproject.eu](http://www.becoolproject.eu)), GRACE ([www.grace-bbi.eu](http://www.grace-bbi.eu)), MAGIC ([www.magic-h2020.eu](http://www.magic-h2020.eu)) and PANACEA ([www.panacea-h2020.eu](http://www.panacea-h2020.eu)). In BECOOL project hemp has been included in rotation systems with two conventional food crops (maize and wheat) in three Mediterranean countries (Italy, Greece and Spain) with dry stem yields higher than 10 t/ha. In MAGIC and GRACE the crop is being grown on marginal lands (marginal lands facing natural constraints and/or contaminated lands) in several EU countries, while in PANACEA has been proposed as a non-food crop with great interest for both farmers and industries.

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## LONG-TERM YIELDS FOR SWITCHGRASS LOWLAND AND UPLAND ECOTYPES GROWN IN THE IN THE MEDITERRANEAN REGION

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Switchgrass is a C4 perennial grass native of North America with long lifetime even longer than 20 years. In most research works on switchgrass the ceiling yields are being reported from the 2nd to the 5th growing year depending on the specific pedoclimatic conditions and the crop management (ecotype choice, plant densities, successful establishment, etc.). Switchgrass varieties are been grouped in two ecotypes; the lowland and the upland ones. The lowland varieties are usually taller, coarser and have a more bunch-type growth and more rapid growing compared to the upland ones. In the late 1990s a number of field trials had been established in Europe (Greece, Italy, Germany, UK and the Netherlands) in a view of a research project entitled “Switchgrass for Energy” ([www.switchgrass.nl](http://www.switchgrass.nl)). In this research work it is presented the effect of variety ecotype (lowland, upland) on long-term switchgrass yields in two field trials established in the framework of the above mentioned research project. The first trial had been established in Greece (Aliartos, 1998-2014) and the second in Italy (Ozzano, 1998-2010). In total thirteen switchgrass varieties (6 lowland and 7 upland ones) had been compared in the two countries. Each plot was 15m<sup>2</sup> (3X5) and the distances between the rows were 15 cm. The plots were seeded at 10 mm depth with a rate of 500 PLS (Pure Live Seed) per square meter. After seeding the soil was rolled in order to ensure a good seed-soil contact. The switchgrass trial in Greece was irrigated (at least three times per growing period; 350 mm in total); while in the Italian trial the plantation was irrigated only with 60 mm of water at the establishment year. At the end of each growing period a final harvest had been carried (2m<sup>2</sup>) from December to January (after the first killing frost) and from the harvested material a quantity of 500 g was collected and separated into stem and leaves. After the separation, the sub-samples from stems and leaves were oven-dried at 85<sup>0</sup>C until constant weight for dry matter determinations. Moreover, the plant height, the stem diameter and the tiller density was measured annually. In both sites the establishment of the crop was quite good. Although switchgrass is not native of the Mediterranean region the long-term trials that had been carried out in both countries gave quite satisfactory yields. It was found that annual yields higher than 8 t/ha can be achieved (in Greece the mean yields of 17 years were higher than 10 t/ha). In both environments the peak of biomass yield was reached between the second and the third year after establishment (higher than 20 t/ha). In both trials the lowland varieties were more productive than upland ones. It should be pointed out that this superiority was more profound in the years with the ceiling yields. It should be pointed out that the lowland varieties gave higher plants with larger stems and lower tiller density compared to upland ones. The upland variety Blackwell gave quite high dry matter yields that were quite close to the reported yields of the lowlands varieties namely Alamo and Kanlow. In comparison with giant reed and miscanthus that also are being tested as perennial lignocellulosic crops for the Mediterranean region it can be said that lower yields can be expected by switchgrass but the cost of establishment is much lower (by seeds vs rhizomes or plants) and with lower irrigation needs. In both sites the lowland type varieties should be preferred for higher dry matter yields (as well as the upland variety Blackwell) and increased lodging resistance.

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# **ABSTRACTS**

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## PROGRESS OF ALTERNATIVE ELASTOMERS WITH HIGH PERFORMANCE

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With extensive interest in sustainable development, the chemical industry is making great attempts to replace petrochemical-based monomers with natural ones. It is strategically important to construct new polymers or replace present polymers by renewable resources. Compared with bio-based plastics, few bio-based elastomers, especially those targeted for engineering applications, were produced. We intended to synthesize a series of novel elastomers, which should possess high molecular weight, low glass transition temperature ( $T_g$ ), and comprehensive mechanical properties based on renewable monomers that are produced on a large scale. The polyester elastomers were designed and synthesized from large scaled diols and diacids such as butanediol, propanediol, sebacic acid, succinic acid, itaconic acid, et al. These polyester elastomers could be prepared into oil resistant rubber products, bio-based and degradable chewing gums, full-bio-based thermoplastic vulcanizate (TPV) products and used as bio-based plasticizers or tougheners for plastics. By combining a molecular structural design with a nanosilica-silane technology to tune the viscoelastic properties of the elastomer composites, we have successfully manufactured silica/poly (di-n-butyl itaconate-co-butadiene) nanocomposite-based green tires that have very low roll resistance and excellent wear-resistance that promote fuel efficiency and our dependence on petrochemical resources. Bio-based poly (dibutyl itaconate-ter-isoprene-ter-4-vinylpyridine) (PDBIIVP) elastomers with different 4-vinylpyridine (4-VP) contents were synthesized by redox emulsion polymerization for the purpose of designing and preparing green graphene oxide (GO)/PDBIIVP nanocomposites with strong interfacial interaction. For the GO/PDBIIVP with 7.0 wt% of 4-VP and 4 phr of GO, the tensile strength increased by 700%, the volume loss of abrasion decreased by 53%, and the gas permeability decreased by 63% compared with those of the neat PDBIIVP. This method may become an important strategy for developing GO-based polymer nanocomposites with high performance. Besides, the NR shortfall problem is very serious in China for its large consumption, over 5 million tons every year, which is 40% of world consumption. Developing the alternative taraxacum kok saghyz as the secondary natural rubber sources is an effective measure to make up for the NR shortage of China, which will be introduced briefly. Besides the biobased elastomers, we also want to improve the sustainability of plasticizers for rubber. Thereafter, soybean oil, palm oil, and modified soybean oil were used as plasticizers for common rubbers as EPDM and NBR. It showed that, the plant oil plasticizers have better plasticization effect on EPDM or NBR, indication they are promising substitute for the petroleum-based plasticizers.

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DEVELOPMENT OF GUAYULE (*PARTHENIUM ARGENTATUM* A. GRAY) IN THE SOUTH OF FRANCE AFTER THE EU-PEARLS PROJECT

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Research activities on guayule started in France and Morocco in the 1980's and again in 2008 with the European project, EU-PEARLS. Guayule research activities continued in France with the implementation of several experimental fields supervised by CIRAD starting in 2012, in the Languedoc-Roussillon region (LR) near Montpellier and in the Oriental Pyrenees near Perpignan. The aim of the French research on guayule was: (i) to produce sufficient quantities of biomass to develop a latex extraction process; (ii) to study the growth and yields of plants based on rubber and resin content measured by ASE and NIRS methods; (iii) to produce quantities of seeds to test guayule as an innovative crop on abandoned vineyards; (iv) to interest farmers in guayule plantation. An experimental plot of 0.25 ha with 2000 plants of five former USDA varieties used for the EU-PEARLS project, was planted in May 2014 and May 2015 in Lansargues, near Montpellier, and in 2017 in five more sites were planted for a total of 1,25 ha of guayule in the south of France. The mortality, growth of plants and rubber and resin content were monitored for four years. The behavior of the five selected lines was compared, depending on the type of soils and climate conditions of the region, considering mainly the dry and cold resistance of the plant. At that stage, there was enough biomass accessible to study the development of a latex extraction process which resulted in an international patent in 2018. This paper summarizes results found at the Lansargues experimental field and at several other guayule plots in the region.

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DISCOVERY OF RUBBER PARTICLE ONTOGENY PATHWAYS DURING *TARAXACUM KOK-SAGHYZ* RUBBER FORMATION

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Information on rubber particle ontogeny is fundamental to explaining natural and induced differences in rubber yield. However, rubber particle ontogeny is not yet fully understood in *Taraxacum kok-saghyz* (TK), an alternative, temperate zone, rubber crop suited to cultivation in the U.S. and Europe. Microscopic analyses of plants from seedlings to 1-yr-olds, indicated that rubber particles originate in the endoplasmic reticulum (ER)-Golgi apparatus vesicular complex. Furthermore, rubber particles were produced in two distinct ways. Some particles were produced by laticifer plastids, membranous organelles found in the cytoplasm of laticifer cells (plastidic rubber). Other non-plastidic particles (cytoplasmic rubber), were often located near or in the tonoplast. These observations provide an understanding of rubber particle ontogeny that can be used to evaluate the impact of different treatments, such as abiotic stresses, on rubber production.

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## GROWTH AND YIELD OF DIRECT SEEDED GUAYULE UNDER SDI AND FURROW IRRIGATION

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Guayule (*Parthenium argentatum* A. Gray) commercialization depends on economical plant production. Establishment costs can be reduced significantly when direct seeding is used instead of transplanting. Since direct-seeded and transplanted guayule plants develop different root structures, they are also expected to have different soil water extraction patterns and thus soil water management requirements. The objective of this study was to evaluate and compare production parameters (biomass, rubber, content, resin content and yield) of guayule irrigated with five different irrigation rates (six treatments) including five with subsurface drip irrigation (SDI) at levels of 50-150% replacement of estimated soil water depletion (SWD) (and denoted as D50-D150, respectively). There was also one treatment (100% replace of SWD) grown with furrow irrigation (denoted as F100). Calculations were made in a root zone soil water balance model. The experiment was repeated in two fields: one in Maricopa, AZ with sandy loam soil and the other in Eloy, AZ with a clay soil. The experiments consisted of 18 plots (6 treatments x 3 replicates). Each plot had 6 beds with 40" spacing at MAC and 8 beds at Eloy. Each bed was 1.02 m wide and 75 m long. The experiment was based on a split-plot design with location as the main plot. The sub-plots (irrigation treatment) were arranged in a randomized complete block design, where the two fields were divided into three blocks and the six treatments were randomly distributed inside each block. The 2-year experiment was initiated on April 20, 2018 at MAC and on April 17, 2018 in Eloy. In both locations, guayule variety AZ-2 was direct-seeded on raised beds spaced 1.02 m apart (20-30 cm on top and 15-20 cm high). A 4-row planter was used to plant the seeds, one row per bed. After planting, sprinkler systems were installed to irrigate the two fields during the first two weeks. The total water applied through the sprinkler system was 296 mm at MAC and 317 mm in Eloy. Prior to initiating treatments, all SDI plots received equal amounts (a total of 887 mm for MAC and 954 mm for Eloy). Treatments started in late-July and early-August at MAC and Eloy, respectively. Total irrigation applied April through December 2018 to D100 and F100 were 1543 mm and 1571 mm, respectively, for MAC and 1512 mm and 1470 mm, respectively, in Eloy. Whole plant samples were harvested in late March 2019 (~11 months after planting). Results indicate that rubber and resin content decreased with increasing water application rate. Biomass and rubber and resin yields were higher at MAC than Eloy for all treatments except the F100, which had higher biomass and resin yield in Eloy. The highest rubber and resin yields for MAC were in the D75 treatment but were not significantly different from the yields in of treatments except the D50. In general, MAC sandy loam soil had higher rubber and resin yields than the heavy clay soil in Eloy.

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## GUAYULE GROWTH AND YIELD OVER TIME AT TWO LOCATIONS AT HIGH AND LOW IRRIGATION TREATMENTS

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Information regarding growth and yield components is critical when determining where guayule (*Parthenium argentatum* A. Gray) will be best suited for commercial production. Two guayule irrigation experiments were planted in April 2018 at Eloy, AZ on a clay soil and at Maricopa, AZ on a sandy loam soil. Guayule was direct seeded in both locations. The harvested treatments were the I100 % and I50 % (replacement of 100% and 50% of estimated soil water depletion) for subsurface drip and flood at Eloy. Same treatments were harvested from the Maricopa field except the I50% flood, which was not available there. Harvests were at 4, 6, 8, 10, 12, 14, and 16 months after planting from the three replicates of each treatment. At each harvest, plots were measured with a 1 m template to assure equal sample size. Plants were cut at ground level and roots were dug to obtain as much of the main taproot as possible. Roots were counted to obtain an estimate of plants per acre and length measured. Fresh and dry weights were obtained. All plants were processed by separating each by leaves, stems, roots, and flowers on the same day they were harvested. Plants were further dried and then ground and analyzed for rubber and resin content. Differences between treatments became evident 14 months after planting. Shrub dry biomass was higher at Eloy compared to Maricopa until the first winter. During that winter and in the early spring, soil temperatures at Maricopa, sandy loam soil, were warmer compared to Eloy, clay soils. Biomass weights at Maricopa were nearly equal until June 2019 when Eloy shrubs were again at higher weights than Maricopa. In the June 2019 harvest, the I100% treatments had higher biomass compared to the I50% treatments at both locations. Differences in root weight are seen in Maricopa between the I50% and I100% drip treatments compared to small differences between Eloy treatments. The proportion of flowers, leaves, and stems changed over time significantly. Since February 2019, the proportion of leaves and stems on the shrub has been stable. Flower proportion increased from April to August 2018. In June 2019, the rubber percent was higher at Maricopa compared to Eloy. That has been the trend since February 2019. It is interesting that peak rubber content for the I50% treatments remains at about the same from February to June 2019. In the I100% treatments, rubber began to decrease in June 2019. Resin content has increased slightly over time but most of the resin content was present in the plant 4 months after planting. The overall rubber yield was very similar for the two locations despite the higher biomass at Eloy. The higher rubber content in the sandy loam soil, at Maricopa, compensated for the lower biomass. There is not much difference between treatments so far, indicating the lower water treatments have not had the proportional effect on yield. Samplings will continue until spring of 2020 when final harvest will be conducted.

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## ASSESSMENT OF IRRIGATION REQUIREMENT FOR GUAYULE USING WINDS MODEL

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With the growing concern/demand for more natural rubber, there comes a dire need to focus on efficient and sustainable growth of industrial crops. Guayule (*Parthenium argentatum*), an indigenous to Southwestern USA, is a perennial shrub, and one of the 2000 species that produces natural rubber. Guayule is a drought tolerant crop; however, it requires more water to achieve maximum rubber and resin yields. Under stress conditions, it would go through a temporary dormancy until water is available, which makes it a suitable crop for the arid regions in the south west such as in Arizona, California, New Mexico and Texas. In this study, irrigation water requirement was evaluated for guayule planted in two fields in the year 2018: one at The University of Arizona, Maricopa Agricultural Center (MAC) in Maricopa, Arizona with sandy loam soil, and the other at the Bridgestone Americas Guayule Research Farm, Eloy, Arizona with clay soil. At both the experiment stations, there are six treatments including subsurface drip and flood irrigation. There are five different irrigation rates on subsurface drip irrigation (SDI) levels with 50%, 75%, 100%, 125% and 150% replacement of estimated soil water depletion (SWD), denoted as D50, D75, D100, D125 and D150, respectively. Additionally, one treatment (100% replacement of SWD) was grown with furrow irrigation and denoted as F100. Plant water use, and irrigation recommendations were calculated using WINDS (Water-use, Irrigation, Nitrogen, Drainage, and Salinity) model, a computer-based tool that runs by soil-water flux and energy distribution equations. Outputs from WINDS include Crop Evapotranspiration (ETc), soil moisture, soil water depletion, and an irrigation schedule (prediction of irrigation amount and date). Using a multispectral sensor carried on a drone, the normalized difference vegetation index (NDVI) was also estimated and correlated to soil moisture content, which is an indicator of crop-water status. Results indicated that the WINDS model was capable of estimating guayule daily ETc and soil moisture content, which correlated well with measured soil moisture content. Moreover, the results from sensors on NDVI depict that sensors can be an effective tool for precision agriculture to assess crop health at each growing stage.

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# LIQUID GUAYULE NATURAL RUBBER, A RENEWABLE PROCESSING AID FOR HIGH-PERFORMANCE NATURAL AND SYNTHETIC RUBBER COMPOSITES

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Processing oils, such as naphthenic oil (NO), are usually petroleum-based, and are widely used to improve the processability of rubber compounds and save processing energy. However, these aids reduce the mechanical performance of the resultant rubber or rubber composite products because they act as passive dilutive additives to the compound. Vegetable-based oils, such as soybean oil-based processing aids also behave as diluents. Liquid guayule natural rubber (LGNR) provides a new, active, processing aid option. LGNR was produced by thermal degradation of guayule rubber and evaluated as a sustainable alternative to NO in natural (rubber tree and guayule rubber) and synthetic (styrene-butadiene) rubber composites. LGNR enhanced processability and reduced energy consumption during rubber compounding similarly to NO. However, LGNR behaved as an active compounding ingredient and, in contrast to NO, maintained or increased mechanical performance and durability of the natural rubber and synthetic rubber composites in which it was used. This new LGNR additive can have broad applicability to the rubber manufacturing industry and is expected to open new markets for sustainable processing aids. Adoption of LGNR also will improve the value proposition for US guayule crops and further expand the practical application of OSU sustainable material research to the U.S. rubber industry.

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# GUAYULE (*PARTHENIUM ARGENTATUM* A. GRAY) SEEDLING TOLERANCE TO TOPICALLY APPLIED CARFENTRAZINE-ETHYL HERBICIDE

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Guayule is a desert adapted plant from the Chihuahuan Desert in North America that produces natural rubber. Weed control in direct-seeded plantings is a significant barrier to commercial rubber production from guayule. Preliminary post-emergence herbicide screening studies in transplanted guayule found that guayule had some tolerance to carfentrazone-ethyl (Aim™ herbicide from FMC®) and other protoporphyrinogen oxidase inhibitors. Studies were initiated in direct-seeded guayule to further characterize guayule seedling tolerance to carfentrazone at multiple locations in southern Arizona using randomized complete block designs with 4 to 6 replications. Carfentrazone was applied broadcast over-the-top of guayule plants at 4 target growth stages: 2, 4, 6 f and 8 to 10 leaf plants. The actual number of leaves per plant were counted at the time of spraying. The post-emergence herbicide treatments were applied using a tractor-mounted boom sprayer equipped with TeeJet® TT-11002 nozzles operated at 279 kPa that delivered a spray volume of 180L/ha at 5 km/hr. The carfentrazone rate ranged investigated included 8.7, 17.5, 26.2, 35.1, 52.7, and 70.1 g/ha; some studies only included the 17.5, 35.1, 52.7 and 70.1 g/ha rates. All carfentrazone herbicide treatments included a non-ionic surfactant at 0.5% v/v. Tolerance was evaluated by comparing pre-spray stand counts with counts collected at various days after treatment (DAT). Additionally, plant height was directly measured and canopy ground cover was estimated from nadir photographs and pixel analysis of the resulting images. Carfentrazone injury symptoms were manifest as necrotic spots on guayule leaves and in the loss of leaves from seedlings. The degree of injury increased as the rate of carfentrazone increased but injury decreased with increasing plant size. The untreated controls showed that some stand loss is normal during establishment. Carfentrazone rates up to and including 35 g/ha did not substantially increase stand loss even at the 2 true leaf and 3.6 true leaf growth stages. At carfentrazone rates of 53 and 70 g/ha there was a slight increase in stand loss but commercially acceptable stands were still obtained (as judged from the lack of skips in the seed-line greater than 0.5 m). Carfentrazone injury resulted in a reduction of leaf area immediately after spraying. The 2 true-leaf guayule canopy ground cover (cm<sup>2</sup>/m-row) 14 DAT with 17, 35, 53 and 70 g/ha was reduced 45, 78, 83 and 72%, respectively, compared to the untreated control. Similarly, 3.6 true-leaf guayule canopy ground cover at 7 DAT with 17, 35, 53 and 70 g/ha was reduced 65, 82, 86 and 89%, respectively, compared to the untreated control. The guayule seedlings grew out of this injury. The heights of seedlings treated with 35 g/ha carfentrazone at the 2, 3.6, 5.6 and 10.4 true-leaf growth stages were only reduced by 13, 20, 15, and 15 percent at 55, 48, 41 and 29 DAT, respectively. Similarly, the heights seedlings treated with 70 g/ha carfentrazone at the 2, 3.6, 5.6 and 10.4 true-leaf growth stages were reduced by 21, 29, 20, and 12 percent at 55, 48, 41 and 29 DAT, respectively. These data indicate that Aim at rates of 17 to 35 g/ha can be used for broadleaf weed control in guayule provided growers are educated to expect some injury immediately after application.

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## GENE EXPRESSION OF GUAYULE FIELD PLANTS UNDER DROUGHT STRESS: A COMPARATIVE RNA-SEQ STUDY

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Guayule (*Parthenium argentatum* A. Gray) is a perennial desert shrub native to the southwestern United States and northern Mexico and represents a potential commercial source of natural rubber (NR, *cis*-1,4-polyisoprene), a strategic raw material necessary for national defense, modern transportation, and medicine. Previous studies have shown that rubber yield in guayule increases under various environmental stresses, including drought stress, under which guayule is naturally native habituated. At the molecular level, drought stress results in differential expression of genes regulating various metabolic pathways. To elucidate drought stress responses in rubber biosynthesis pathways as well as identify drought stress related genes in guayule, transcriptome data were generated from stem bark tissues harvested in two-year-old guayule field plants following high and low irrigation treatments. A comprehensive transcriptome database was built using genome-guided and *de novo* RNA-seq assembly, yielding 230,554 unique transcripts with a N50 of 1,638 bp. Putative functions could be assigned to 70.15% of the transcripts based on BLAST searches against several public protein and transcription factor annotation databases. A total of 1475 differentially expressed genes (DEGs) were identified when comparing the two irrigation treatments, with 796 and 679 up regulated and down regulated, respectively, under water limiting conditions. Candidate secondary metabolite genes related to rubber synthesis, rubber particle associated genes, and genes related to drought stress response were experimentally validated for their expression using q-PCR analysis. Rubber and resin yield were quantified and plants subjected to drought conditions were found to produce more rubber. Yield results were used to study correlations of secondary metabolic pathway gene expression to rubber biosynthesis in guayule. In conclusion, we report the identification of a large set of guayule cDNA unigenes from stem bark tissues, providing insights into the genetic and molecular basis of rubber production and response to drought stress in guayule.

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## GUAYULE GERMPLASM CHARACTERIZATION FOR VARIATION IN PLOIDY AND BIOMASS PRODUCTION

Von Mark V. Cruz, Amber Lynch, Guangyao (Sam) Wang, Stefan Dittmar, Theresa Sullivan, Russell Prock, William Niaura, and David A. Dierig

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Many companies have initiated sustainability initiatives. As the world's largest tire company, Bridgestone embarked to commercialize guayule (*Parthenium argentatum* A. Gray) as an alternative source of tire-grade rubber to achieve its long-term vision of manufacturing products from raw materials that are fully renewable and sustainable by 2050. Guayule crop improvement efforts rely on a diverse set of germplasm to enable genetic gain in the breeding program. Characterization of available germplasm collections is important for gathering information about the amount of diversity that breeders can work with. Guayule has a complex mode of reproduction which presents a challenge to breeders. Diploids ( $2n=2x=36$ ) are known to be sexually reproducing while polyploids ( $2n=3x$  to  $6x$ ) are facultative apomictic in nature. Identifying these types of materials in the collection is critical for making decisions in the breeding program as well as characterization of trait potential. This study, as part of the Sustainable Bioeconomy for Arid Regions program, aims to evaluate the accession level variability in ploidy of guayule germplasm and biomass yield which contributes to the shrub's total rubber yield. Fifty four (54) accessions from the U.S. National Plant Germplasm System were direct seeded in two fields at Eloy, AZ and established using sprinkler irrigation on April and May 2018. Leaf tissues were obtained from individual seedlings for flow cytometry analysis. Shrubs were harvested at 10 and 11 months after planting and analyzed for biomass and rubber content. The predominant ploidy observed on the germplasm set was 4x (64%) followed by 3x (34%). Fourteen hexaploid (6x) plants were identified out of the 1,493 analyzed. Among the germplasm, 11619 and N565II had variable ploidy with plants that are 3x to 6x. Twenty six accessions are uniform and have plants that have similar ploidy, while twenty eight accessions are variable with more than two ploidy types among plants. The highest diversity in ploidy in terms of the Shannon-index was on 11619 (1.08), CFS24 (0.81), and CAL2 (0.80). CAL2, CAL1 and AZ2 were observed to have the highest dry biomass (>600g per plant), while 11635 and R1092 had the least amount (<110g per plant). The mean dry biomass of all accessions was 287g. The highest mean rubber content was observed on AZ6 (4.07%), followed by 11693 (3.78%) and lowest on R1037 (2.05%) and CAL1 (1.99%). These data and trait ranking of shrubs that were less than one year old will be compared with observations from 24-month-old shrubs at the next harvest.

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DOWN-REGULATION OF SQUALENE SYNTHASE  
IN GUAYULE (*PARTHENIUM ARGENTATUM*)

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Guayule (*Parthenium argentatum* A. Gray) is a shrub that naturally grows in a semi-arid environment of southwestern Texas to the Chihuahuan desert of Mexico. Guayule plants produce natural rubber (NR) and store them in their stem bark tissues. In guayule plants, NR biosynthesis increases in response to abiotic and biotic stresses. The majority of NR synthesis occurs during the vegetative or dormant period under cold, non-freezing temperatures. Establishing guayule as an alternative rubber-producing crop in the United States will provide supply security for a critical agricultural material and significant benefit for the US rural economy. NR is produced through the isoprenoid (mevalonate (MEV)) pathway in plants. Another isoprenoid metabolite, squalene, produced in plants, might compete with NR for available carbon. Squalene synthase (SQS) is the essential enzyme involved in squalene, a shared precursor for phytosterol and triterpene biosynthesis in plants. In this study, we successfully downregulated the *SQS* gene from guayule by RNA interference (RNAi). Our lab generated a construct, down-regulating *SQS* (*SQSi*) with the purpose of redirecting the pool of farnesyl pyrophosphate (FPP) toward NR production in guayule. Transgenic lines with lower SQS expression were generated. Several of the resulting genotypes showed a correlation of lower *SQS* expression and slightly higher NR content (w/w%) compared to wild-type (WT) and empty vector (EV) controls. These and additional results will be presented.

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GUAYULE RESPONSE TO PLANT POPULATION  
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Optimum plant population is critical for guayule (*Parthenium argentatum* A. Gray) commercial production and varies with genotypes. Two plant population studies with five plant populations and two distinctly different guayule genotypes were planted at Eloy, AZ in April, 2018 and at Tucson, AZ in September, 2018. With row spacing of 101 cm, five in-row spacings (76, 46, 30, 15, and 7.5 cm) correspond with five targeted plant population, 12916, 21527, 32291, 64582, and 129162 plants/ha. The two genotypes were tall and spreading AZ-2 and short and compact Sel-1. After stand establishment and thinning, NDVI (normal differential vegetation index), canopy width, canopy height, and canopy temperature were measured weekly at Eloy using phenotyping platform build by Bridgestone. For all measurements, the differences between AZ-2 and Sel-1 were significant. AZ-2 had wider and taller canopy as well as higher NDVI value. Because of higher biomass and higher transpiration, canopy temperature of AZ-2 were also lower than Sel-1. The effects of plant population treatment on NDVI, canopy width, and canopy temperature can also be seen clearly. Biomass sampling at 7 months and 11 months at Eloy showed that biomass increased with higher plant population and tall genotype AZ-2 had significantly higher biomass compared to Sel-1. Plant size decreased as plant population increased, and AZ-2 plant size was much larger than Sel-1 plant size. Both rubber and resin content did not respond to plant population treatment in the first two samplings. However, AZ-2 genotype had lower rubber content and higher resin content according to NIR measurements. More samplings will be conducted in fall 2019 and final harvest will be conducted in spring 2020 to compare the effects of plant population and genotype on biomass yield and rubber yield.

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## HIGH RESOLUTION MASS SPECTROSCOPY FOR CHARACTERIZATION OF RESIN FROM GUAYULE (*PARTHENIUM ARGENTATUM*)

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Guayule (*Parthenium argentatum* A. Gray), a shrub native to the arid region of the U.S. southwest and Mexico belonging to the *Asteraceae* family, is a source of high quality, hypoallergenic natural rubber with applications in pharmaceutical, tire, and food industries. Production of rubber results in a substantial amount of resin-containing residues which contain a wide variety of secondary metabolites (sesquiterpene esters, triterpene alcohols, fatty acids, etc.). In order to enhance the economic viability of guayule as an industrial crop, value-added use of the residues is needed and has the potential to reduce gross rubber production costs as much as 26-49%. The main objective of this research is the characterization of guayule resin using rapid and accurate analytical techniques to identify compounds of potential commercial value. Guayule resin is inherently complex and includes many high-molecular-weight and non-volatile compounds that are not easy to observe using traditional chromatographic techniques (like GC-MS and HPLC). In this study, high-resolution Fourier Transform Ion Cyclotron Resonance Mass Spectroscopy (FT-ICR-MS) technique was used to characterize hundreds of compounds with over a wide range of molecular weights and degrees of aromaticity at higher levels of mass accuracy than other forms of mass spectrometry. The inherent high mass accuracy and resolution of FT-ICR MS allow for the detection and identification of thousands of compounds within a single mass spectrum and typically used to analyze complex mixtures such as petroleum, biofuels, dissolved organic matter, lipids, and proteins. Atmospheric pressure photoionization (APPI) is used to ionize both polar and non-polar compounds, especially aromatic species, for detection by mass spectrometry. Resin samples were diluted in 50:50 chloroform: methanol to 1 mg/ml stock solutions. Stock solutions were further diluted to 50 µg/ml in toluene for (+/-) APPI FT-ICR MS analysis. The obtained FTMS spectrum contained approximately 4500 peaks in the m/z range of 150-550. The major peaks correspond to m/z 199.11 (C<sub>14</sub>H<sub>14</sub>O), m/z 255.23 (C<sub>16</sub>H<sub>32</sub>O<sub>2</sub>), m/z 279.23 (C<sub>18</sub>H<sub>32</sub>O<sub>2</sub>), m/z 380.31 (C<sub>27</sub>H<sub>40</sub>O), m/z 396.30 (C<sub>27</sub>H<sub>40</sub>O<sub>2</sub>), m/z 398.32 (C<sub>27</sub>H<sub>42</sub>O<sub>2</sub>), m/z 407.26 (C<sub>27</sub>H<sub>36</sub>O<sub>3</sub>), m/z 408.28 (C<sub>27</sub>H<sub>36</sub>O<sub>3</sub>), m/z 421.35 (C<sub>30</sub>H<sub>44</sub>O), m/z 437.34 (C<sub>30</sub>H<sub>44</sub>O<sub>2</sub>), m/z 439.36 (C<sub>30</sub>H<sub>46</sub>O<sub>2</sub>), m/z 455.35 (C<sub>30</sub>H<sub>48</sub>O<sub>3</sub>), m/z 469.33 (C<sub>30</sub>H<sub>46</sub>O<sub>4</sub>), m/z 471.35 (C<sub>30</sub>H<sub>48</sub>O<sub>4</sub>), m/z 473.36 (C<sub>30</sub>H<sub>50</sub>O<sub>4</sub>), and m/z 379.26 (C<sub>26</sub>H<sub>36</sub>O<sub>2</sub>), which most likely represent triterpenoids, steroids and fatty acids compounds discussed in literature. From these spectra, a comparison could be made with the groups of compounds in guayule resin identified in previous studies using other methods. The FT- MS data provides more information about new classes of compounds in the guayule resin for investigation of potential applications and improved chemical separation techniques.

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## WHOLE FARM ANALYSIS TOOL FOR EVALUATING THE ADOPTION OF GUAYULE AND GUAR INTO SOUTHWEST PRODUCERS CURRENT OPERATION

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The Sustainable Bioeconomy for Arid Regions (SBAR) Center of Excellence was established in September 2017, with the intended purpose of developing a systems approach for feedstock development, production, and delivery in the Southwest United States. SBAR works to optimize and integrate the production of guayule (why-oo-lee) and guar to enable the Southwest United States to impact the biofuels and other high-value product markets. Guayule (why-oo-lee) (*Parthenium argentatum* A. Gray) plant is a native to the North American Chihuahuan desert and the Southwestern United States and produces natural rubber. Currently, the Brazilian rubber tree, *Hevea brasiliensis*, which is mainly grown in the tropical regions of Southeast Asia and Africa is the primary source of natural rubber. The United States is the major importer and consumer of natural rubber. Because of rising demand, high price variability, and supply uncertainty, the natural rubber industry is looking for other alternatives to diversify the market. Guayule is a promising alternative source of natural rubber, with a long history, but limited industrialization. A principal objective of the SBAR project is to provide stakeholders, interested in expanding crop options with regional solutions that are economically viable, socially acceptable, and meet the water conservation needs of the arid Southwest (AZ, CA, NM, and TX). The introduction of any new crop into a current production system is always a difficult balance between current production practices, existing commodity markets and the economic impact the adoption will have relative to the current profits of the operation. Additional challenges occur due to imperfect market information as the local market may not exist for the new crop being evaluated. Understanding these changes are often difficult and for farmers interested in expanding crop options that might support rubber and biofuel industries, guayule and guar could be one option. To effectively evaluate the potential adoption of these two crops, the Authors have developed a whole farm analysis tool which will allow producers to evaluate the net returns to the operation given varying levels of acreage adoption, crop mixes and changes in production inputs their by allowing the producer to make an more informed decision about the economics and overall fit of the crops into their operation.

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# **ABSTRACTS**

**GENERAL CROPS & PRODUCTS DIVISION**

**ORAL PRESENTATIONS**

**CHAIR**

**ANA LUISA FERNANDO, NOVA UNIVERSITY OF LISBON, LISBON,  
PORTUGAL**

## EVALUATING CROP WATER STATUS FOR GUAR USING WINDS MODEL

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In the western states of the U.S., including Arizona and New Mexico, water is a limited resource, making deficit irrigation one of the highly adopted agriculture practices. Additionally, researchers are now considering drought tolerant crops as alternatives to overcome water stress. One of the drought tolerant crops is guar, a legume that is sun-loving and perfect for arid regions. With limited moisture in soil, it faces delays in maturity but doesn't die. It takes about 120-150 days until harvest, for the indeterminant variety. Guar has a multitude of products including guar gum, fodder, vegetable, and green manure. Over the years, there has been an increase in industrial interest for its gum. In this experiment, guar was grown in 2018 at New Mexico State University Agriculture Research Center in Clovis, New Mexico using split-split Randomized Complete Block Design (RCBD) with 3 factors. The first factor was pre-irrigation condition where one condition was giving 5 inches of water to the field, and the other condition was with no water given to the field before sowing. The second factor involves four irrigation treatments; namely, full irrigation, water stress at vegetation stage, water stress at reproductive stage, and rainfed. The third factor includes 2 different cultivars of guar: Kinmen and Monument. For this study, only Kinmen cultivar was considered. The crop water status was additionally assessed by estimating the normalized difference vegetation index (NDVI) using a multispectral sensor carried on a drone. The NDVI values were correlated to soil moisture content. The crop coefficient (Kc) for guar was another parameter that was outdated and not available for the study area. The study developed the crop coefficient for guar and with a total of 8 treatment combinations and modeled using WINDS model (Water-use, Irrigation, Nitrogen, Drainage, and Salinity). It is a computer-based tool that runs by soil-water flux and energy distribution equations. Crop coefficient, Evapotranspiration (ETc), soil moisture, soil water depletion, and an irrigation schedule were simulated from the model. Guar was harvested 137 days after planting and the results show the developed Kc values as 0.4, 1.14, and 0.267 for Kc\_initial, Kc\_mid and Kc\_end, respectively. These values are very close to the FAO-56 coefficient values for legumes. Furthermore, the model results depicted correlation with the measured soil moisture and due to rainfall in the year 2018, the crop did not get much water stressed at any of the growth stages. The cumulative difference between the rainfed and full irrigation treatments was 200 mm. The results of NDVI showed great potential to precision using remote sensing. The overall crop water status shows that guar is an excellent drought-tolerant crop and based on weather prediction, lesser irrigation can also be given.

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## IMPORT DEMAND AND POTENTIAL FOR DOMESTIC PRODUCTION OF GUAR

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The Sustainable Bioeconomy for Arid Regions (SBAR) Center of Excellence was established in September 2017 with the support from USDA-NIFA Grant No. 2017-68005-26876. SBAR's research and outreach works to optimize and integrate the production of guayule (why-oo-lee) and guar to enable sustainable biofuels and other high-value product markets in the Southwest United States. Guar is a drought tolerant legume that is mainly produced in India and Pakistan. India is the primary supplier of guar and produces about 80 percent of total global production. The benefits of Guar to U.S. farmers as green manure, livestock feed, and selling value-added products such as guar gum. Due to its low water use and nitrate fixating qualities, guar can provide benefits to producer current crop rotations and potentially increase total farm profitability. The objective of this research is to analyze the import demand for guar and determine the market potential of producing guar in the southwestern United States. The research estimates an inverse demand function to estimate import demand for guar seed. The model estimates that the price of guar seed is a function of annual seed imports, the number of natural gas wells in the U.S., import, and export price ratio for natural gas, and a dummy variable that takes the value of 1 in peak price years and 0 otherwise. The research used annual data from the USDA on guar imports to the U.S. from 1989 to 2016 to estimate an average price. The model has an R square of 0.89 suggesting that the model has a good fit. This means that 89% of the variance in guar import price can be explained by the variance in one or more of the variables. The empirical results indicate that all estimated variables are statistically significant. There is a negative relationship between quantity imported and import price, which is consistent with the demand theory. One of the most important factors when determining the price of guar seed is the number of natural gas wells in the U.S. This means that an increase in the number of natural gas wells in the U.S. would greatly increase the price for guar. Guar's drought tolerance, low input requirements, and nitrogen fixation qualities make it an ideal crop to be incorporated into current crop rotations. As we look towards the future, producers in the southwest will need alternative crops that increase profits while decreasing water usage and total inputs. Guar fits well as a potential crop that producers could use to improve profits while decreasing water consumption. Also, the nitrogen fixation abilities of guar can decrease the variable costs of crops following in rotation. The future of domestic production of guar is highly dependent on trends in the oil industry, further domestic research, and domestic marketing of guar. Thus, through research and extension activities that will be performed by the SBAR team, farmers in Southwest United states will eventually be able to take advantage of this huge market presented by the high demand for guar gum.

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## SEEDING DATE EFFECT ON GRAIN SORGHUM PERFORMANCE IN NORTH DAKOTA

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Grain sorghum [*Sorghum bicolor* (L.) Moench] is an economically and historically important world crop with the greatest production in the United States. Successful grain sorghum production requires matching variety maturity and seeding date for a growing region. Current commercial varieties exhibit late maturity and are not adapted to North Dakota's shorter growing season with cooler temperatures. The study objectives are to evaluate early-maturing, high-yielding open-pollinated sorghum genotypes and seeding date at North Dakota locations to determine crop performance. The experiment was a RCBD split-plot arrangement with the main plot seeding date and the subplot genotype. Three seeding dates were spaced at eight-day intervals and began on May 22 at the northern Carrington and southern Prosper locations. Six genotypes included two commercial hybrids and four open-pollinated genotypes previously screened from national germplasm sources. Analysis indicated the seeding date x genotype interaction significant for days to 50% anthesis, 1000 seed weight, and grain yield at each location. Days to 50% anthesis were 9 to 10 and 5 to 8 days earlier for the open-pollinated genotypes than the hybrids at Carrington and Prosper, respectively. As seeding date became later, hybrid and open-pollinated days to 50% anthesis decreased 5 and 1 d, respectively at Carrington. At Carrington, yield was similar at seeding date 1 for all genotypes, but at seeding dates 2 and 3 yield was lower for hybrids AG1401 and RS320W, compared with the open-pollinated genotypes PI574595, SARE10, SARE14, and SARE17. At Prosper, hybrids AG1401 and RS320W yield was reduced at seeding date 3 compared to dates 1 and 2, which produced similar yield. Genotypes PI574595, SARE10, SARE14, and SARE17 yield was similar across seeding dates. Results indicate the open-pollinated genotypes are earlier maturing than the hybrid genotypes and maintain yield at later seeding dates, whereas hybrid yield decreases as seeding date advanced, especially at the northern, cooler, shorter season at Carrington. Hybrid yield decrease at later seeding dates was less dramatic at the southern Prosper location, where the earlier maturing open-pollinated genotypes yield was similar across seeding dates.

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SEEDING DATE AND SEED TREATMENT EFFECT ON  
INDUSTRIAL HEMP STAND ESTABLISHMENT

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Stand establishment is directly related to the most important yield component, plant population, for determining crop performance at harvest. Planting depth, seeding date, and soil water are abiotic factors that affect soil temperature and water absorption for germinating seeds. Seed quality related to size, germination, and vigor are important biologically in achieving optimum crop stands which for wheat (*Triticum aestivum* L.), corn (*Zea mays* L.), and soybean [*Glycine max* (L.) Merr.] typically represent 85 to 90% of pure live seed planted. Hemp (*Cannabis sativa* L.) live seed emergence is lower and generally rated at 70% and represents a higher seed cost to the producer in achieving recommended stands. The objective of this study is to investigate seed treatment effects on improving hemp stand establishment. A RCBD experiment with four replicates, two seeding dates, and 14 seed treatments (including a nontreated control) was conducted at Prosper, ND, during the 2019 growing season. Dual-purpose hemp cultivar 'Anka' seeding dates were targeted when spring soil temperatures reached those recommended for wheat and soybean planting. Seeding rate was 130 pure live seed/m<sup>2</sup> sown at a soil depth of 20 mm. Plots consist of four rows each spaced 30 cm apart and 3 m in length. Stands/emerged seedlings were counted three times post planting at approximately 10, 20, and 30 d for each planting date. Seedlings were counted as emerged when the cotyledons were unfolded at growth stage 0003 or later stage. The early date 1, d-10, d-20, and d-30 pure live seed emergence (PLSE) results ranged from 32 to 42, 46 to 55, and 45 to 56%, respectively among the 14 seed treatments. The nontreated control PLSE for date 1 was 40, 50, and 50% for d-10, d-20, and d-30, respectively. These results indicate potential seed treatment benefits for increasing hemp seedling emergence and established stands.

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## USING DORMANT BUDS FOR PRESERVATION OF INDUSTRIAL WOODY SPECIES. THE *SALIX* CASE

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Beyond landscape applications, willow (*Salix* spp.) is an emerging lignocellulosic crop producing biomass as a source of energy and fibers. Intense research on willow improvement and development of mechanical cultivation and harvest techniques is underway in several countries (e.g., United Kingdom, Australia, Ireland and the U.S.). *Salix* trees and shrubs may be grown on marginal land as a short-rotation coppice and are easily propagated by rooted cuttings in new field stands. Mass cultivation of any crop often makes a crop vulnerable to diseases and pests; hence, preservation is critical in maintaining genetic resources for future use. The USDA-ARS, National Plant Germplasm System maintains 62 accessions (33 taxa) at its Ames, Iowa location. For three years, the Agricultural Genetic Resources Preservation Research Unit in Fort Collins, CO, tested eight of these accessions for cryopreservation of dormant buds (DB) by using a modified DB technology developed for apples. The modification included longer DB twig segments (10 and 6 cm vs. 3.5 cm in the apple protocol), no desiccation of DB segments and viability testing in a sterile soil substrate (instead of grafting) after exposure to liquid nitrogen vapor (LNV; -182 to -196°C). Post-cryopreservation viability evaluated as the ability to develop leaves and/or shoot(s) ranged from 43.9 to 82.2% for 6 and 10 cm DB segments respectively, varied between years and species, and was positively correlated with shoot and root development ability in the initial (not LNV exposed) DB segments and with the twig diameter. The results suggest the possibility of cryopreserving willow genetic resources by using our modified DB method; and, in this way, 42 accessions have already been successfully cryopreserved. We suspect that the same procedure could be applicable for long-term preservation of other industrial woody crops (e.g., aspen (*Populus* L.), eucalyptus (*Eucalyptus* L'Hér.), maple (*Acer* L.), and birch (*Betula* L.)).

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# YIELD POTENTIAL AND BIOMASS CHARACTERISTICS OF THE PERENNIAL CROPS GIANT REED (*Arundo donax* L.) AND SWITCHGRASS (*Panicum virgatum* L.) IN SOILS CONTAMINATED WITH HEAVY METALS

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Among the various impacts caused by man to the environment, soil contamination deserves attention. This gives rise to a number of environmental problems such as desertification, contamination of water resources and/or contamination of food crops, which can lead to serious health problems for humans directly or indirectly. To avoid these situations, it is necessary to decontaminate the soils, which can occur through various techniques (physical, chemical and biological methods). The use of plants for the decontamination of soils (phytoremediation), and specifically the use of energy crops, is an interesting alternative. Along with the decontamination action, the biomass produced may provide an additional income, when used for bioenergy or biomaterials, and the process contributes to the bioeconomy by reducing the dependence on fossil fuels. Therefore, the aim of this work was to study the effects of different heavy metals (Zn, Cr, Pb, Cd, Ni, Cu) on giant reed (*Arundo donax* L.) and switchgrass (*Panicum virgatum* L.) growth, productivity and biomass quality. The soils were artificially contaminated (Zn: 900 mg/kg; Cr: 600 mg/kg; Pb: 900 mg/kg; Cd: 8 mg/kg; Ni: 220 mg/kg and Cu: 400 mg/kg) and the tests were performed in pots. The concentrations chosen are equivalent to twice the limits established by the Decree Law 276 of 2009 (Portuguese regulation that establishes the regime for the use of sewage sludge in agricultural soils). Results indicate that switchgrass is more sensitive to heavy metals than giant reed. Both crops showed tolerance to Zn and Pb contamination and giant reed also showed tolerance to Cd, Ni and Cu. However, in Cr contaminated soils, a significant loss in giant reed yields was observed. Switchgrass yields were significantly affected by Cd and Ni contamination and this crop was unable to grow in Cr and Cu contaminated soils. In this establishment year, giant reed was three times more productive than switchgrass, and showed to be more promising in heavy metals contaminated soils. Results also show the soil contamination has an effect on biomass characteristics. When contamination hasn't resulted in an effect in yields, the ash content was similar to the ash content of the crops from the control pots. But, the yield reduction caused by contamination induced a concentration of mineral matter in the biomass, and therefore, higher ash content was obtained in those plants, which can limit the use of this biomass as a feedstock.

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# **ABSTRACTS**

## **POSTER PRESENTATIONS GENERAL CROPS AND PRODUCTS**

ROOT NODULATION IN GUAR (*CYAMOPSIS ETRAGONOLOBUS* L. TAUB.): EFFECTS OF SOILS, RHIZOBIUM INOCULANTS, AND GUAR VARIETIES

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Guar is a leguminous crop plant that produces seed containing galactomannan gum, which is used in industrial applications as a lubricant, binder, thickener, and emulsifier, among other functions. In the U.S., the primary production area for guar is in the Southern Great Plains region. As a legume, the primary ecosystem service regional agricultural producers expect from guar is nitrogen fixation, but a common perception is that guar does not nodulate effectively. The objective of this replicated and repeated greenhouse study was to test the effects of contrasting soils, representing typical alkaline soils in which guar is cultivated worldwide, and *Rhizobium* inoculants on nodulation and plant growth characteristics in two guar varieties. In the study, abundant nodulation was observed. The soils had contrasting effects on nodulation, with a high nodule number of low weight (497 mg / 24.3 nodules) in the clay loam and low nodule number of high weight (583 mg / 8.64 nodules) in the sandy loam, but no effect of the inoculants was observed. The difference in nodule characteristics between the soils may have resulted from differences in indigenous *Rhizobia* population sizes and/or species available to associate with guar roots or other factors. The lack of inoculant effects may have resulted from high indigenous levels of *Rhizobia* in the soil and/or low concentrations of *Rhizobia* or uncompetitive *Rhizobia* delivered through the seed-applied inoculants. Based on the results of this study, we expect that guar will nodulate and fix nitrogen effectively in field conditions, given that these processes are not inhibited by exogenous factors, such as water stress. Achieving increases in nodulation and nitrogen fixation above baseline levels will require a concerted effort to develop effective inoculants for guar, which may offer a unique opportunity to expand biological nitrogen fixation in agriculture in semi-arid regions.

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## USE OF OPTICAL SEED SORTERS FOR OPTIMIZING PLANT GENETIC RESOURCE SEEDS LOTS

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The USDA-ARS genebank at the North Central Regional Plant Introduction Station in Ames, IA conserves more than 50,000 accessions of plant genetic resources and is also the home for the Ames component of the Germplasm Enhancement of Maize (GEM) Project. Maintaining and providing high quality plant genetic resources and associated information for crop improvement is a key part of our mission. Producing, processing, and providing high quality, disease-free seeds is a labor intensive and expensive process in terms of both resources and time. Programmable optical seed sorters are useful for separating seeds based on size, shape, and color factors. Two optical sorters have been used, the first is a Metrix instrument manufactured by VMek<sup>3</sup>, to determine sorting criteria for an array of crop seeds including maize, millet, sorghum, soybean, amaranth, and various vegetables. The user interface enables differentiation of acceptable from unacceptable seeds, identification of areas of a seed for selection focus, input of red/blue/green color value criteria, etc., and provides a variety of statistical options and data capture. It was possible to separate diseased and/or discolored seeds, eliminate a high percentage of seeds that had pre-germed (sprouted), optimize seed lots based on appearance characteristics, and also for seed size/shape to facilitate mechanical planting of maize by research planters. Images and data to be shared. The second instrument is the QSorter<sup>3</sup> from QalySense, which uses color vision and NIRS (Near Infra-red Spectroscopy) and captures images and spectral data. An algorithm developed by QalySense has been used to successfully sort haploid from non-haploid maize seeds with greater than 90% accuracy. These haploids were generated by the Iowa State University Double Haploid Center using a maternal inducer line with the R-Navajo marker gene. There is an engagement in developing algorithms to help characterize seed properties.

<sup>3</sup>Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA.

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## SEASONAL WATER EXTRACTION PATTERNS OF GUAR UNDER DIFFERENT IRRIGATION STRATEGIES IN THE SOUTHERN HIGH PLAINS

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Agriculture production is highly dependent on the availability of water. Ogallala aquifer, being the main water source in Southern the High Plains, is not recharging. Crops with lower water requirements and good economic returns are needed. Guar (*Cyamopsis tetragonoloba* (L.) Taub.) is a leguminous, drought tolerant crop with industrial importance. Guar gum from seed is used in fracking and many other industries. The objective of this experiment is to analyze the effect of pre-season and in-season irrigation strategies on water dynamics of two diverse guar genotypes. The design was strip split plot design with both pre-irrigation having two levels and in-season irrigation treatment having four levels [i.e. full irrigation (FI), no irrigation during reproductive growth stage (Rstss), no irrigation during vegetative growth stage (Vstss) and no irrigation after crop establishment (Rainfed)] as strip factors and cultivar having two levels [i.e. Kinman and Monument] as the subplot factor with four replications for each treatment. Maximum water was extracted from 0.7 to 1.3 m soil depth. This indicates the capacity of extracting water from deeper soil depths. Evapotranspiration and water extraction were more in pre-irrigation than no-pre-irrigation. Higher WUE (water use efficiency) under Rstss and Rainfed treatments suggest that these treatments utilized the available water more efficiently. The cultivar Kinman showed higher WUE. Thus, applying pre-irrigation and growing Kinman cultivar of guar with no additional irrigation during reproductive growth stage is much beneficial and sustainable approach.

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## LIFE CYCLE ASSESSMENT OF GUAR AGRICULTURE IN THE SOUTHWEST USA

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Guar (*Cyamopsis tetragonoloba* (L.) Taub) is an annual desert legume crop that is native to subtropical and semi-arid regions of India and Pakistan. Its main product, guar gum, is the source of a polysaccharide emulsifier that is used mainly in the food industry as a thickener and in the oil and gas industry during the fracking recovery process. The continual rise of US fracking and the expansion of shale oil gas fracking to countries like China and Russia has significantly increased the world market demand for processed guar. This global surge has resulted in an unmet domestic demand for guar products and co-products in the US which offers an opportunity for the growing of guar in the US to expand and provide a more sustainable source to meet the demand. 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 ever-increasing reliance has encouraged the investigation of expanding US grown guar to support the development of a sustainable bioeconomy in the Southwest US. Some of the preliminary work of this investigation is focused on developing models to quantify environmental sustainability of guar cultivation. While a few guar sustainability studies have been conducted, there is a paucity in the current available literature of agriculture process specific (before guar bean processing) studies as well as studies specific to the southwestern United States. This study completed a cradle-to-gate Life Cycle Assessment (LCA) of guar grown in the US Southwest based on literature data, highlighting areas for agricultural changes that could result in environmental improvements. Through using this technique that quantifies the environmental impact of processes from raw materials extraction to end of life and applying computational modeling tools and the TRACI 2.1 life cycle impact assessment (LCIA) method, environmental impacts were evaluated. Preliminary results of agricultural modeling show that irrigation and harvesting practices have the highest impact among all TRACI categories. A preliminary scenario 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%. Another preliminary scenario analysis compared Urea and 2 other commonly used N-fertilizers and showed that the impacts of the three were very similar with minimal differences. In order to optimize the overall agricultural process of guar and more accurately determine impacts, experimental work and data is needed to validate the model development which is limited with the current literature gaps, including lack of direct field emissions (N&P runoff, groundwater infiltration, and particulate dispersion) data.

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SEED VIABILITY FROM 30 ROSELLE (*HIBISCUS SABDARIFFA* L.) ACCESSIONS  
REGENERATED AT USDA, ARS, PGRCU IN GEORGIA, USA

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The National Plant Germplasm System (NPGS) within the United States Department of Agriculture (USDA), Agricultural Research Service (ARS), and Plant Genetic Resources Conservation Unit (PGRCU) is dedicated to the curation of high quality roselle (*Hibiscus sabdariffa* L.) germplasm for distribution to the scientific community worldwide. Roselle is a very important crop because the calyces can be used to produce health teas, jelly, chutney, and syrup. The current roselle collection consists of approximately 84 accessions and 55 of these are available for distribution. It was previously thought that roselle accessions could not produce viable seeds when regenerated under field conditions at the USDA, ARS, PGRCU in Byron, GA due to their photoperiod sensitivity. The objective of this research was to determine if viable seeds could be regenerated from any of the 84 roselle accessions in Byron, GA during 2018. Roselle seeds from 84 accessions were planted by directly seeding in the field at Byron, GA during mid-June, 2018. Potentially viable seeds were harvested from 30 accessions prior to the first hard freeze during November, 2018. The calyces containing the seeds were dried at 21°C and 25% RH for about 1 week. Then the calyces were threshed and maintained in a freezer at -18°C until germination testing (~90 days). Eleven to 100 seeds per accession were planted in 6.4 x 7.0 cm jiffy pots (Hummert International, Earth City, MO, USA) containing Promix HP potting soil (Griffin Greenhouse, Ball Ground, GA, USA). The seedlings were grown in a greenhouse for 4 weeks (March to April, 2019) without supplemental lighting at 21 to 26°C. Germination counts will be recorded weekly for 4 weeks with a final count during the first and second weeks of April. The plants will be monitored for vigor and health.

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## PANACEA - A THEMATIC NETWORK TO DESIGN THE PENETRATION PATH OF NON-FOOD CROPS INTO EUROPEAN AGRICULTURE

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Non-food crops (NFC) are considered those that do not enter the food chains and are used to produce a wide range of bio-based products including: polymers, lubricants, construction materials, pharmaceuticals, as well as bioenergy and fuels. In the last decade there has been a great increase in the cultivation area of two major oil crops namely rapeseed and sunflower for non-food use (biodiesel production; first generation biofuels). Currently, a wide range of non-food crops plantations can be found in most EU countries, targeting the production of biobased products and bioenergy. However, in spite of considerable investment in research and development, NFCs are not widespread in European agriculture, mainly due to challenges in supply chains as well as gaps in the policy framework and in the investment incentives. The increasing need for feedstock to supply the bio-based industries makes the successful penetration of NFC in EU agriculture necessary. PANACEA project ([www.panacea-h2020.eu](http://www.panacea-h2020.eu)) aims to design the penetration path of non-food crops into EU agriculture producing feedstocks for bio-based products and materials to feed EU's circular economy. The project started in November 2017 and will run for 36 months. The main activities of the project are: a) to create an inventory on non-food crops and to select those crops that close to agricultural practice and to carry out a SWOT analysis for them, b) to record and analyse the farmers' and industry needs for feedstock from non-food crops, c) to create national roadmaps for the successfully penetration of non-food crops in ten European countries and then to prepare the EU roadmap for this, d) to train the practitioners (farmers, agronomists and near to graduation farmers) for the non-food crops that are near to practice e) to create a platform where all information that will be collected will be uploaded (the platform will be updateable, connectable and searchable). The main impact of PANACEA thematic network is to contribute to the successful deployment of the vast reservoir of existing scientific and practical knowledge on non-food crops and to improve the knowledge exchange between scientists and practitioners. The project is in progress and its main achievements so far are: a) an inventory for non-food crops including more than 200 research projects (covering 93 non-food crops), more than 900 references, b) a list of 29 non-food crops that are near to practice that have been grouped to oilseeds, lignocellulosic, carbohydrate, woody and specialty crops c) a SWOT analysis where the strengths and the opportunities of the selected 29 non-food crops had been analysed, d) a study where the farmers' and industry needs have been reported, d) training material for students, agronomists and farmers and e) a platform that is ready to be realised. It should be mentioned that for farmers the major factors towards the decision to grown non-food crops are: a) the profitability of the non-food crops, b) the market demand for feedstock from these crops and c) the easy access to the markets. Moreover, the farmers stated that the availability of a management guide on how to grow the non-food crops would be very helpful for choosing to grow non-food crops. In France the farmers were interested on double crops in one year as the best option to insert the non-food in their food agricultural systems.

Acknowledgements: The PANACEA project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773501.

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## WHICH INDUSTRIAL CROPS CAN BE GROWN ON MARGINAL LANDS?

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Industrial crops can provide abundant renewable biomass feedstocks for the production of high added-value bio-based commodities and bioenergy. They can be broadly categorised as oil, lignocellulosic, carbohydrate or specialty crops. Most of them are multipurpose crops (like cardoon, industrial hemp, flax, etc.) offering the opportunity to follow a cascade bio refinery concept to produce a number of value-added bio products and bioenergy, thus feeding the bio based economy. Prospectively, industrial crops can increase and diversify farmers' income through access to novel bio-based markets, and the possibility to exploit marginal land with limited value for conventional agriculture. In recent years, a debate has emerged regarding food security and land use for bioenergy/industrial non-food crops. Cultivating industrial crops on marginal land unsuitable for food production is consistently proposed as a viable alternative to minimize land-use competition for food production, and its adverse effects (direct or indirect) on food security, land based GHG emissions and biodiversity loss. The term 'marginal land' has entered the wider political debates, and today biofuel crops are generally promoted and supported on marginal land; nonetheless, marginal land has been not yet unequivocally defined, and there is not a clear information on where, when and how much genuine marginal land is available. In the framework of MAGIC project (HORIZON 2020; [www.magic-h2020.eu](http://www.magic-h2020.eu)) a number of selected industrial crops are being grown on marginal land facing natural constrains, while contaminated and degraded land are also been included. MAGIC aims to promote the sustainable development of resource-efficient and economically profitable industrial crops grown on marginal and contaminated land. During the first year of the project a total number of 20 industrial crops had been selected as the most promising to be grown on marginal and contaminated lands in several sites in Europe. The selected industrial crops have been grouped as follow: a) Oilseeds and specialty crops; camelina, crambe, castor bean, Ethiopian mustard, safflower, lupin, hemp, and cardoon, b) lignocellulosic crops: perennial herbaceous crops (switchgrass, miscanthus, giant reed, reed canary grass, cardoon, tall wheatgrass, Wild sugarcane), fibre crops (industrial hemp, fiber sorghum) and woody species (willow, poplar, Siberian Elm, Black locust) and c) carbohydrate crops (sweet sorghum and lupin). In the view of the project three types of field trials are being carried out: a) continuation of already established long-term field trials on perennial herbaceous (switchgrass, miscanthus, reed canary grass, giant reed, tall wheat grass, cardoon) and woody species (willow, poplar), b) new field trials under different types of marginal lands either on small plots or on strip trials and c) trials on pots testing marginality factors such as heavy metals and salinity. In the trials that have been established in the framework of MAGIC the most appropriate agronomic practices with limited input requirements are being investigated, while will be also tested new varieties/hybrids that will be developed in the project (from month 18 and onwards). The field trials have been established in ten EU countries (Greece, Italy, Spain, Portugal, France, The Netherlands, Germany, Poland, Latvia, and Ukraine).

A database on industrial crops will be available soon in the project website (the first version has been already delivered), where it could be found not only information for the selected industrial crops mentioned above but for a total number of 38 industrial crops with factsheets per crop. During the project guidelines for farmers for the successful cultivation of the selected industrial crops will be prepared and will be distributed and discussed in dedicated project's events.

Acknowledgements: MAGIC (Marginal lands for growing industrial crops: Turning a burden into an opportunity) has received funding from the European Union's Horizon 2020 Programme under Grant Agreement 727698.

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# **ABSTRACTS**

## **POSTER PRESENTATIONS**

### **MEDICINAL AND NUTRACEUTICAL PLANTS**

## EXTRACTS OF AGRITO (*RHUS MICROPHYLLA* ENGELM. EX A. GRAY) FOR THE CONTROL OF PLANT PATHOGENIC FUNGI

Ana V. Charles-Rodríguez<sup>1</sup>, Luz L. Rivera-Solís<sup>1</sup>, António A. Vicente<sup>2</sup>, Joana T. Martins<sup>2</sup>, Zlatinha Genisheva<sup>2</sup>, Armando Robledo-Olivo<sup>1</sup>, Susana González-Morales<sup>1</sup>, Gustavo López-Guarín<sup>1</sup>, Dolores G. Martínez-Vázquez<sup>1</sup>, and María L. Flores-López<sup>3</sup>

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The greatest losses in crops in the field and postharvest stage are mostly produced by the attack of fungi. *Fusarium oxysporum* and *Corynespora cassiicola* are two devastating plant pathogenic fungi that infect several crops (e.g. tomato and cucumber). The conventional agriculture uses chemical pesticides; however, a large majority of crops are generating resistance, in addition to having a negative impact on health and the environment. The use of plant extracts has emerged as a natural alternative within the framework of organic agriculture, highlighting the plants of the Mexican Semidesert. In this context, the properties of agrito (*Rhus microphylla*), a plant used in the traditional medicine, have not been studied. Thus, the objectives of this work were: to evaluate the antifungal activity *in vitro* of aqueous (AE), ethanol (EE), and hydro-alcohol (HAE) extracts of berries of *R. microphylla* on *F. oxysporum* and *C. cassiicola*; and to characterize the extracts in the terms of total phenolic compounds (TPC) by Folin Ciocalteu and ultra-high-performance liquid chromatography (UHPLC) methods, and antioxidant activity expressed as the concentration required to obtain a 50% of inhibition of radical scavenging activity (IC<sub>50</sub>). The EE showed the highest ( $p < 0.05$ ) content of TPC (201.6 ± 3.3 mg gallic acid (GA) g<sup>-1</sup> extract), characterized by the presence of gallic acid (321.9 ± 4.0 mg L<sup>-1</sup>) and *p*-cumaric acid + epicatechin (42.2 ± 2.9 mg L<sup>-1</sup>); followed by HAE (151.0 ± 3.9 mg GA g<sup>-1</sup> extract), which mainly contains gallic acid and *p*-cumaric acid + epicatechin (98.6 ± 4.4 and 78.2 ± 1.5 mg L<sup>-1</sup>, respectively); and AE (146.8 ± 0.1 mg GA g<sup>-1</sup> extract), in which gallic acid was detected at a concentration of 203.2 ± 0.7 mg L<sup>-1</sup>. However, EE and AE did not present significant differences in the antioxidant activity, as both showed an IC<sub>50</sub> of 0.1 ± 0.0 mg mL<sup>-1</sup>, while for HAE the IC<sub>50</sub> value was 0.2 ± 0.0 mg mL<sup>-1</sup>. These results are interesting and support the antifungal behavior of the extracts. For both fungi, the antifungal activity was concentration-dependent and varied according to the fungus genera, being the EE that had a significant inhibition of 100% growth of both fungi from the concentration of 2500 mg L<sup>-1</sup>. The HAE allowed an inhibition about 60% also at 2500 mg L<sup>-1</sup> for both fungi, and 100% of inhibition of *C. cassiicola* at 3000 mg L<sup>-1</sup>. The AE exhibited the lowest ( $p < 0.05$ ) antifungal effect with inhibition values of 20.8% ± 3.4 and 62.8% ± 1.5 at 3000 mg L<sup>-1</sup> for *F. oxysporum* and *C. cassiicola*, respectively. The EE and HAE of berries of *R. microphylla* are promising as a natural alternative to control phytopathogenic fungi in crops of commercial importance.

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## FLOURENSIA CERNUA, AN OUTSTANDING PLANT IN THE ARID AND SEMI-ARID ZONES OF MEXICO

Diana Jasso de Rodríguez<sup>1</sup>, Raúl Rodríguez-García<sup>1</sup>, M. Lourdes V. Díaz-Jiménez<sup>2</sup>, José A. Villarreal-Quintanilla<sup>1</sup>, M. Liliana Flores-López<sup>1</sup>, and Fidel M. Peña-Ramos<sup>1</sup>

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*Flourensia cernua* is an endemic plant that grows in Mexico, perfectly adapted to the arid and semi-arid zones, which are characterized by drought, high and low temperatures and high UV radiation. In the extracts have been identified secondary metabolites that have biological potential, such as antialgal, antitermite and antifungal. The metabolites are polyphenols, lactones, benzofuran and benzopyrans. The objective of the present study was to show the results of the recent researches carried out in *F. cernua*, which scientifically position it as an outstanding plant due to its biological potential. Information is presented on the results obtained by the research team of the Phytochemistry Laboratory of the UAAAN. In addition to the results obtained by other research groups. Focused on the search of biofungicides of plants of the region to maintain the sustainability of the environment, crops and food and reduce the use of synthetic chemicals, we have continued the studies of *in vitro* antifungal activity of the extracts of ethanol and water from leaves and branches of *F. cernua*, against pathogens such as *Fusarium oxysporum* and *Rhizopus stolonifer* that affect crops of commercial interest. The extracts of the leaves in ethanol of *F. cernua* inhibited *F. oxysporum* and *R. stolonifer* at MIC<sub>50</sub> of 619 and 958 mg L<sup>-1</sup>, respectively. The chemical profiles of the ethanol and aqueous extracts of leaves and branches of *F. cernua* were identified. Recently, nano-laminated coatings with *F. cernua* extract were elaborated, which extended the shelf life of tomato fruits by reducing weight loss and microbial growth, as well as reducing gas exchange and ethylene production and maintaining the firmness and the color of the fruit. Extracts and secondary metabolites identified from *F. cernua* possess: a high effectiveness in the inhibition of postharvest fungi; as well as a natural source of antifungal agents for the production of biofungicides. The nano-laminated coatings with *F. cernua* extended the shelf life of the tomato. Due to its phytochemical composition and biological potential, *F. cernua* is an outstanding plant from the arid and semi-arid zones of Mexico.

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ANTIFUNGAL ACTIVITY OF SECONDARY METABOLITES OF EXTRACTS OF STEMS AND RHIZOMES OF *JATROPHA DIOICA* AND ITS CONTROL OF *FUSARIUM OXYSPORUM* IN TOMATO.

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*Jatropha dioica* Sessé ex Carv., whose common name is dragon's blood, grows wild in the semi-arid zones of northeastern Mexico. This plant has been little studied scientifically, but due to its traditional use, antimicrobial properties are attributed to it. The objectives of the present study were: To obtain the extract from the stems and rhizomes of *J. dioica*, to identify the secondary metabolites present in the extract, and to evaluate the antifungal activity of the extract in the control of *Fusarium oxysporum* in tomato plants, in the greenhouse. The stems and rhizomes were collected and the extract was obtained with the 25/75 % ethanol / water mixture, the chemical composition was identified by GC-MS. The experiment was established under a completely randomized design, in a greenhouse, with eight treatments and 10 repetitions. The treatments were: T1, absolute control; T2, inoculated control; T3, 100; T4, 300; T5, 500; T6, 1000; T7, 1500 and T8, 2000 mg L<sup>-1</sup>, extract dose. The tomato seedlings in the transplant were inoculated with a *F. oxysporum* spore solution of 1.7x10<sup>6</sup> spore's mL<sup>-1</sup>. The extracts were applied four times: to the transplant, at 10, 20 and 40 days after the transplant. The evaluated variables were: incidence and severity, length and diameter of stem, dry weight of leave and stems by treatment; dry weight of root, number of bunches, number of fruit, total weight of fruit. Seven compounds were identified, including ethyl isoallocholate and ergosta-5, 22-dien-3-ol, acetate. These metabolites have been reported for their antimicrobial and antifungal activities. The plants of T6 (1000 mgL<sup>-1</sup> extract dose), had the largest length of stems, dry weight of leaves, number of fruit and total weight of fruit. This indicates a better control of the pathogen by this treatment, which could be attributed to the matrix of secondary metabolites that produce a synergy between them, protecting the plants from the attack of *F. oxysporum*. It is concluded that the stems and rhizomes extract of *J. dioica*, contain secondary metabolites that act as antifungals in tomato.

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## EFFECT OF THE TEMPERATURE ON THE ANTIOXIDANT QUALITY AND SHELF LIFE OF CONCENTRATE OF PITAHAYA (*PACHYCEREUS GRANDIS*)

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The cacti are found mainly in arid and semi-arid areas, Mexico is characterized by wide range of these species and its commercial use focuses on producing juices, concentrates, desserts, syrups, jams and dehydrated. The pitahayas are a type of cacti and may be considered as a functional food because it protects those who consume it for chronic diseases, due to its high antioxidant activity and by its content of phenols. *Pachycereus grandis* is a species native to Mexico that has a wide morphological variation and that has multiple uses, mainly by the consumption of the fruit, in addition to the optimal utilization of the stems for fences, erosion control, and as fuel. The expiration date is an important requirement of all foods produced and processed. Each food has and must recognize, a microbiological, a chemistry and an organoleptic expiration, because all foods break down, although at a different speed. At the time of any parameter within these aspects are deemed unacceptable, the product has reached the end of its useful life. The present investigation in particular on a concentrate of the variety *P. grandis*, with the objective to determine the shelf life of evaluating quality attributes such as phenols, flavonoids, betaxantinas and betacyanins, because a product with commercial success must have an expiration date acceptable and consistent. Red pitahaya (*P. grandis*) was acquired from the municipality of Tepalcingo, Morelos, Mexico and preserved in a freezer at a temperature of -18°C. The defrost process was carried out in a refrigerator at an average temperature of 10°C per 24 h. The shell was removed of the fruits, after the pulp was removed and placed in a dual checkmark and thus the concentrated by evaporation because the product is placed in metal containers. Accelerated Life tests were carried out in a bioclimatic chamber to three different temperatures (11.3, 21.3 and 31.3°C), taking 4 containers for 0, 30, 60, 90, 120, 150 and 180 min. to assess in each one of them, the antioxidant capacity as well as the content of pigments and then determine the speed of deterioration. Determination of phenols was carried out using the Folin-Ciocalteu, using the equation obtained from the curve of the calibrated with a standard solution of gallic acid. Quantification of flavonoids: was obtained from a curve of catechin. Content of pigments: was performed in a metanolic extract obtained from the concentrates by measuring the absorbance at 538 nm and 483 nm for betacyanins and betaxantinas, respectively. The determination of shelf-life was determined by the method Q10. An analysis of one-way ANOVA, with an index of 95% confidence. The quality attributes of showed no significant differences to increase the temperature were the flavonoids, betaxantinas and betacyanins, since they have a stable behavior, although there is a small decline statistically is not important. In this case, the quality attribute of critical or with greater loss are the phenols, because they are the most susceptible to changes in temperature and in function of these, you should evaluate the limit of the shelf life of the concentrate of fruit.

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# **ABSTRACTS**

## **POSTER PRESENTATIONS NATURAL RUBBER AND RESINS**



## THE ECONOMIC POTENTIAL OF PRODUCING GUAYULE IN THE SOUTHWEST

Sita Khanal<sup>1</sup>, Clark Seavert<sup>2</sup>, Paul Gutierrez<sup>1</sup>, and Trent Teegerstrom<sup>3</sup>

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The Sustainable Bioeconomy for Arid Regions (SBAR) Center of Excellence was established in September 2017 with the support from USDA-NIFA Grant No. 2017-68005-26876. SBAR's research and outreach work to optimize and integrate the production of guayule (why-oo-lee) and guar to enable sustainable biofuels and other high-value product markets in the Southwest United States. Guayule (*Parthenium argentatum*) plant is a native to the North American Chihuahuan desert and the Southwestern United States and produces natural rubber. Currently, the Brazilian rubber tree, *Hevea brasiliensis*, which is mainly grown in the tropical regions of Southeast Asia and Africa is the primary source of natural rubber. The United States is the major importer and consumer of natural rubber. Because of rising demand, high price variability, and supply uncertainty, the natural rubber industry is looking for other alternatives to diversify the market. Guayule is a promising alternative source of natural rubber, with a long history, but limited industrialization. A principal objective of the SBAR project is to provide stakeholders, interested in expanding crop options with regional solutions that are economically viable, socially acceptable, and meet the water conservation needs of the arid Southwest (AZ, CA, NM, and TX). For farmers interested in expanding crop options that support rubber and biofuel industries, guayule could be one option. The present study provides the extension publication on economic and technical information on growing guayule in the form of enterprise budgets. In addition, the study includes the various scenario of net returns of establishing and producing guayule at varying biomass prices, yields and production costs per acres which is helpful in evaluating the financial risk associated with an enterprise. Thus, the Southwest United States will eventually be able to take advantage of this huge market presented by the high demand for guayule.

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POLLEN STUDIES IN GUAYULE: COMPARISON OF STAINING AND SAMPLING  
PROCEDURES AND SURVEY OF POLLEN SIZE VARIATION

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Guayule (*Parthenium argentatum* A. Gray) is a rubber bearing plant of the Compositae family. The species has been the focus of research and development activities of private and public organizations after a renewed interest in the species as an alternative source of natural rubber and for its potential as a new crop in the US Southwestern region. Guayule has a complex mode of reproduction with diploids that are known to be sexually reproducing and polyploids that are apomictic in nature. The ploidy levels of guayule range from a diploid ( $2n=2x=36$ ) to hexaploid ( $2n=6x=108$ ). Breeding activities focus on hybridization and selection with pollination among plants as a routine activity. Seed set in guayule depends on successful pollination for full endosperm development. The seed quality and quantity during breeding and seed production activities are critical for the success of guayule commercialization efforts. In other plant taxa, pollen characteristics influence pollen tube growth and reproductive success. This study was conducted make comparisons between pollen staining protocols for viability assessments and to determine the variability of pollen size and viability across flower development stages and germplasm types. A total of 55 plants were sampled and flowers were fixed in Farmer's solution and dissected for pollen observations in June 2019. The mean viability was slightly higher when using Lactophenol Cotton Blue stain (57.83%) compared to Alexander staining (55.44%) but not significantly different. The mean pollen viability was found highest on diploids and hexaploid plants with 59.1% and 66.7%, respectively. Among the germplasm, the highest viability was observed on PARL 931 and HS11-70 (100% and 99.95%, respectively) and low on W6-429-090 (26.5%), EB2WN-06027/Cal3 (5.75%), and PARL 924 (0.00%). Viable pollen was observed at six different flower stages that are from 25 to 31 growing degree days (GDD) apart with the last observation made at 147 growing degree days (GDD) from flower bud stage. The pollen viability was variable across flower development stages with highest values on both diploids and polyploids at the stage which was 31 growing degree days (GDD) from flower bud formation. We recommend this stage as the most ideal for estimating guayule pollen viability and as a standard for comparing across germplasm and seasons. Guayule pollen sizes ranged from 9.86 $\mu$ m to 31.12 $\mu$ m, with the viable pollen having a mean diameter of 19.87 $\mu$ m and non-viable pollen 21.22 $\mu$ m. Among a subset of fifteen germplasm analyzed comprising diploid and polyploids the largest mean pollen size was observed on 11619 (23.29 $\mu$ m) and PARL 916 (23.19 $\mu$ m) and smallest on 11591 (16.39 $\mu$ m) and HS diploids (16.36 $\mu$ m). Whether the smaller pollen size in diploids are advantageous for pollinator transport or have other functional role remains to be studied.

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BIOENGINEERING OF GUAYULE (*PARTHENIUM ARGENTATUM* G.) TO ENHANCE  
TOCOPHEROLS CONTENT

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Guayule (*Parthenium argentatum* A. Gray) is a rubber-producing plant currently being cultivated as a source of natural rubber in Arizona, USA. Rubber extraction from guayule requires addition of antioxidants to prevent oxidation and overall aging of the rubber latex. These antioxidants may have negative impacts on human health and to the environment. Our goal is to develop a guayule line resistant to oxidative stress and thus improved rubber quality. In preliminary work, addition of the bio-based antioxidant  $\alpha$ -tocopherol to extracted guayule rubber improved the thermo-oxidative resistance. This result lead us to hypothesize that increased *in vivo* guayule tocopherol content could protect rubber latex during the extraction process. With the objective of enhancing tocopherol content in guayule, we overexpressed four tocopherol pathway genes from *Arabidopsis thaliana*. A unique binary vector with all four genes, each driven by a unique constitutive promoter, was constructed for *Agrobacterium*-mediated guayule G7-11 (AZ2) transformation. Eight independent transgenic lines were successfully generated and insertion of the four transgenes verified through DNA polymerase chain reaction (PCR). Results of transgenes expression levels and transgenic lines phenotypes will be presented.

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## DEVELOPMENT OF A REMOTE CROP CONDITION SENSING SYSTEM UTILIZING INTERNET OF THINGS TECHNOLOGY & CLOUD COMPUTING

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Guayule and several other energy or biomass crops in the Southwest are drought tolerant and can be suitable crops in the Southwest during expected periods of intermittent drought. In order to characterize guayule crop status in experiments and in expected commercial plantings, inexpensive drought stress sensors were designed. With new advances in internet of things (IoT) devices, affordable, robust, and easy to use technology are becoming more common place in industrial applications. This advancement is slow to move into more traditional agriculture, primarily due to increased maintenance demand, unfamiliarity or uncertainty by growers, and lack of infrastructure for such technology. With an increased amount of technology, there is also an increased complexity for growers. However, modern IoT devices can be modified to meet grower's demands and ensure that these devices do not hinder normal growing operations. There is therefore a need to utilize IoT technology to enable growers to maximize crop productivity while minimizing labor, waste reduction, and increased complexities for the growers. Such technology can also provide large amounts of timely data that can prove to improve growing practices. The objective of this research was to develop a cloud based-sensor system utilizing IoT devices to provide data regarding crop canopy temperature and soil moisture content. These measurements improve irrigation management and scheduling. The system is composed of a microcontroller responsible for interfacing with sensors & the cloud, two input-output microcontrollers, and two commercially available sensors. The system microcontroller is a Raspberry Pi 3B+ running a Debian operating system and the sensors consist of an Acclima Time Domain Reflectometer (TDR)-310S and a FLIR Lepton thermal infrared camera. System measurements are taken every five minutes for the TDR and every thirty minutes for the thermal camera, with the camera producing both quantitative and qualitative data. The data from the remote system is stored on a MariaDB database hosted on a RedHat server. Furthermore, this data can be displayed on a graphical user interface (GUI) such as a mobile application or website for the grower to view. All the software for the system was written in Python 3 due to its vast number of libraries, simple syntax, and simple compilation methods; these Python libraries are key and allow for the code to interface with sensors with ease and allow for easy data transfer from sensor to cloud.

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## RESULTS OF THE AUGUST 2019 TEXAS GUAYULE EXPLORATION TRIP

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Guayule (*Parthenium argentatum*) is native to the Chihuahuan Desert ecosystem, which means that the native distribution within the United States is limited to the Big Bend region of southern Texas. With the support of the New Crops Crop Germplasm Committee and the USDA Plant Exploration Office, we recently completed an exploration trip to Texas to collect wild guayule in an attempt to add genetic diversity to the National Plant Germplasm System (NPGS) public collection. The current collection lists 121 accessions of *P. argentatum*, but only 26 are available for distribution. By searching historical herbarium records and working with local botanists and land managers, we were able to collect seed from 15 new guayule populations that have never been collected for NPGS. In addition, we re-sampled from some populations from the 2005 and 2008 collection trips by Terry Coffelt, Dave Foster and Mike Stout and added 2 collections of *P. incanum* and one *P. confertum*. The seed collected will be preserved at the National Arid Land Plant Genetic Resources Unit in Parlier, CA and made available for distribution after increase. We will present maps and information on the new collection locations and discuss strategies for further conservation of guayule genetic resources.

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## DORMANCY AND THE GUAYULE (*PARTHENIUM ARGENTATUM* A. GRAY) SOIL MICROBIOME

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The plant/soil microbiome is broadly implicated in plant health and disease. Soil bacteria, archaea and fungi interact with plants to enhance soil nutrient availability, mediate plant stress responses, and provide pathogen protection. Guayule (*Parthenium argentatum* A. Gray), a perennial shrub native to the U.S. and Mexico, is under development as an industrial crop in the semi-arid southwest, as an industrial source of natural rubber, organic resins, and biomass. Despite decades of research and development very little is known about how guayule plants interact with soil microbes. Irrigation field studies underway as part of the Sustainable Bioeconomy for Arid Regions (SBAR) Coordinated Agricultural Program have offered an opportunity to explore this question. The overall objective is to perform a baseline study of the general ecology of the guayule root soil rhizosphere, including physical, chemical, and microbial composition. Here, we evaluate these data as a function of the metabolic state of the plant, before, during, and after winter dormancy. Three temporal sampling points (November 13, 2018, February 12, 2019, and April 22, 2019) corresponded, respectively, to the time of cold-induced increase in rubber biosynthesis; the period of winter ‘dormancy’ with little biomass growth but active rubber synthesis; and the Spring period of rapid plant growth. Field measurements of plant carbon fixation rate, combined with rubber biosynthesis rate, gene expression, rubber content and molecular characteristics were assessed. High molecular weight rubber was detected in plants at first harvest, after only 7 months of growth. As expected, rubber transferase activity was highest in November. The photosynthetic rate and rubber content were highest in April. These data will allow associations between the rhizosphere chemistry and microbiome and guayule plant physiology before, during, and after winter dormancy to be explored. Results will constitute the first step to development of microbiome functional genomics in guayule, especially important in future plant improvement.

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## TEMPERATURE REQUIREMENTS FOR GUAYULE SEED GERMINATION

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One hurdle for commercializing guayule (*Parthenium argentatum* A. Gray) as a crop is establishment by direct-seeding in the field. For successful establishment, understanding seed germination requirements and seedling vigor are essential. Among these factors, temperature is one of the most important factors affecting seed germination and crop establishment. Information such as temperature for optimum germination rate, temperature range for acceptable germination rate, low temperature tolerance, and high temperature tolerance can all help decisions on guayule variety choice, planting time, and management practices. Thermogradient table was used to measure temperature requirements for germination of 36 guayule genotypes. 25 seed of each genotypes was placed in a petri dish filled with wet filter paper and seed germination rate was calculated after 7 and 14 days. The experiment was repeated six times. Ten temperature treatments were used (day/night): 13.5/10.4, 16.0/12.6, 18.1/14.4, 20.8/16.2, 23.2/18.2, 25.9/20.4, 27.8/21.8, 30.4/23.6, 33.0/25.5, and 35.4/27.1. Data were analyzed to compare the sensitivity of seed germination to temperature, the most suitable temperature for seed germination, seed germinate rate at low temperature and high temperature. The relationship between guayule seed germination rate and temperature was adequately explained by quadratic curves. Response of guayule seed germination rate to temperature varied significantly. The most suitable temperature for seed germination among 44 guayule genotypes had a range of 17.8 to 26.9°C, with an average temperature of 21.8°C. For the genotypes with low temperature requirements for seed germination, the relative germination rate at 10°C ranged from 66 to 84%, indicating that the germination rate at 10°C for these genotypes were still above 66% of the highest germination rate. At 35°C, seven genotypes had over 50% of relative germination rate, indicating seed from these genotypes are more tolerant to high temperature. This study indicates that wide variation exists on temperature requirements of guayule seed germination.

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# **ABSTRACTS**

## **POSTER PRESENTATIONS**

### **OILSEEDS**



# TARGETING IMPROVEMENT OF SEED QUALITY IN *CAMELINA SATIVA* THROUGH DEVELOPMENT OF A FAST NEUTRON (FN) MUTAGENESIS POPULATION

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*Camelina sativa* is an emerging oilseed crop with potential for production in temperate areas world-wide [1]. As a relatively undeveloped crop, there is significant potential for improvement of both agronomic and seed quality characteristics. Camelina is also a popular model in plant biology research with a short life-cycle and amenability to genetic transformation. The camelina genome has been sequenced [2] and there are extensive genomic resources available. As part of a project aimed at manipulation of seed oil content and composition in camelina, a mutagenesis approach is being applied. Although genome editing techniques could make traditional mutagenesis almost redundant in crop improvement, certain markets will not accept crops modified by newer technologies. Crop improvement through mutagenesis breeding is a well-established and a variety of methods can be used to induce mutations ranging from point mutations to large deletions and genetic rearrangements. For our work, fast neutron (FN) mutagenesis was chosen. FN mutagenesis induces a range of mutations including deletions, and this method was selected due to its potential to inactivate genes present as tandem duplications in the camelina genome. Seeds were irradiated in batches of 100g at dosages from 7 to 50 Grey (Gy). Irradiation was conducted at the UC-Davis, McClellan Nuclear Research Centre, California USA. Germination assays indicated that germination of M1 seeds was no different to control seeds, even at the highest dosage. A population of mutagenesis lines is now being established and DNA collected for screening. A small number of lines have been chosen for genotyping by sequencing (GBS), to estimate the nature and degree of mutation, and a PCR based strategy to screen for deletions in target genes is currently being evaluated. As a hexaploid species with 3 subgenomes of very high sequence similarity, significant challenges must be overcome. Phenotype screening including seed oil content and fatty acid composition is also being conducted.

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THE POTENTIAL OF CAMELINA (*CAMELINA SATIVA* L. CRANTZ) AND CRAMBE (*CRAMBE ABYSSINICA* HOCHST. EX R.E. FRIES) IN MARGINAL SLOPY LAND OF THE MEDITERRANEAN REGION

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In the recent years the demand of biomass feedstock for the bio-based industry is rapidly increasing. Simultaneously, the long-term debate between food security and land use for the bio-based industry has become more and more intense. In order to ensure a low land-use competition with food production, the use of marginal land has been proposed as a suitable alternative to cultivate industrial crops for produce the above-mentioned feedstock. Although an unequivocally definition of marginal land does not exist, in the framework of the EU project MAGIC (GA. 727698), land affected by biophysical constraints (e.g., poor chemical composition, steep slope, salinity, sodicity, etc.) has been identified as suitable for growing non-food crops. Among others crambe and camelina, in view of their resilient attitude and limited input requirement, have been targeted as non-food crops for marginal land. The aim of this work has been to compare the agronomic performance of crambe and camelina grown both in a marginal land (field with 15% slope) and in a favourable one (plain field). The choice of steep slope is related to widespread presence of such marginal condition in the South-West area of Bologna (Italy). Both fields are in the experimental farm of University of Bologna at Ozzano dell'Emilia (44° 27' N, 11° 29' E, 67 m a.s.l.), which is an organic farm. In the field with steep slope the crops are managed in big strips of about 1000 m<sup>2</sup>, without replications, while in the plain area a randomized complete block design ( $n=4$ ) has been adopted with plots of about 40 m<sup>2</sup>. The same agronomic management has applied both in marginal and favourable land, and the crops were rain fed. Organic fertilizer (NP 6-16) has been applied on camelina and crambe before sowing with a dose of 325 and 650 kg ha<sup>-1</sup> respectively. Camelina (cv. Cypress, Linnaeus Plant Science, Canada) has been sown in autumn (16 November 2018) with a seeding rate of 7 kg ha<sup>-1</sup> and a row distance of 0.17 m. Crambe (cv. Galactica, WUR, The Netherlands) has been sown in late winter (5 March 2019) with the same row spacing of camelina but a seeding rate of 15 kg ha<sup>-1</sup>. For both crops the establishment was quite difficult in the marginal field compared to the plain one and a strong weed pressure has been noticed. At harvest plant density on marginal field has been on average about 75% less than that measured on favourable condition (67 vs. 250 m<sup>-2</sup> respectively) for camelina, and similarly about 59% less for crambe (70 vs. 168 m<sup>-2</sup>). Additional data concerning seed yield and seed quality will be presented later at the congress. For sure, an improved calibration of seeding rate together with alternative sowing equipment should be tested in the future to improve crop establishment to a more satisfactory level.

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## SPATIAL AND CONTACT REPELLENCY OF COCONUT MATERIALS AGAINST BITING FLIES

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Many blood-suck insects are capable of transmitting human and animal pathogens worldwide. Repellants are a primary tool for reducing the impact of biting insects on humans and animals. A new inexpensive derivative from coconut oil (fatty acids and esters) were found to be excellent insect repellent. Stable flies are one of the most detrimental arthropod pests to U.S. livestock. With changing climate and agronomic practices, they have expanded their roles as pests and disease vectors. Their painful bites reduce livestock productivity, annoy companion animals, and interfere with human recreational activities. Current management technologies are unable to effectively manage stable flies. The present study reports new data concerning the contact and spatial repellency antifeedancy, and toxicity of coconut oil fatty acids and their methyl ester derivatives to stable flies.

Plant derivatives acting as insect repellents or insecticides are nothing new. The first successful plant-based insect repellent was citronella oil that contains the active ingredient citronellal, but with a limit to its effectiveness. Three medium chain fatty acid methyl esters (C<sub>8:0</sub>, C<sub>10:0</sub> and C<sub>12:0</sub>) showed strong antifeedancy against stable flies. The strengths of antifeedancy of three methyl esters were dose-dependent. Only the C<sub>8:0</sub> acid and C<sub>8:0</sub>- and C<sub>10:0</sub> methyl esters elicited significant electroantennograms (EAG) responses. Laboratory single cage bioassays revealed that 1000 mg dose of coconut oil fatty acids and C<sub>8</sub> methyl ester displayed active spatial repellency. All three methyl esters showed some levels of toxicity against stable flies.

Contact repellency (antifeedancy) is the main method that coconut fatty acids deter stable fly blood-feeding. The C<sub>8:0</sub>, C<sub>10:0</sub> and C<sub>12:0</sub> coconut fatty methyl esters act not only as strong antifeedants, but also possess strong toxicity against stable fly adults. Only limited spatial repellency was found for the coconut oil fatty acid mixture and C<sub>8:0</sub> methyl ester. Cattle treated with the coconut oil fatty acid formulation had significant protection against biting flies which may be the longest lasting repellent reported to date. The cost of applying a coconut fatty acid repellent to cattle is estimated to be extremely cost effective, less than 0.1 U.S. \$ per treatment for animals of 800 to 1000 pounds in size. Such an economically sound practical tool could be easily adopted for livestock animal producers as well as other public health applications for preventative measures (repellent barriers).

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## AQUEOUS FRACTIONATION OF MUCILAGE AND PROTEIN FROM CAMELINA SEEDS

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*Camelina sativa* (L.) Crantz (*Brassicaceae*) is an ancient oilseed crop that was grown extensively in Europe in the 19th century. Camelina has several agronomic advantages for production, including early maturity, adaptability to freezing temperatures, and resistance to common cruciferous pests and pathogens, making it suitable to be grown on lands where food crops such as corn and soybean may not be feasible. Camelina seeds contain 30-45% oil with  $\alpha$ -linolenic acid (30-40%), linoleic acid (15-25%), and eicosenoic acid (13-18%) as major FAs. The oil also contains high amounts of tocopherols, which imparts oxidative stability to the highly polyunsaturated oil. The seed meal contains 43.6% (fat free dry matter) protein and has a good balance of amino acids. In addition, the seed coat contains mucilage accounting for  $\leq 10\%$  of the seed weight. Renewed interest in camelina production has brought attention to the mucilage and protein as value-added co-products. In this study, we evaluated two schemes of producing mucilage and protein from camelina seeds in addition to the oil. One process started with separating the mucilage from hydrated (1:30, w/v solid to liquid ratio) intact camelina (var. Joelle) seeds (ICS). The protein was extracted from the defatted degummed camelina seeds (DDCS) at pH 9.5 and then precipitated at pH 4.0. In another process, the seed oil was extracted by cold pressing and hexane extraction to produce defatted camelina press cake (DCPC). The mucilage and protein were extracted simultaneously from DCPC at pH 9.5. The liquid fraction containing the protein and soluble mucilage was recovered by filtration and the protein was precipitated at pH 4.0. The protein extracts were dialyzed (3 kD MWCO) against water and then freeze-dried. The mucilage fractions were dried in a forced-air oven at 80°C. The mucilage recovered from ICS accounted for 8.8% of the starting seed and contained 0.9% oil and 14.6% crude protein. The protein fraction obtained had 88.6 % crude protein and accounted for 11.8% of the DDCS. The mucilage extracted from DCPC accounted for 27.0% of starting material and contained 0.1% oil and 48.5% crude protein. Although a considerable amount of protein was absorbed by the mucilage, a significant protein fraction was still recovered (8.6% of DCPC) containing 75.4% crude protein. The difference in composition of the mucilage and protein produced by each process will determine the application of these products.

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## UNLOCKING PENNYCRESS POTENTIAL: RAPID DOMESTICATION THROUGH BREEDING AND BIOINFORMATICS AT THE UNIVERSITY OF MINNESOTA

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Pennycress (*Thlaspi arvense* L.) could make a large impact as a cash cover crop for the corn-soybean crop rotation in the Upper Midwest. Pennycress is planted in the fall, survives harsh winter conditions, and produces a harvestable oilseed in late spring, in time for planting a traditional summer crop such as soybeans. From fall to spring, pennycress reduces nutrient leaching and soil erosion and suppresses the growth of spring weeds. However, before pennycress can be implemented on the Midwestern landscape, it must be domesticated. Our objective is to rapidly develop pennycress varieties with improved agronomics and seed quality and that lack weedy traits such as pod shatter or non-uniform germination. Previously, this objective could have taken hundreds of years to complete. Using next-generation sequencing, bioinformatics, and super-computing tools, we expect to develop fully domesticated pennycress in under 15 years. In less than 7 years, we have created genomic resources for pennycress including a transcriptome, draft genome, numerous whole genome sequencing analyses, and a mutant gene index. We are now in the process of creating linkage mapping populations and new chromosome scale genome assembly. Using these resources, we have eliminated weedy traits such as pod shatter and identified key genes for improving the seed and oil quality of pennycress by reducing glucosinolate and erucic acid.

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VARIATION OF HEXANE EXTRACTABLE HYDROCARBONS IN NATIVE POPULATIONS OF  
WILD *HELIANTHUS ANNUUS*

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There has been increased attention given to the need to develop plant species as alternative sources of fuels, chemicals, feeds, and other important materials, particularly for industrial nonfood uses. Such developments could reduce our nation's dependency on foreign sources of many strategic and essential materials and could stimulate economic growth in the United States. Crop wild relatives of sunflower occur over a wide range of habitats with wild annual sunflower (*Helianthus annuus* L.) the most common and widely distributed. Limited previous studies have evaluated this species for hydrocarbons. The objective of this study was to determine the yield of total hydrocarbons (HC) from leaves of populations ranging from eastern Oklahoma to North Dakota, to coastal southern California. The highest yielding populations were in the Texas Panhandle (6.0 to 7.99%), and the lowest yields were in Camp Verde, AZ, NM mountains, Bozeman, MT, and ND-MN. Medium-high yields were found in northern UT and southern ID. Three populations near Waco, TX had large yield differences ranging from 4.9 to 6.2%, but a fourth population had a low of 3.6%. Some native populations appeared to be contaminated by germplasm from cultivated sunflowers and these populations had very low yields (2.6 to 3.6%). Population variability in HC yields varied geographically and between nearby populations, suggesting the micro-habitat environments are important, as well as limited genetic population size. The current study expanded the range of the populations examined to include samples from the total range of the species. This study indicated that there are populations with levels of total hydrocarbons from the leaves that may be useful for breeding and selection. Previous studies have shown that in wild annual sunflower simultaneously breeding for increased yield of hydrocarbons and biomass is achievable.

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## HOW MUCH IS SOLE-CROPPING SYSTEM SUSTAINABLE FOR CAMELINA AND CRAMBE?

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Crambe (*Crambe abyssinica* R.E. Fries) and camelina (*Camelina sativa* L. Crantz) are two oilseed crops belonging to the *Brassicaceae* family. Typically crops belonging to this family highly suffer from sole-cropping system, as extensively reported for oilseed rape (*Brassica napus* L. var. *oleifera*). Otherwise crambe and camelina are considered resilient species as demonstrated in the framework of the COSMOS (G.A. 635405) project, while in the MAGIC project (G.A. 727698) they have been identified also as suitable to grow in marginal land. But for a stable introduction of these two new oilseeds into typical European crop rotation schemes a full understanding of the effects of sole-cropping have never been carried out before. At this scope a multi-location and multi-year trial has been established in Italy (Bologna, 44°33'N, 11°23'E) and Greece (Aliartos, 8°22'N, 23°6'E) in 2017 and it is still ongoing, comparing the effect of sole-cropping vs. wheat-oilseed succession on one commercial variety of camelina (Midas, Linnaeus Plant Science, Canada) and on one of crambe (Galactica, Wageningen University and Research, The Netherlands). Since establishment in spring 2017, each year the oilseed is sown either on the past year stand or in a new stand in which winter wheat was grown the season before. The experimental design is a randomized complete block with 4 replicates. From the analysis of the first 2-year data surveyed at Bologna an interesting “species x cropping system” interaction effect emerged for seed yield, with camelina significantly suffering from mono-succession (-17%) while in crambe an increase on yield was surveyed (+10%). For all the other analyzed seed quality parameters (i.e., seed weight, oil and protein contents, fatty acid composition) negligible effects due to cropping system were surveyed in both species. The inclusion of the data obtained in Greece together with a further year of trials (2019) will permit to more clearly quantify the effect of sole-cropping systems in these two emerging oilseed crops, with outstanding potential for the European bio-based industry. From these preliminary results crambe seemed more suitable to sole-cropping system than camelina.

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## SELECTED OILSEED CROPS TO BE GROWN ON MARGINAL LANDS IN EUROPE

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Oilseeds are an important category of industrial crops since they offer feedstock for a large number of value-added products and biofuels. In Europe two oilseed crops are mainly been cultivated for first generation biofuels (rapeseed and sunflower). Flaxseed and industrial hemp are being grown in smaller areas in Europe for value-added applications. There is an increasing demand for oilseed crops that is been supported by the following facts: a) in EU up to 30% of the mineral oil-based chemicals and materials would be replaced with bio-based alternatives by 2030, b) the EU bio-plastics market was estimated at around 485 million € in 2013 with a potential increase to 900 million € in 2017 and to 1.4 billion in 2020, (55% increase), c) the bio-lubricants market, valued 410 million € in 2010, will reach to 640 million euros in 2020 (growth 56%) and d) the market for bio-based surfactants is expected to increase to about 1.3 billion € in 2030; while currently is 680 million euros (growth 91%). At the same time in Europe the marginal land facing natural constraints has been estimated as the 28% of the total agricultural land (MAGIC project). Part of this land is already been cultivated with food and feed crops, while part of it can be cultivated with several industrial crops such as oilseeds. In the framework of MAGIC project (HORIZON 2020; [www.magic-h2020.eu](http://www.magic-h2020.eu)) a total number of thirteen oilseed crops had been initially selected as candidate crops to be grown on marginal lands. By following a multi-criteria analysis eight oilseed crops have been selected as the most promising ones to be grown on marginal lands namely camelina, safflower, castor, crambe, pennycress, industrial hemp, cardoon and lupin. Camelina is annual short growing cycle (90-120 days), winter and spring crop, native of Europe. It is currently been tested in another two EU research projects namely COSMOS ([www.cosmos-h2020.eu](http://www.cosmos-h2020.eu)) & BIO4A ([www.bio4a.eu](http://www.bio4a.eu)), while in ITAKA project ([www.itaka-project.eu](http://www.itaka-project.eu)) camelina cultivated on marginal lands in Spain for aviation biofuels with seed yields varied from 0.5 to 2.5 t/ha. Crambe is annual spring crop with a growing cycle 85-105 days that had been domesticated to Mediterranean region. It is relatively drought tolerant and tolerates pH from 5.0 to 7.8. Castor bean is annual spring crop that needs 120-150 days to reach the harvesting time. It can be grown on marginal lands, which are not competitive with food (economic viable solution for non-productive lands). It can tolerate pH 5.5-6.5 and saline soils but not low temperatures. Ethiopian mustard is considered drought tolerance crop and thus it is a promising crop for the Mediterranean region and for areas with dryness problems. It tolerates soils with pH 5.5-8.0. Safflower (winter or spring crop) with 110-150 growing cycle. It can be grown successfully on dry lands. It has a strong taproot and thus thrives in dry climates. Pennycress (winter or spring crop) has shorter growing cycle than camelina. It has gained attention in USA as a short cycle crop that can be grown on unused land. It has low demand on soil nutrition and water demand. It is frost tolerant (up to -20°C). Industrial hemp (multipurpose spring crop) it is considered as candidate crop for phytoremediation. In GRACE project ([www.grace-bbi.eu](http://www.grace-bbi.eu)) it is grown on contaminated lands. Lupin is an annual crop with growing cycle around 150 days. It has been selected by LIBBIO project ([www.libbio.net](http://www.libbio.net)) as a crop that can be grown on poor and marginal lands. It tolerates the acid soils and it is considered drought tolerance.

Acknowledgements: MAGIC (Marginal lands for growing industrial crops: Turning a burden into an opportunity) has received funding from the European Union's Horizon 2020 Programme under Grant Agreement 727698.

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# **ABSTRACTS**

## **POSTER PRESENTATIONS FIBERS AND CELLULOSICS**

## KENAF (*HIBISCUS CANNABINUS* L.): A HIGH YIELDING BAST FIBER CROP FOR THE MEDITERRANEAN REGION

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Kenaf (*Hibiscus cannabinus* L., family Malvaceae) is an annual spring crop that is mainly cultivated for its fibrous stem. Kenaf stems contain two major fiber types, the one contains long fibers situated in the cortical layer, and the other one contains short fibers located in the ligneous zone. Most studies agreed that it is originated from Africa. Its cultivation in China started in the beginning of 20<sup>th</sup> century where reached its highest planting area in 1980's. It was introduced in USA during the Second World War. The research in Europe has started in the beginning of 1990s where it was cultivated for biobased materials and bioenergy. All these years the European research on kenaf had been carried out with varieties imported mainly from USA (Tainung 2, Tainung 1, Everglades 41, Everglades 71, Whitten, G4, Dowling and Gregg) in the view of the European research project BIOKENAF ([www.cres.gr/biokenaf](http://www.cres.gr/biokenaf); 2003-7). In the framework of FIBRA project ([www.fibrafp7.net](http://www.fibrafp7.net); 2012-15) two high yielding kenaf hybrids had been tested in Greece imported from China (H328 & H368). Both gave high yields; 23.3 t/ha for H328 and 24.5 t/ha for H368. It should be pointed out that the corresponding mean dry matter yields for two late varieties imported from USA were 21 t/ha for Tainung 2 and 19.9 t/ha for Whitten. Currently, kenaf is one of the under study lignocellulosic crops in the European research project entitled BECOOL (HORIZON 2020; [www.becoolproject.eu](http://www.becoolproject.eu)). Field trials had been established in three Mediterranean countries (Greece, Italy and Spain) for two subsequent years (2017 and 2018) and the tested kenaf hybrid was H328 (developed by IBFC in China). In Greece the kenaf plantation was quite high (around 5 m) and the plants had stems with large basal stem diameter (24.5 mm). The mean dry stem yields were 26.6 t/ha. The bark yields were 10.2 t/ha (38.25% of the total dry stem weight). The moisture content of the harvested stems was quite high (72%). It should be pointed out that among the three sites the highest yields were recorded in Greece and the lowest ones in Spain.

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## SORGHUM, INDUSTRIAL HEMP, SUNN HEMP, AND KENAF CAN PRODUCE FEEDSTOCK FOR ADVANCED BIOFUELS IN THE MEDITERRANEAN REGION

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Lignocellulosic crops can be categorized to: perennial crops (grasses or herbaceous such as switchgrass, giant reed miscanthus, cardoon, etc.), woody species (willow, poplar, etc.) and annual herbaceous lignocellulosic crops (sorghum, industrial hemp, etc.). They can produce feedstock for bioenergy and bioproducts. In the framework of the project BECOOL ([www.becoolproject.eu](http://www.becoolproject.eu)) both perennial grasses and annual herbaceous crops are being studied as feedstock for advanced biofuels in the Mediterranean region (Greece, Italy and Spain). The perennial grasses have been compared on long-term field trials established on less favourable agricultural lands, while the annual herbaceous crops are being tested in a rotation trial that is including both food (corn and wheat) and non-food crops (sorghum, industrial hemp, sunn hemp and kenaf). Moreover, the four annual herbaceous crops are being compared in field trials that have been established next to the rotation trials. The aim of this research work was to present and compare the biomass productivity of four annual herbaceous lignocellulosic crops (industrial hemp, kenaf, biomass sorghum and sunn hemp) established in central Greece. Four field trials had been established in spring 2018. Each crop had been cultivated in three planting densities (70 cm between the rows; 5, 10 or 15 cm within the rows) and in three replications. These trials had been established next to a rotation trial where five rotation cycles are being compared; one conventional (C: corn-wheat) and four innovative (R1: maize-industrial hemp-wheat-sunn hemp, R2: maize-kenaf-wheat-sunn hemp, R3: maize-kenaf-wheat-sunn and R4: sunn hemp-wheat-sunn hemp). The four trials have been established from the late April till mid-May 2018 and the harvesting had been done from mid-September to early October 2018. In all trial a basic fertilization (NPK: 11-15-15) had been carried out before sowing, while a top nitrogen fertilization (75 kg N/ha) had been applied 30 days after crops emergence through the drip irrigation system. When the crops had been established in separate field trials, the dry matter yields were 28 t/ha for kenaf, 41 t/ha sorghum, 20 t/ha for sunn hemp and 15 t/ha for industrial hemp. When the crops had been tested in the rotation cycles, sorghum was again the most productive of the four (41 t/ha), followed by sunn hemp (26 t/ha), kenaf (25 t/ha) and industrial hemp (19 t/ha). It should be noted that part of the leaves for industrial hemp and kenaf had been fallen down at the harvesting time. Lodging problems had been recorded in the plots of industrial hemp, although it was not the tallest plantation (around 3 m). Although kenaf and sorghum plots were quite higher (5 m) no lodging problems had been recorded. Further laboratory analysis had been carried out in terms of their biomass characterization and it was found they had quite comparable calorific values (around 3800 kcal/kg). In terms of ash content kenaf and industrial hemp were the ones with the lowest values especially when the bark had been removed from the stems (the ash content in the core was 1.5 to 2%).

Acknowledgements: The BECOOL project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No. 744821.

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