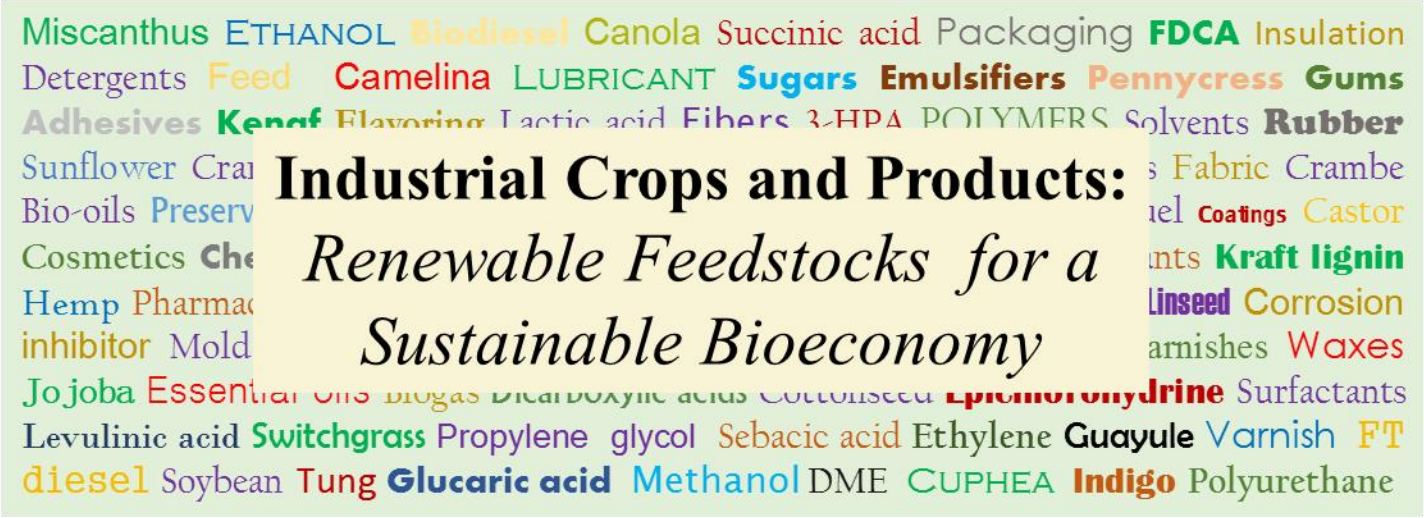
ASSOCIATION FOR THE ADVANCEMENT OF INDUSTRIAL CROPS

29th Annual Meeting



Industrial Crops and Products:

Renewable Feedstocks for a Sustainable Bioeconomy

Gateway Hotel & Conference Center
Ames, Iowa USA
September 10-13, 2017

AAIC BOARD OF DIRECTORS

Association for the Advancement of Industrial Crops

29th Annual Meeting

Gateway Hotel & Conference Center
Iowa State University
Ames, Iowa USA
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Industrial Crops and Products:
Renewable Feedstocks for a Sustainable Bioeconomy

CONFERENCE ORGANIZATION

General Co-Chairs	
Roque L. Evangelista USDA-ARS, NCAUR, Peoria, IL	Laura Marek Iowa State University, Ames, IA
Registration Valerie H. Teetor University of Arizona, Tucson, AZ	**Awards** Marisol T. Berti North Dakota State University, Fargo, ND
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Abstracts Roque L. Evangelista Mila P. Hojilla-Evangelista USDA-ARS, NCAUR, Peoria, IL	**Logistics** Aubrey Robertson Jennifer Vit Iowa State University, Ames, IA
Division Chairs	
Oilseeds Efthymia Alexopoulou Centre for Renewable Energy Sources and Saving, Athens, Greece	**Natural Rubber & Resins** Hussein Abdel-Haleem USDA-ARS, ALARC Maricopa, AZ
Fiber & Cellulosic Crops Dilpreet Bajwa North Dakota State University, Fargo, ND	**General Crops & Products** Ana Luisa Fernando Universidade NOVA de Lisboa Caparica, Portugal
Medicinal & Nutraceutical Crops H Rodolfo Juliani Rutgers, The State University of New Jersey, New Brunswick, NJ	

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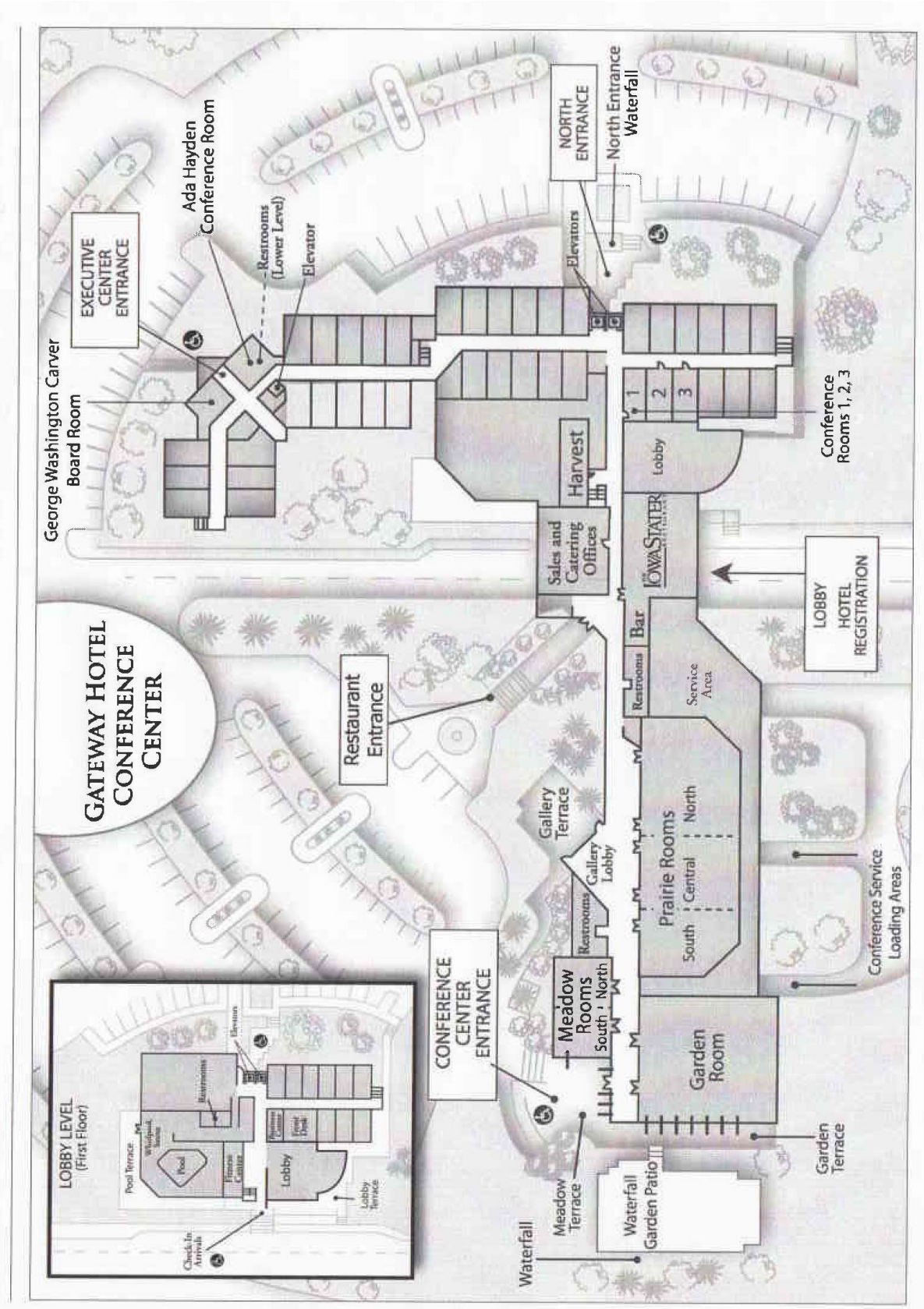
Gateway Hotel & Conference Center



CONFERENCE PROGRAM

SUNDAY – September 10, 2017

Registration	Garden Lobby	1:00 - 6:00 PM
Crop Germplasm Committee Meeting	North Meadow	2:00-4:00 PM
AAIC Board Meeting	Conference Room 1	4:00 - 5:00 PM
Poster Set-up	Garden Room	4:00 - 6:00 PM
Opening Reception & Poster Viewing	Garden Room	6:00- 9:00 PM

POSTERS

Productive performance of winter camelina grown in contrasting environments: Northern Italy vs. Minnesota, USA
Federica Zanetti, Russ W. Gesch, Jane M.F. Johnson, Giuseppe Di Girolamo, and Andrea Monti

Progress towards developing early maturing winter varieties of *Camelina sativa* as oilseed cover crops for northern climates
James V. Anderson, Wun S. Chao, David P. Horvath, Russ W. Gesch, and Marisol T. Berti

Acetyl-diacylglycerides produced by modified camelina (*Camelina sativa*)
Roque Evangelista, John Ohlrogge, Terry Isbell, Bryan Moser, Timothy Durrett, and Steven Cermak

Oil concentration and fatty acid profile of naturalized wild *Helianthus annuus* populations from Australia
Gerald J. Seiler

Biobased lubricant from used cooking oils
Steven C. Cermak, Jill K. Moser, Terry A. Isbell, Jakob W. Bredsguard, Gene E. Lester, and Rex E. Murray

Screening forage sorghum [*Sorghum bicolor* (L.) Moench] genotypes for cold tolerance
Swarup Podder, Marisol Berti, Alan Peterson, Sergio Cabello, Bryce Andersen, Dulan Samarappuli, and James Anderson

Yield and biomass quality of kenaf (*Hibiscus cannabinus* L.) irrigated with wastewaters – The effect of ammonium ions and nitrates
A.L. Fernando, M. Ferreira, B. Barbosa, and E. Alexopoulou

Guar, roselle, and sesame genetic resources currently used as ingredients in some medicinal products and several potentially new medicinal uses
J.B. Morris, M.L. Wang, and B. Tonnis

Development of edible nano-laminated coatings with antimicrobial resins of *Flourensia cernua* and their application to extend the shelf-life of tomato (*Solanum lycopersicum* L.) fruits
Diana Jasso de Rodríguez, Esperanza de J. Salas-Méndez, António A. Vicente, Ana Pinheiro, L. F. Ballesteros Giraldo, P. Silva, Raúl Rodríguez-García, F. Daniel Hernández-Castillo, M. Lourdes V. Díaz-Jimenez, José A. Villarreal-Quintanilla, María L. Flores-López, and Dennise A. Carrillo-Lomelí

Apoptotic activity of Flourensia spp
Diana Jasso de Rodríguez, Dennise A. Carrillo-Lomelí, Nuria E. Rocha-Guzmán, M. Rocío Moreno-Jiménez, José A. Villarreal-Quintanilla, Raúl Rodríguez-García, and M. Lourdes V. Díaz-Jimenez

Physical characterization of chitosan/montmorillonite incorporated with *Rosmarinus officinalis* l. essential oil
V.G.L. Souza, J.R.A. Pires, P.F. Rodrigues, A.A.S. Lopes, F.M.B Fernandes, and A.L. Fernando

Multi-environment performance of *Taraxacum kok-saghyz* (Rodin) clones to validate indirect selection
Sarah K. McNulty, Zinan Luo, Nikita Amstutz, and Katrina Cornish

MONDAY – September 11, 2017

MORNING
PLENARY SESSION (Garden Room)
Chair: Roque Evangelista

8:00- 8:55	**Robert Brown, Bioeconomy Institute, Iowa State University** *Overcoming the barriers to a sustainable bioeconomy*
8:55- 9:50	**Emily Heaton, Department of Agronomy, Iowa State University** *Perennial solutions to annual problems?*
9:50-10:10	Coffee Break
10:10-11:05	**David Grewell, Agricultural and Biosystems Engineering, Iowa State University** *Bio-based construction adhesives*
11:05-12:00	**Norman Cloud, Kemin Industries, Inc., Des Moines, IA** *Kemin Specialty Crops: Vertically integrated, sustainably grown crops for extraction of bioactive molecules*

AFTERNOON

Tour Schedule

12:00pm	Board bus - Gateway Underpass, by entrance across from the hotel front desk
12:10	Bus departs Gateway
12:30	**Boxed lunch served at Plant Introduction Station**
1:00-3:00	**Plant Introduction Station Tour**
3:00	Board bus
3:10	Bus Departs Plant Introduction Station
3:25-5:25	**BioCentury Research Farm Tour**
5:25	Board Bus
5:35	Bus Departs BioCentury Research Farm – Returns to Gateway

Dinner on Your Own: Shuttle provided to Ames restaurants from 6:00 to 8:00 pm – Shuttle picks up at Gateway Underpass

TUESDAY – September 12, 2017

MORNING

OILSEED DIVISION (Garden Room)
Chair: Efthymia Alexopoulou

8:00-8:30	**Research on oilseeds in Europe** *Efthymia Alexopoulou*
8:30-8:50	**Winter camelina root system under contrasting environments** *Federica Zanetti, Jane M.F. Johnson, Russ W. Gesch, Nancy Barbour, and Andrea Monti*
8:50-9:10	**Winter camelina: Cultivar variation and sowing rate** *Russ Gesch, Heather Mathew, Adriana Alvarez De la Hoz, and Robert D. Gardner*
9:10-9:30	**Fall seeding of spring camelina: an opportunity for farmers in Northern Italy** *Federica Zanetti, Christina Eynck, Giuseppe Di Girolamo, Daria Righini, Deb Puttick, and Andrea Monti*
9:30-9:50	**Industrial oilseed crop germination in response to salinity** *Heather L. Matthees, Matthew D. Thom, and Russ W. Gesch*
9:50-10:10	COFFEE BREAK
10:10-10:30	**Crambe: A widely adaptable spring oilcrop for Europe** *Michal Krzyżaniak, Federica Zanetti, Efthymia Alexopoulou, Myrsini Christou, Mariusz J. Stolarski, Eibertus N. Van Loo, Jacek Kwiatkowski, and Andrea Monti*
10:30-10:50	**Developing a method for measuring toxicity of castor (*Ricinus communis*) meal using domestic fly** *Liv S. Severino, Bruna S.S. Mendes, and Antonio S.E. Vasconcelos*
10:50-11:10	**Relay cover crops in soybean (*Glycine max* (l.) Merr.) cropping systems in eastern North Dakota** *Nicholas J. Steffl, K.A. Aasand, B.L. Johnson, P.J. Petersen, and M.T. Berti*
11:10-11:30	**Corn relay cropping with winter rye, field pennycress, and winter camelina** *Kyle A. Aasand, N.J. Steffl, B.L. Johnson, P.J. Petersen, and M.T. Berti*
11:30-12:00	Division Meeting

LUNCH (South Prairie)

AFTERNOON

GENERAL CROPS & PRODUCTS (Garden Room)
Chair: Ana Luisa Fernando

1:00-1:20	**Pros and cons of irrigating perennial grasses with wastewaters** *J. Costa, B. Barbosa, and A.L. Fernando*
1:20-1:40	**Effect of irrigation and plant density on yields of *Miscanthus x giganteus*** *Efthymia Alexopoulou and Myrsini Christou*
1:40-2:00	**Marginal land for growing industrial crops: Turning a burden into an opportunity** *Efthymia Alexopoulou, Myrsini Christou, Ioannis Eleftheriadis, Ioanna Papamichael, and Kostas Tsiotas*
2:00-2:20	**Yield and phytoremediation potential of perennial grasses in heavy metal contaminated soils under low irrigation** *B. Barbosa, S. Boléo, S. Sidella, J. Costa, M. P. Duarte, S.L. Cosentino, and A.L. Fernando*
2:20-2:40	**NH3 ENERGY+: Optimal fuel, fertilizer, and energy storage medium** *Norman Olson*
2:40-3:00	COFFEE BREAK
3:00-3:20	**Status of genetic resources of guayule and other industrial crops at the USDA National Arid Land Plant Genetic Resources Unit in Parlier, CA** *Claire Heinitz*
3:20-3:40	**Physical and chemical properties of biochars produced from MWRDGC biosolids for utilization in sand-based turfgrass rootzones** *Steven F. Vaughn, F.D. Dinelli, J.A. Kenar, M.A. Jackson, and S.C. Peterson.*

MEDICINAL & NUTRACEUTICAL PLANTS (Garden Room)
Chair: H. Rodolfo Juliani

3:40-4:00	**Effect of semi-desert plants as growth regulators in tomato plants (*Solanum lycopersicum* L.)** *Diana Jasso de Rodríguez, Alejandro Reyes-Sebastián, Raúl Rodríguez-García, Homero Ramírez-Rodríguez, José A. Villarreal-Quintanilla, M. Lourdes V. Díaz-Jimenez, Antonio Juárez-Maldonado, Norma A. Ruiz-Torres, Fidel M. Peña-Ramos, and Dennise A. Carrillo-Lomelí*
4:00-4:20	**The chemistry and quality of Liberian spices** *Larry Hwang, Jim Simon and H. Rodolfo Juliani*
4:20-5:00	Division Meetings

Dinner on Your Own: Shuttle provided to Ames Restaurants from 6:00 to 8:00 pm - Shuttle picks up at Gateway Underpass.

WEDNESDAY – September 13, 2017

MORNING

NATURAL RUBBER & RESINS (Garden Room)
Chair: Hussein Abdel-Haleem

8:00-8:30	**Current prospects for a natural rubber industry in the U.S.** *David Dierig, William Niaura, V. Mark V. Cruz, and Guangyao (Sam) Wang*
8:30-8:50	**Efficient guayule latex extraction** *Katrina Cornish*
8:50-9:10	**Guayule latex supports production of the first medical radiation attenuation glove** *Katrina Cornish and Zhenyu Li*
9:10-9:30	**Differential expression of drought-stress associated genes and their impact on rubber synthesis in guayule (*Parthenium argentatum*)** *Grisel Ponciano, Arcadio Valdez Franco, William Belknap, Yong Gu, Yi Wang, Naxin Huo1, Doug Hunsaker, Diaa Elshikha, and Colleen McMahan*
9:30-9:50	**Negative regulation of allene oxide synthase in guayule by salicylic acid increases natural rubber content** *Dante F. Placido, N. Dong, G. Ponciano, C. Dong, B.G. Kang, V.M.V. Cruz, D. Dierig, M. Whalen, and C. McMahan*
9:50-10:10	COFFEE BREAK
10:10-10:30	**Silica and egg shells synergistically reinforce guayule (*Parthenium argentatum*) natural rubber composites** *Xianjie (Tony) Ren and Katrina Cornish*
10:30-10:50	**Heredity of taproot phenotype in *Taraxacum kok-saghyz* (Rodin)** *Sarah K. McNulty, Nikita Amstutz, and Katrina Cornish*
10:50-11:10	**Water-based processes for the extraction of natural rubber from *Taraxacum kok-saghyz* (TK) roots** *David A. Ramirez-Cadavid, Frederick Michel Jr.1, and Katrina Cornish*
11:00-11:40	Division Meeting

AFTERNOON

GENERAL MEMBERSHIP LUNCHEON MEETING (South Prairie)
12:00 Noon – 1:20 PM

FIBER & CELLULOSIC CROPS (Garden Room)
Chair: Dilpreet Bajwa

1:30-1:50	**Comparative studies among several kenaf varieties in Greece** *Efthymia Alexopoulou, Defang Li, and Federica Zanetti*
1:50-2:10	**Investigation of kenaf foliage as a potential biocide in compositon panels** *D.S. Bajwa, A. Norris, E. Alexopoulou, R. Ibach, and S.G. Bajwa*
2:10-2:30	**Seeding date, cultivar, and seed treatment effects on industrial hemp (*Cannabis sativa* L.) stand establishment in North Dakota** *B.K. Hanson, V. Chapara, T. Hakanson, L. Henry, J. Kostuik, M.T. Berti, P.J. Petersen, and B.L. Johnson*
2:30-2:50	**Compatibilization improves performance of biodegradable biopolymer composites without affecting UV weathering characteristics** *N.S. Yatigala, D.S. Bajwa, and S.G. Bajwa*
2:50-3:10	**Epoxidized sucrose soyate as a primary binder in particleboard manufacturing** *A.J. Norris and D.S. Bajwa*
3:10-3:30	**Techno-economic analysis and life cycle assessment of bioadhesive derived from glycerol** *Minliang Yang*
3:30-4:00	Division Meeting

BOARD MEETING (Conference Room 1)
4:00-5:00 PM

AWARDS BANQUET 5:30-8:30 PM (South Prairie)

ABSTRACTS

Plenary Session

OVERCOMING THE BARRIERS TO A SUSTAINABLE BIOECONOMY

Robert C. Brown

Iowa State University, Ames, IA, USA

A bioeconomy secures sustainable supplies of carbon and energy from agriculture. This contrasts with our current petroleum economy, which relies on geological deposits of fossil carbon and energy. The United States set a course toward a bioeconomy in 2005 with the establishment of the Renewable Fuel Standard, which mandated gradually increasing volumes of biofuels to replace imported petroleum. The subsequent boom in building corn ethanol plants quickly surpassed the mandated volumes of biofuels and gave promise of a future that converted advanced feedstocks like cellulosic biomass and algae into a wide range of fuels, power, and biobased products. Twelve years after this promising start, one might charitably suggest that the bioeconomy has stumbled. Many in the press and environmental lobby have gone from lauding bioenergy to criticizing or, even worse, ignoring its role in providing future energy supply. The cost of petroleum has dropped from over $150 per barrel in 2008 to less than $50 per barrel today. Talk of "peak supply" of petroleum has shifted to predictions of "peak demand", suggesting that liquid fuels, whether produced from petroleum or biomass, will follow the buggy whip into oblivion to be replaced by solar powered electric vehicles. None of this bodes well for the future of the bioeconomy. This presentation delineates the barriers to continued progress toward a sustainable bioeconomy, which includes inherent weaknesses associated with current biorenewable resources and technologies and external threats from competing sources of carbon and energy. Advances in technology and adoption of policies that can overcome these barriers will be described.

Contact: Robert C. Brown, Bioeconomy Institute, Iowa State University, 1140 E BRL Bldg., 617 Bissell Rd., Ames, IA, 50011. Tel: 1(515)294-7934. E-mail: rcbrown3@iastate.edu

PERENNIAL SOLUTIONS TO ANNUAL PROBLEMS?

Emily Heaton[1], Elke Brandes[1], Mauricio Tejera[1], Gabe McNunn[1,2], Andy VanLoocke[1], and Lisa Schulte[1]

[1] Iowa State University, Ames, IA, USA
[2]AgSolver, Inc., Ames, IA, USA

Society is demanding more sustainable bioenergy and agricultural systems, but farmers who could provide both do not have sufficient information to confidently change from the status quo. This presentation will cover results of novel modelling assessments that indicate the agriculturally dominate state of Iowa, USA, could achieve nearly half of state water quality improvement targets simply by converting highly unprofitable parts of corn/soybean fields to switchgrass (*Panicum virgatum* L.) using a precision conservation approach. Further, this approach would meet nearly 1% of federal billion-ton biomass targets, while improving the overall farm economy. Implementing precision conservation, however, requires high-quality land and crop data, as well as widespread adoption of modern agricultural equipment. In the interim, steady markets for biomass could increase whole-field adoption of perennials with improved ecosystem services. We will describe current progress with miscanthus (*Miscanthus* × *giganteus* Greef et Deu.) in Eastern Iowa, where it is being grown on >300 ha for heat and power generation, under 10-yr contracts that provide a stable market. We will also provide results from the Long-term Assessment of Miscanthus Productivity and Sustainability (LAMPS) project, the first replicated chronosequence miscanthus field trial, which is elucidating the changing nitrogen requirement of this crop as it ages, with implications for feedstock composition, quality, and long-term sustainability. We integrate research results to generate new understanding that farmers, lenders, and industry stakeholders need to assess the risk and resilience of bioenergy and agricultural systems.

Contact: Emily Heaton, Dept. of Agronomy, Iowa State University, Ames, IA 50011. Tel: 1 (515)294-1310. Email: heaton@iastate.edu

BIO-BASED CONSTRUCTION ADHESIVES

David Grewell, Kendra Allen, Eric Cochran, Chris Williams, and Ty'Jamin Roark

Iowa State University, Ames, IA, USA

This paper reviews the development and characterization of a bio-based construction adhesive using glycerin from transesterification of soybean oil for the production of biodiesel. The results indicate that the bio-based adhesive has the ability to perform as well as, and in some cases better than commercially available petrochemical adhesives. The bio-based adhesive utilizes renewable feedstocks, has zero VOC (Volatile Organic Compounds), and is sustainable. The bio-based adhesive was compared to commercial petrochemical adhesives in terms of lap shear strength, water stability, creep resistance, and three point bend strength. In addition, construction materials, such as oriented strand boards (OSB) were produced with the bio-based adhesive and compared to commercially available OSBs. Based on three-point bend tests and water stability, the results indicate that the bio-based OSB products performed as well as OSB products based on petrochemicals. Future tasks involve discovering and optimizing more applications for the bio adhesive such as rubber adhesion and flexibility, and pressure sensitive applications.

Contact: David Grewell, Agricultural and Biosystems Engineering, Iowa State University, Ames, Iowa 50011 USA, Tel.: 515-294-2036, E-mail: dgrewll@iastate.edu

KEMIN SPECIALTY CROPS: VERTICALLY INTEGRATED, SUSTAINABLY GROWN CROPS FOR EXTRACTION OF BIOACTIVE MOLECULES

Norman P. Cloud

Kemin Industries, Inc, Des Moines, IA, USA

Kemin Industries, Inc. is a leading supplier of functional ingredients to multiple market sectors including human health, human food, animal feed and pet food, personal and household care, and crop protection. These functional ingredients are bioactive molecules with specific activities as diverse as antioxidants, antimicrobials, anti-inflammatory, foaming agents and functional proteins. Currently, more than 35% of Kemin Industries raw materials are sourced from green plants with the potential to be much higher. Some ingredients are commodity based, but many of these unique compounds are produced or sourced from specialty crops with limited production worldwide. Understanding the biological activity, and determining the chemical structure(s) underpinning that activity, is core to the Kemin business model for plant derived materials and our partnership with customers. To start, identifying the best genus and species, geographic growing areas, and agronomic practices are required well before commercial production can be considered. This requires innovation and significant R&D investment to identify, source, scale and grow a crop in large enough acres to be commercially viable. Seemingly simple concepts such as field establishment or even sourcing germplasm to establish fields are often hurdles that need to be overcome. Weed control strategies and equipment availability are typically more limited with specialty crops than conventional crops. Additionally, seasonal variability, harvest timing, post-harvest handling, and quality control all need to be considered, often without prior market guidance on best practices. Kemin Industries is vertically integrated to address these challenges while partnering with independent growers, who have vast agronomic experience and know their land. Three crops; Rosemary, Mint and Monarda, along with associated cropping systems will be presented. The focus will be on the agronomic pieces required, from establishing fields through harvest of biomass. Non-proprietary equipment used in the field will be shown, as well as, the type of data required for decision-making to manage fields and optimize yield of the molecule of interest.

Contact: Norman Cloud, Manager, Research Agronomy, Specialty Crops, Kemin Industries, Inc. 1900 Scott Avenue, Des Moines, IA, 50317 USA. Tel: 515-559-5477. E-Mail: norman.cloud@kemin.com

Oral Presentations: Oilseeds Division

RESEARCH ON OILSEEDS IN EUROPE

Efthymia Alexopoulou and Myrsini Christou

Center for Renewable Energy Sources and Saving, Pikermi, Greece

The current global oilseeds production is 572 m t and the main oilseed crops are: soybean (348 m t), rapeseed (69 m t), sunflower (46 m t), cottonseed (39 m t), peanut (42 m t) and others (22 m t). In EU, the total oilseeds production is 33.5 m t with rapeseed as the most important (22 m t) followed by sunflower (9 m t). In Europe, a number of oilseed crops are being exploited apart from the ones mentioned above as source of biofuels and biochemicals. The oilseed crops that are being studied are: camelina (*Camelina sativa* L.), crambe (*Crambe abyssinica*), safflower (*Carthamus tinctorius* L), Ethiopian mustard (*Brassica carinata* L.), castor (*Ricinus communis* L.), cardoon (*Cynara cardunculus* L.), industrial hemp (*Cannabis sativa* L.), calendula (*Calendula officinalis* L.), wild tobacco (*Nicotiana glauca*), cuphea (*Cuphea* spp), lesquerella (*Lesquerella fendleri*), pennycress (*Thlaspi arvense* L.) and lunaria (*Lunaria annua* L.). Camelina has been selected in ITHAKA project as appropriate oilseed crop for marginal lands and has been investigated as feedstock for jet fuels production (www.ithaka.org). Camelina and Crambe have been selected by COSMOS project (http://cosmos-h2020.eu) as sources for medium-chain oils for specialty oleo chemicals. Ethiopian mustard had been investigated with rapeseed in the EU project entitled FAIR CT96 1946: "The outset of a new crop for biomass and industrial non-food oil". Cardoon has been tested in a number EU projects, with the most recent under BIOCARD and OPTIMA (www.optimafp7.eu). Castor, cuphea, lunaria and lesquerella had been selected, among other oilseed crops, in EUROBIOREF project (www.eurobioref.org; biorefinery project) as sources of oil for several chemical uses. *Nicotiana glauca* had been included in MultiBioPro project (www.multibiopro.eu) as a crop that can be grown in areas that are unsuitable for normal agriculture. Industrial hemp had been studied recently as a multipurpose crop (seed and/or fiber) in MULTIHEMP project (http://multihemp.eu). Moreover, most of the above-mentioned oilseed crops had been included in two EU research networks namely Crops2Industry (www.crops2industry.eu) and 4FCROPS (www.cres.gr/4fcrops). Currently, for next four years, several oilseed crops that can be cultivated successfully on marginal lands will be cultivated in MAGIC project (H2020).

Contact: Efthymia Alexopoulou, Centre for Renewable Energy Sources and Saving, 19th km Marathonos Avenue, 19009, Pikermi, Greece; Email: ealex@cres.gr

WINTER CAMELINA ROOT SYSTEM UNDER CONTRASTING ENVIRONMENTS

Federica Zanetti[1], Jane M.F. Johnson[2], Russ W. Gesch[2], Nancy Barbour[2], and Andrea Monti[1]

[1] University of Bologna, Bologna, Italy
[2] USDA-ARS-NCSCRL, Morris, MN, USA

Keen interest in developing camelina (*Camelina sativa* [L.] Crantz) as a viable oil crop is demonstrated by more than 450 publications on this species since 2013. Nonetheless, studies focusing on the root development of camelina are still lacking. In order to improve the knowledge on camelina root development, and to investigate the effect of contrasting environments on its morphology, a common field experiment was set up in Morris, Minnesota (USA, 45°35' N, 95°54' W) and in Bologna (Italy, 44°30' N, 11°21' E) during 2015-16 growing season. Winter camelina, Joelle, was sown at the two locations comparing two contrasting seeding densities: high density (HD) vs. low density (LD). The experimental design was a randomized complete block with three replications in Bologna and four in Morris. Roots were sampled when camelina reached full flowering stage. Two cores per plot were taken in Morris and four in Bologna and were split into five depth increments (0-0.10, 0.10-0.20, 0.20-0.30, 0.30-0.60, and 0.60-0.90 m), prior to root determinations. Simultaneously with root sampling, camelina plants were sampled from 0.50 m of row at the same site as the soil samples to obtain aboveground biomass. Camelina root biomass was significantly affected by location, with Bologna producing 250% higher biomass than at Morris ($P \leq 0.05$). Root biomass decreased with depth, although intermediate layers (0.10 to 0.60 m) did not significantly differ from each other. Sowing density significantly impacted root biomass, with plants grown at lower density presenting the highest root biomass ($P \leq 0.05$). A significant "location x soil depth" interaction was detected: Bologna had three-fold greater root biomass than in Morris down to 0.60 m depth. Camelina shoot biomass at flowering followed the same trend as root biomass, with plants grown at Bologna accumulating 190% more biomass compared to those grown in Morris. The increased root and aboveground biomass of camelina when grown under a milder Mediterranean environment such as Bologna, likely explains the higher productive potential achievable by this species compared to cold temperate sites, like Morris.

Contact: Federica Zanetti, Dept. of Agricultural Sciences, Alma Mater Studiorum, University of Bologna, Viale G. Fanin 44, 40127 Bologna (Italy). E-mail: federica.zanetti5@unibo.it

WINTER CAMELINA: CULIVAR VARIATION AND SOWING RATE

Russ W. Gesch[1], Heather L. Matthees[1], Adriana Alvarez De la Hoz[2], and Robert D. Gardner[2]

[1]USDA-ARS-NCSCRL, Morris, MN, USA
[2]University of Minnesota, MN, USA

Winter camelina has been proven to be a freeze-hardy, early maturing, winter annual crop that allows potential for dual cropping options in short-season temperate environments. However, little is known about genotypic variation of winter camelina or best management for its production. Traits including earlier maturity, improved seed yield, and oil quality would benefit its large-scale adoption as a winter annual crop. A three-year field study was conducted in west central Minnesota, USA, to evaluate the productivity of four winter camelina genotypes (Joelle, Bison, WG1-35, and WG4-1) at three different sowing rates (3.4, 6.7, and 10 kg ha^{-1}). Joelle camelina had the highest winter survival rate ranging from 50 to 90% across three growing seasons. Although final plant density increased with seeding rate across genotypes, it only impacted seed yield one out of three years, likely due to camelina's yield compensation ability. Averaged across years and sowing rates, Bison yielded the greatest (944 kg ha^{-1}) followed by Joelle (865 kg ha^{-1}), while WG1-35 (650 kg ha^{-1}) was the lowest. Both Joelle and Bison flowered earlier than the other two cultivars. Joelle seed had the highest oil content, averaging 41%, and had significantly greater oleic (C18:1) and lower linoleic acid (C18:2) contents than the other cultivars. There was no cultivar difference with respect to erucic acid (C22:1) content, which averaged about 2% across genotypes. Despite the small sampling pool of cultivars used, results indicate that genotypic variation exists in winter camelina for improvement of key productivity traits.

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FALL SEEDING OF SPRING CAMELINA: AN OPPORTUNITY FOR FARMERS IN NORTHERN ITALY

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Camelina (*Camelina sativa* [L.] Crantz) is a member of the *Brassicaceae* family, encompassing both spring and winter types, with the latter requiring vernalization to produce seed. It has been shown that spring camelina is highly adaptable, able to grow in a wide range of different environmental conditions. In particular, there is evidence that in locations characterized by mild winters, as prevalent in the Mediterranean area, spring camelina can be successfully grown as a winter crop. In the framework of the European project COSMOS (Camelina & crambe Oil crops as Sources for Medium-chain Oils for Specialty oleochemicals) a 2-year plot experiment (2015-2017) was established at the experimental farm of the University of Bologna (44° 30’ N, 11° 23’ E). The aim of the study was to compare a spring (Midas) and a winter (Luna) camelina cultivar in response to two fall seeding dates (early and late October) and two seeding rates (conventional vs. reduced) in a randomized complete block design with four replications. Bologna has a North Mediterranean climate; deep soil, fertile, and classified as silt-clay-loam with an organic matter content of 1.6%. The two growing seasons showed different meteorological conditions: in 2015/16, winter was characterized by mild temperatures (5.3°C) and 230 mm of precipitation; in 2016/17, winter temperatures were lower (3.6°C) and rainfall was only 89 mm. Although remarkably less developed in the second year (-50% of aboveground biomass compared to first year), camelina was confirmed to be well adapted to local conditions. The rate of winter survival was high (83%), even for Midas, and was not influenced by seeding rate nor by sowing date. Growth cycle of camelina was very short (~1200 growing degree days, GDD, from sowing to harvest). In both seasons, the spring cultivar Midas reached maturity at the end of May, 5-7 days earlier than the winter cultivar Luna. In the first season, seed yield of both genotypes exceeded 2 Mg DM ha^{-1}; there was no significant effect of seeding date, seeding rate or cultivar. Midas presented significantly higher harvest index than Luna (0.26 vs. 0.23, $P \leq 0.05$). Seed oil yield was confirmed stable and averaged 0.86 Mg DM oil ha^{-1}. The amount of polyunsaturated fatty acids (PUFAs) in the oil was found to be significantly affected by seeding date and cultivar, with Midas presenting higher C18:3 and lower C18:2 contents than Luna. The early maturity of camelina, particularly when spring camelina was grown as a winter crop, could be appreciated by local farmers as it would allow them to grow a second crop (i.e., corn, soybean) in the same season (double cropping).

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INDUSTRIAL OILSEED CROP GERMINATION IN RESPONSE TO SALINITY

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Soil salinity is a growing problem throughout the world, and crops that can successfully withstand the osmotic and ionic stresses are limited. The tolerance of several oilseed crops to germinate in saline conditions is not known. Therefore, a germination experiment was conducted to determine camelina (*Camelina sativa*), winter pennycress (*Thlaspi arvense* L.), echium (*Echium plantogineum*), cuphea (*Cuphea viscosissima X Cuphea lanceolata*), and calendula (*Calendula officinalis*) tolerance to germinating under saline conditions. Three replicates of fifty seeds were germinated in petri dishes saturated with CaCl, NaCl, and Na_2SO_4 salts with an electrical conductivity (EC) of 0, 2, 4, 8, and 16 dS m^{-1}. Fully germinated seeds were counted and removed for a 21 day period, and the entire experiment was repeated twice. Final germination percent fit to a logistic curve, corrected germination rate index, and germination velocity were calculated for each species, salt type, and EC combination. Slope intercept models were used to determine the threshold salinity at which germination declines. Overall, as the EC increased, final germination, corrected germination rate index, and germination velocity declined. Camelina and cuphea germination was tolerant to salinity with a salinity threshold of 8.0 and 3.1 dS m^{-1} with slight reductions in germination with further increases in salinity. Sodium sulfate was more detrimental to camelina germination while NaCl was more detrimental to cuphea. Pennycress and calendula were moderately tolerant to salinity with average thresholds of 5.9 and 2.7 dS m^{-1}, but with greater reductions in germination with increases in salinity especially when germinated with Na^+– based salts. Echium germination remained low and showed little response to salt type or increasing EC. These oilseeds therefore show potential for adoption in saline soil conditions.

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CRAMBE: A WIDELY ADAPTABLE SPRING OILCROP FOR EUROPE

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Crambe (*Crambe abyssinica* Hochst ex R.E. Fries) is a short-season spring crop with good potential for different European environments. Crambe seed yield is reported to vary from 1.2 to 3.5 Mg ha^{-1}, depending on environment, climate, location, etc. Crambe has some distinctive traits with respect to other more widely studied *Brassicaceae* (e.g., rapeseed, camelina, Ethiopian mustard). In particular, it produces seeds that are singly encapsulated in an indehiscent capsule; furthermore, the erucic acid content in its oil (>55%) is the highest within the *Brassicaceae* family, rendering its oil very suitable for specific industrial applications. Moreover, due to its seed composition (fatty acids and glucosinolates), crambe is widely identified as a non-edible oilcrop, not competing with food/feed species. In the framework of the EU project COSMOS (H2020, www.cosmos-h2020.eu) a multi-location and multi-year screening trial has been set up in Greece, Poland, Italy, and The Netherlands in 2015 and 2016. A common experimental protocol was agreed upon by all partners to compare ten different crambe lines supplied by WUR. Sowing date was optimized for each environment and ranged between mid-March in Italy and mid-April in The Netherlands and Poland. The length of crambe growth cycle remained quite stable across all test locations (~110 d, from sowing to harvest) and no difference for this trait was observed among tested lines. Seed yield of crambe was confirmed remarkable (grand mean: ~2.2 Mg DM ha^{-1}), but in environments characterized by deep fertile soils, like Italy and The Netherlands, seed production of the most productive genotypes exceeded 3 Mg ha^{-1}. Also, in more limiting environments (i.e., Greece and Poland, characterized by poor soil and sub-optimal climate) an average seed yield of ~2 Mg DM ha^{-1} was achieved. Oil content was confirmed a stable trait for crambe with an average value of 37% DM (grand mean). Seed weight was more influenced by environment than by cultivar choice, with crambe grown in the northern location (Poland) being able to produce the heaviest seeds, even when compared to more productive locations (+15% seed weight, Poland vs. Italy). The shortness of its growth cycle and the good productive stability, demonstrated across a wide range of European climates, would represent very valuable characteristics for crambe, thereby making the introduction of this new non-food oilseed into typical crop rotations a feasible option in the short run.

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DEVELOPING A METHOD FOR MEASURING TOXICITY OF CASTOR (*Ricinus communis*) MEAL USING DOMESTIC FLY

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The oil extraction of castor seed (*Ricinus communis*) generates large volumes of a meal with high protein content that can potentially be used as animal feed. However, the presence of the highly toxic ricin protein in the meal restricts this option. Currently, the defatted meal is predominantly used as low-value products such as organic fertilizer. Many studies confirmed that castor meal can be detoxified by combinations of heat, shear, and addition of ingredients with high alkaline or acidic pH, and that the detoxified meal is an efficient source of protein for ruminants. Nevertheless, castor meal is not being used as an animal feed in large scale due to the lack of methods for confirming its safety by industry and animal growers. Such method needs to be reliable regarding the toxicity measurement and does not require highly trained people and expensive laboratory equipment. A method for measuring toxicity of castor meal is being developed using domestic flies (*Musca domestica*) as bioindicator of toxicity. A population of flies is maintained with artificial diet in laboratory conditions. The protocol for keeping this population is well established, cheap, and easily transferred. Samples of about 10 g of castor meal were placed in cups, covered with 5 mm of the substrate used for flies oviposition (wheat bran with a few ingredients), and placed overnight inside the flies cage. The flies lay their eggs in the substrate, the samples are removed, and then placed in a closed container. When the eggs hatch in the substrate, the larvae move downwards to feed on the protein-rich castor meal sample. The initial tests were made with samples of castor meal collected in an oil extraction facility in Itupeva-SP, Brazil. Sample #1 was taken just after the expeller (having being exposed to steam for warming the seed and to pressure and shear during mechanical oil extraction). Sample #2 was taken from the exit of the solvent extraction (after being additionally exposed to alkaline steam and extrusion for expansion, hot hexane for solvent oil extraction, and heat for solvent removal). Electrophoresis measurements showed that ricin content was lower in sample #2. The preliminary results showed that the development of flies is different in both samples. The mean number of fly pupae developed was 42.2 in sample #1 compared with 181.0 in sample #2. The first pupae in sample #1 emerged four days later than in sample #2. The mean weight of pupae was 9.4 mg in sample #1 compared with 5.3 mg in sample #2. The number of adult flies that emerged was 16.4 in sample #1 compared with 121.6 in sample #2. The viability of pupae (adult fly emerged/pupae) was 38.9% in sample #1 and 67.2% in sample #2. The next steps will consist of additional validation of the toxicity measurement, simplification of the protocol, assessment of repeatability, and validation of the results compared with tests in animals that will be potentially fed with castor meal.

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RELAY COVER CROPS IN SOYBEAN (*Glycine max* (L.) Merr.) CROPPING SYSTEMS IN EASTERN NORTH DAKOTA

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Cover crop acreage continues to increase as soil profile, grazing, and ecosystem benefits become better known. The profit aspect of sustainability has the potential to be further improved by producing relay crops that have an added commodity grain value. A RCBD 3x3 factorial experiment with a control treatment was conducted at Prosper, ND, to evaluate grain value from winter annual oilseed crops and rye relayed into a soybean-soybean rotation in 2016 and 2017. Winter camelina (*Camelina sativa* L.) and field pennycress (*Thlaspi arvense* L.), two industrial biofuel crops, and winter rye (*Secale cereale* L.) were relay sown by surface broadcast at three seeding dates corresponding to soybean growth stages R6, R7, and R8 in Year-1. Traits evaluated included grain yield and 1000 seed weight for soybean. Stand establishment, fall and spring stand counts, flowering, grain yield, and 1000 seed weight were evaluated on the oilseed cover crop treatments. Year-1 results indicate soybean yield and 1000 seed weight were not influenced by the cover crop seeding date treatments when compared with the control treatment. Soybean yield was 3287 kg/ha when averaged across the control and cover crop seeding date treatments, and 23% greater than the county average soybean yield in 2015. Cover crop seeding date influenced cover crop stand establishment and fall and spring stand counts. Field pennycress fall stand counts were 581, 384, and 344 plants/m^2 for seeding dates R6, R7, and R8, respectively. Fall stand counts for camelina averaged 203, 397, and 925 plants/m^2 and for winter rye averaged 108, 145, and 209 plants/m^2 for seeding dates R6, R7, and R8, respectively. Soybean was relay seeded on May 12th, 2017 (Year-2) into the cover crops at the early flowering growth stage. Direct grain harvest of cover crops will occur in late June/early July over the top of the soybean plants which will continue development until harvest in early/mid Sept. Relay cropping systems utilizing winter camelina and field pennycress indicate potential as an adaptable management practice on farms in this region, however, continued research must be conducted to optimize management practices.

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CORN RELAY CROPPING WITH WINTER RYE, FIELD PENNYCRESS, AND WINTER CAMELINA

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Corn (*Zea mays* L.) is historically an economically important crop in the Midwest, but there are currently few options for utilizing relay cover crops in corn production. This study evaluates the benefits of cover crops which includes improving land-use efficiency in a corn-soybean rotation with field pennycress (*Thlapsi arvense*), winter camelina (*Camelina sativa* L.), and winter rye (*Secale cereale* L.) in eastern North Dakota. The study was a RCBD 3x3 factorial with cover crops and cover crop seeding dates generating nine treatments and also a sole crop corn check treatment. Corn was planted on May 5th, 2016 with relay cover crop seeding dates broadcast sown at corn growth stages R4, R5, and R6 in Year-1. Soybean (*Glycine max* (L.) Merr.) was relay planted into the oilseed cover crops the following year on May 12, 2017, (Year-2), before stem elongation/flowering of the oilseed cover crops. Field pennycress and winter camelina will be direct-harvested over the understory soybean plants in late June/early July (Year-2). In Year-1 corn grain yield was not affected by the cover crop seeding date treatments compared with sole crop corn check treatments. Corn grain yield averaged 14,363 kg/ha across all treatments and was 53% higher than the county average corn yield in 2015. Cover crop stand counts for field pennycress were 701, 680, and 713; for camelina were 668, 713, and 1160; and for rye were 131, 194, and 200 plants/m^2 for seeding dates corresponding to corn growth stages R4, R5, and R6, respectively. Rye had the highest green cover at 21%, 27%, and 14%; field pennycress green cover was 11%, 15%, and 6%; and winter camelina green cover was 2%, 3%, and 12%, for growth stages of R4, R5, and R6 respectively. Improving land use efficiency by harvesting three grain crops in two growing seasons is a targeted goal of this study. While maintaining corn and soybean yield is important and increasing land use efficiency shows promise in a corn/soybean cropping system with relayed oilseed cover crops, this research needs further replication in years and locations to determine optimum planting and harvest timing with the winter annual oilseeds.

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Oral Presentations: General Crops & Products Division

PROS AND CONS OF IRRIGATING PERENNIAL GRASSES WITH WASTEWATERS

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The production of energy crops has been presented as a promising alternative to partially replace fossil fuels. Among the various species that can be grown to generate energy, perennial crops are desirable because of their high productivity, resistance to low water regimes (characteristic of Mediterranean countries during summer), and resistance to pests. Yet, irrigating biomass during cultivation can cause the depletion of water resources, an important environmental constraint in the Mediterranean region due to water scarcity. In this context, perennial crop production under different types of wastewater irrigation was reviewed, with the aim of identifying its benefits and drawbacks. Pilot and field studies indicate that perennials show potential to simultaneously deliver high yields, restore soil properties, and promote water quality improvement under wastewater irrigation. Their production in water-scarce regions could provide environmental benefits and social and economic opportunities, as well as, safeguard freshwater resources. Nevertheless, this practice has environmental and social concerns due to the presence of harmful substances in wastewater, such as pathogenic microorganisms and toxic elements, e.g. heavy metals and pesticides, which can end up in the soil or be leached to the groundwater. Several technical and economic barriers should also be considered when designing and managing a system, such as wastewater characteristics and distribution, and the quantity and quality of biomass produced. In order to promote the sustainable reuse of wastewater for irrigation of perennial crops, further research is needed, factoring in issues such as yields, inputs and costs, as well as potential environmental and socio-economic impacts. It is recommended that site-specific factors, such as the type of soil, should be accurately assessed to evaluate the adequacy among crop, location and wastewater, in order to overcome negative impacts and public rejection.

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EFFECT OF IRRIGATION AND PLANT DENSITY ON YIELDS OF MISCANTHUS X GIGANTEUS

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Miscanthus x giganteus is the result of a cross between *M. sinensis* and *M. sacchariflorus*. It was collected in Japan, introduced in Denmark in 1935, and thereafter, distributed throughout Europe. This perennial grass has a lifespan that varied from ten to twenty years. In the 1960s, it was studied in Denmark due to its high productivity in cellulose fibre. From 1980s and onwards, Miscanthus x giganteus was studied mainly as a potential biomass crop for energy production in several European countries. Nowadays, it is considered as a key lignocellulosic crop for the production of advanced biofuels and bio-products. Recently, miscanthus had been evaluated under the European research project entitled OPTIMA (www.optima.fp7.eu; 2011-5). A number of field trials had been established in the Mediterranean region (Greece, Italy, Spain, and Portugal). This presentation will cover the field trial that was established in central Greece. The tested factors were: four irrigation rates (0, 25, 50 and 100% of potential evapotranspiration, PET) and two plant densities (rhizome spacing of 50 and 100 cm within the rows, while the distance between the rows was70 cm). The rhizomes were planted on May 6th, 2012. The mean plant heights were 252 cm (Year 1), 309 cm (Year 2), and 313 cm (Year 3). When the irrigation rate was increased from no irrigation to 100% of PET, the plant height also increased. The number of tillers/m^2 was 222 at the end of the first year, which remained almost the same in the following two years (231 and 234). Irrigation also increased the number of tillers/m^2 from 166 (non-irrigated plots, 2nd year) to 289 (fully irrigated, 2nd year). The diameter at the base of the stems increased yearly during the growing periods; i.e., 7.65 mm in the establishment year, 8.78 mm in Year 2, and 8.95 mm in Year 3. The second growing period recorded the highest dry biomass yields, with mean values of 25.91 Mg ha^{-1}. The yields in the 2nd year were 2.5 times higher compared to the establishment year. The yields in the 3rd year were much lower at 17.96 Mg ha^{-1}. When irrigation was increased, the yields also increased (from 16.96 Mg ha^{-1} in the non-irrigated plots to 33.96 Mg ha^{-1} in the fully irrigated ones, 2nd year). In the first year, plots with high density (50 cm within the rows) produced higher yields than the lowdensity plots (100 cm within the rows), but the opposite results were recorded in the second and the third year growing periods. When two harvest times were tested in the third growing period (mid-December and mid-January), it was found that when the harvest was delayed to mid-January, the fresh and dry matter yields decreased by 14% and 8%, on dry basis, respectively. The moisture content at the final harvest varied from 30 to 40%, averaged overall factors, and the stems accounted for 71% of the harvested material at the end of the 2nd year. It was also found that the ash content (whole biomass) decreased when the irrigation rate was increased. Thus, in the non-irrigated plots the ash content of the harvested biomass (December 2014) was 5.44%, while in the fully irrigated plots, the ash content was 3.84%. The corresponding ash contents for the harvested biomass at the end of January were 4.41% and 3.57%, respectively.

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MARGINAL LAND FOR GROWING INDUSTRIAL CROPS: TURNING A BURDEN INTO AN OPPORTUNITY

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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 offering the opportunity to follow a cascade bio refinery concept to produce a number of value added bio products and bioenergy. Prospectively, industrial crops can increase and diversify farmers' income through access to novel bio-based markets and exploiting marginal land with limited value for conventional agriculture. Cultivating industrial crops on marginal land unsuitable for food production is a viable alternative to minimize land-use competition for food production and its adverse effects 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 not yet been defined unequivocally, and there is no clear information on where, when and how much genuine marginal land is available. In the framework of a 4-year EU research project (Horizon 2020, MAGIC: Marginal lands for growing industrial crops) that will start on 1st of July 2017, selected industrial crops will be grown on marginal land, including contaminated and degraded lands. MAGIC aims to promote the sustainable development of resource-efficient and economically profitable industrial crops grown on marginal land. An up-to-date database of existing resource-efficient industrial crops will be developed with information on their agronomic characteristics, input requirements, yield performance, and quality traits for end-use applications. Moreover, a Decision Support System (DSS) will be developed and validated with the active involvement of farmers and end users. Current and future marginal lands in Europe will also be mapped, characterised, and analysed to provide a spatially explicit classification that will serve as ~~a~~ basis for developing sustainable best-practice options for industrial crops. The most promising crop species will be identified taking advantage of the profound experience of the consortium and in a multi-actor approach with stakeholders. Further investigations will include the creation of new breeding tools and strategies towards better crop varieties, the identification and optimization of appropriate agronomic practices with limited input requirements, and the development of suitable harvesting strategies and logistics to optimise the biomass supply-chains. The impact of MAGIC will be maximized by integrating sustainability aspects (covering environment, society and economy) of the value chains. Success stories of industrial crops in EU regions will be analysed addressing technical, environmental, economic and social issues to produce policy recommendations and best-practice guidelines for their promotion at local/regional level. The project results, database, maps and the DSS tool will be used to increase farmers' awareness and establish strong links with the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP AGRI).

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YIELD AND PHYTOREMEDIATION POTENTIAL OF PERENNIAL GRASSES IN HEAVY- METAL CONTAMINATED SOILS UNDER LOW IRRIGATION

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The increasing demand for biomass for the production of bioenergy is generating land-use conflicts which might be avoided through the establishment of dedicated energy crops on marginal land, e.g. heavy-metal contaminated land. Giant reed (*Arundo donax* L.) and *Miscanthus* spp. are two energy crops with tolerance to heavy metals contaminated soils. However, the level of contamination may affect the productivity and the biomass quality of these grasses. In a previous study, it was found that giant reed and *Miscanthus x giganteus* yields were negatively affected when grown in heavy-metal contaminated soil under full irrigation (950 mm) to overcome water stress. However, both crops can be considered interesting candidates for heavy metals phytoextraction, based on the metal accumulation observed and the high biomass produced. In this work, the yields and the phytoremediation potential of these perennials were tested but under low irrigation (450 mm). For two years, giant reed was tested on contaminated soils containing 450 and 900 mg Zn kg^{-1}, 300 and 600 mg Cr kg^{-1} and 450 and 900 mg Pb kg^{-1}, while *Miscanthus* x *giganteus*, was tested on contaminated soil that had 450 and 900 mg Zn kg^{-1}. Results indicate that yields were not affected by the heavy metal contamination but were affected by the level of irrigation. Significantly lower yields were obtained under the low water regime, which compromises economical utilization. The lower yields obtained also caused lower accumulation of metals in the biomass. However, despite the observed reduction in the accumulation, both crops still presented favorable potential for phytoextraction.

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NH3 ENERGY+: OPTIMAL FUEL, FERTILIZER, AND ENERGY STORAGE MEDIUM

Norman K. Olson

NH3 Association, Ames Iowa, USA

NH3 (aka "The Other Hydrogen") rises above other alternative fuel candidates based on its stellar characteristics and numerous additional benefits beyond its use as a fuel. Simply stated, NH3 is the most cost-effective, energy dense means of storing and delivering hydrogen. NH3: has excellent environmental performance; extremely high engine efficiency potential; can be produced from any and all primary energy sources; has excellent end-use flexibility; and has a decades-long, proven, acceptable safety record. The fact that NH3 also serves as the most cost-effective means of delivering nitrogen fertilizer provides enormous additional benefits, especially to developing countries. NH3 is: an optimal solution for long-term storage of intermittent/stranded renewable energy; an efficient, environmentally friendly refrigerant; an excellent household cleaner; and a versatile chemical precursor. No other alternative fuel can deliver the comprehensive benefits associated with NH3.

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STATUS OF GENETIC RESOURCES OF GUAYULE AND OTHER INDUSTRIAL CROPS AT THE USDA NATIONAL ARID LAND PLANT GENETIC RESOURCES UNIT IN PARLIER, CA

Claire Heinitz

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Access to diverse and well-characterized genetic resources is key for the development of any new crop. The USDA National Plant Germplasm System maintains collections of several industrial crops for arid lands at the National Arid Land Plant Genetic Resources Unit in Parlier, CA (NALPGRU). NALPGRU collects, maintains, characterizes and distributes germplasm of taxa spanning all divisions of the AAIC. Guayule (*Parthenium argentatum*) produces natural rubber, resins and hypoallergenic latex. Jojoba (*Simmondsia chinensis*), lesquerella (*Physaria spp.* and *Paysonia spp.*), and meadowfoam (*Limnanthes spp.*) produce seeds with unique oils and waxes. *Hesperaloe, Agave,* and *Yucca* can all be used for fiber or cellulosic biomass. Prickly pear cactus (*Opuntia spp.*) is a multi-use crop used for fresh food, medicinal and nutraceutical value, and animal feed. Currently, prickly pear is now under development as a high water-use efficiency biomass crop. The history and current status of the collections will be presented, along with a discussion of new management priorities. The recent characterization of genetic diversity in the guayule collection by researchers at Cornell University has exposed potential mistakes in some accessions that will be investigated, but it also allows for the definition of a "core set" of diverse germplasm for breeding and evaluation, and an informed discussion on gaps that still remain in the collection. Future research goals and opportunities will be discussed for each of the collections, with a focus on *Parthenium* and *Opuntia*.

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PHYSICAL AND CHEMICAL PROPERTIES OF BIOCHARS PRODUCED FROM MWRDGC BIOSOLIDS FOR UTILIZATION IN SAND-BASED TURFGRASS ROOTZONES

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Biosolids are several forms of treated sewage sludge that are intended for use as soil conditioners for horticultural, agricultural and industrial crops. In the U.S. biosolids may only refer to conditioned sludge that meets USEPA pollutant and pathogen requirements for land application and surface disposal. Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) biosolids are classified as Class A biosolids, which is a designation that meets US EPA Part 503 guidelines for land application with no restrictions and can be legally used as fertilizer on municipal parks, golf courses, or for home gardens. We have been studying the use of biochars (pyrolyzed biomass) derived from a variety of feedstocks for replacing peat in the construction of new sand-based turfgrass rootzones such as golf greens, tees and athletic fields to increase water and nutrient retention. In addition, as biochar decomposes extremely slowly, its lifespan in the rootzones should be much longer than peat. However, biochars produced from traditional sources such as wood wastes have low bulk densities (~ 0.2-0.3 g cm^{-3}) compared to sand (~1.9 g cm^{-3}), potentially allowing upward migration of the biochar, diminishing its water and nutrient retention in the turf rootzones. However, MWRDGC biosolids have a bulk density similar to sand (~1.9-2.0), indicating that biochars produced from it would also have high bulk densities, preventing it from migrating in rootzones. The objectives of this research were to determine the chemical and physical properties of biosolids pyrolyzed at several different temperatures, and their effect on perennial ryegrass growth. Biosolids were thermally treated in an oxygen-free (nitrogen atmosphere) retort oven at 300, 400, 500, 700 and 900 ^{o}C to form five granular biochars. As pyrolysis temperatures increased, bulk densities, total surface areas, micropore surface areas, % minerals and pH values of the biochars increased, while % carbon decreased compared to untreated biosolids. FTIR analysis showed decreased surface functionality as pyrolysis temperature increased. Perennial ryegrass (*Lolium perenne* L. 'Nui') plants were grown in mixtures of 10% (v/v) biosolids or 10% (v/v) of the various biochars and 90% coarse sand. Ryegrass plants grown in the 300 ^{o}C biochar mixture had the highest dry weights of any of the treatments after 4 weeks of growth. Ryegrass plants grown in the 400 ^{o}C biochar mixture also had dry weights greater than the untreated biosolids mixture control, although dry weights of ryegrass grown in the 500, 700 and 900 ^{o}C biochar mixtures were lower than the control. These results indicate that biochar produced from pyrolyzing MWRDC biosolids at 300 ^{o}C would have excellent potential as a peat replacement for water and nutrient retention in sand-based rootzones.

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Oral Presentations: Medicinal & Nutraceutical Plants

EFFECT OF SEMI-DESERT PLANTS AS GROWTH REGULATORS IN TOMATO PLANTS (*Solanum lycopersicum* L.)

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A great variety of wild plants that thrive under the extreme climatic conditions in the semi-arid regions of northern Mexico produce numerous compounds that are of great utility to plants and humans. Some of these compounds are brasinoesteroids, a family of phytohormones with steroidal structure and act as plant growth regulators at low concentrations. The aims of this research were to determine and identify the chemical compounds extracted from four semi-desert plants of the northern Mexico: *Rhus muelleri*- leaf (RM), *R. trilobata*-leaf (RT), *Flourensia microphylla*-leaf (FM) and *Cucurbita foetidissima*-fruit (CF), and also to evaluate these plants extracts as growth inductors in tomato (*Solanum lycopersicum* L.) plants. The methanol extracts from the four plants were prepared and then analyzed using a GC-MS system. The growth-inducing activities of the methanolic extracts were evaluated in tomato plants in greenhouse. A completely randomized design experiment was employed in evaluating eight treatments: four plant extracts (RM, RT, FM, CF), three phytohormones (indol acetic acid, 6 benzyl aminopurine and gibberellic acid), and one control (without extract or phytohormone). Extracts and phytohormones concentrations were at 75 ppm. Each treatment was replicated seven times. The data were analyzed by analysis of variance and the treatment response means were compared using Tukey's test (p=0.05). Compounds similar to brasinoesteroids were identified in the extracts from the *Rhus* species. In *F. microphylla*, precursor compounds of 3-indol acetic acid were found. Extracts from the four semi-desert plants evaluated have the ability to promote plant growth and fruit yield in tomato.

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THE CHEMISTRY AND QUALITY OF LIBERIAN SPICES

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Several studies have shown that non-timber forest products (NTFP) can contribute to household food security by providing food, medicines, and raw materials for enterprises, as well as commodities for trade. Liberia has a long history of the use of NTFP by forest dwellers. Several spices are used by people in the Guinea forest of Liberia. One of the most used spices is country spice or Ethiopian pepper (*Xylopia aethiopica*), from an aromatic evergreen tree native to tropical West Africa. The objective of this work was to conduct chemical analyses on Liberian spices to determine the chemical properties and establish quality trade standards to contribute to the development of new natural plant products. The three Liberian spices used in this study were country spice or Ethiopian pepper (*Xylopia aethiopica*), West African Black Pepper (*Piper guineense*) and Grains of Paradise (*Aframomum melegueta*). Among the chemical protocols run were sensory (aroma and color), macroscopic (foreign materials), proximate composition (e.g. total proteins, ashes, crude fats) and chemical analysis (composition of volatiles). Different parts of the fruit (pod) were used, such as whole fruits, capsules and seeds. The study showed that the seeds contained a similar profile of essential oils as the whole fruit, suggesting potential new uses for the parts of *Xylopia aethiopica* dried seeds based on chemical composition of the volatile oils. The West African Black Pepper samples showed variation in the profile of essential oils, with some samples being high in linalool, a chemical compound that provides floral notes to botanicals. The lesser known spice Grains of Paradise, which included samples from Ghana and Liberia, showed similar and more stable profile of essential oils, dominated by (E)-Caryophyllene and α -Humulene. The chemical variation of these spices can be used to develop potential new products based on the chemical composition of the volatile oils. The development of new products from spices requires setting up chemical characters that will help consumers define the quality of these spices and ultimately increase interest in these products.

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Oral Presentations: Natural Rubber & Resins Division

CURRENT PROSPECTS FOR A NATURAL RUBBER INDUSTRY IN THE U.S.

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Guayule (*Parthenium argentatum* Gray) production in the Southwestern U.S. may be economically feasible soon if an industry that includes the utilization of all coproducts can be established or if one of those areas become an economically significant contributor. Guayule has been the focus of research investigations as a domestic source of natural rubber by public entities since the Emergency Rubber Project in the 1940s. Bridgestone has made a significant investment in the crop improvement, processing, and co-product development to bring guayule to commercial production. Three significant recent events are energizing this. First, a five-year USDA, NIFA, Biomass Research and Development Initiative (BRDI) grant was completed that provided new research findings and tools for guayule. The second, an event organized by USDA and Bridgestone brought industry, commercial groups, government, and academics together to examine the barriers preventing full commercialization of guayule and find partnerships able to overcome them. The third is a not yet public formal announcement coming in the near future. Bridgestone has three objectives for its Agro Operations that will be discussed including crop improvement through breeding and genetics, agronomic advancements, and development of relationships with growers.

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EFFICIENT GUAYULE LATEX EXTRACTION

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Guayule (*Parthenium argentatum* Gray) is a U.S. native source of natural rubber. Guayule latex can support the production of guayule on a small scale by its use in high value niche markets. Competitiveness in the commodity markets (*e.g*. tire rubber) requires very large acreages and processing capacity. However, efficient laboratory and pilot scale guayule latex extraction protocols developed at USDA have not yet been effectively translated to industrial scale. The objectives of this study were to optimize the latex yield *in planta*, and during extraction, and improve latex purity and consistency. Losses and impurity issues were specifically addressed and amended using a combination of process development and equipment construction and validation. Our new robust process is described and efficiencies reported and compared, where possible, with earlier processes. Guayule bagasse from this process can be pyrolyzed to a 50,000J/g bio-oil. In conclusion, Guayule latex production remains a commercially viable option and can address premium niche markets which, together with bio-oil production, will support the acreage expansion needed for tire rubber.

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GUAYULE LATEX SUPPORTS PRODUCTION OF THE FIRST MEDICAL RADIATION ATTENUATION GLOVE

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Guayule (*Parthenium argentatum* Gray) is a U.S. native source of natural rubber. Effective commercialization of guayule requires its use in high value, premium, niche product markets, ideally those which cannot be addressed by conventional natural and synthetic rubber and latex. One such application, in which the exceptional properties of guayule rubber and latex can be uniquely exploited, is the radiation attenuation (RA) glove. Currently, FDA has approved RA gloves only as personal protective equipment and requires health care workers to wear a medical glove beneath the RA glove. Double-gloving is uncomfortable, expensive and significantly reduces tactile sensation and dexterity due to thickness and slippage. A single, medically qualified, RA glove is greatly desired. This cannot be achieved using latex from *Hevea brasiliensis* (Meull. Arg) rubber trees, because the amount of RA filler need to attenuate radiation reduces the mechanical properties of the gloves to below the properties mandated by FDA for surgeons' (ASTM D3577) and examination (ASTM D3578) gloves. Guayule rubber is softer and stretches further than commercially-available rubber latex. Guayule rubber also has high polymer-filler interactions, due to its unbranched, high molecular weight *cis*-1,4-polyisoprene rubber polymers. Previous studies showed that guayule rubber and latex have considerably higher filler loading capacities than Hevea rubber and latex. EnergyEne has developed prototypes of the first medical RA glove, made with guayule latex, that meet the mechanical performance required by the ASTM surgical (D3577) and examination (D3578) glove standards and the degree of attenuation required by the ASTM radiation attenuation standard (D7688). This unique glove also is circumallergenic because guayule latex naturally avoids Type I latex allergy and the xanthate-based accelerators used, ZDNC and DIXP (Robinson Bros, UK), do not induce contact reactions. For end-users, these properties mean better tactile sensation, less hand fatigue, and potentially lower puncture risk, combined with allergy-safety. These benefits make this glove ideal for fluoroscopy assisted surgical operations. An application for a 510(k) premarket approval will be submitted to FDA. Unlike general medical exam gloves, which have been largely replaced with synthetic materials, the current labelling requirements for guayule rubber gloves will not seriously affect the marketability of a guayule RA medical glove. The RA gloves currently used already bear the latex allergy caution label without the mitigating text approved for guayule. In addition, significant use of a guayule RA medical glove will allow creation of an adverse reactions medical data base that can be used to support a citizen's petition to remove the Hevea-specific allergy caution label from guayule products.

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DIFFERENTIAL EXPRESSION OF DROUGHT-STRESS ASSOCIATED GENES AND THEIR IMPACT ON RUBBER SYNTHESIS IN GUAYULE (*Partheniun argentatum*)

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The perennial shrub guayule (*Parthenium argentatum*) is currently being developed as a domestic source of natural rubber in the US. One essential program in crop improvement is the availability of genetic information, such as whole genome sequence and transcriptomics, as the information is critical to breeding and/or genetic engineering to develop elite lines. For guayule, developing elite lines with high rubber yielding is highly desirable. With the goal of laying the foundation for molecular breeding in guayule, we used next-generation sequencing technology to acquire genomic and transcriptome sequences. In a recent guayule irrigation management field experiment, we found that rubber yield responded linearly to total water applied. To identify novel genes associated with rubber synthesis, we sequenced polyA-RNA libraries derived from two tissue types, control and drought-stressed conditions. Data analysis of differentially expressed genes between the two sets of transcript sequences allowed generation of candidate genes list related to rubber-synthesis. We are validating the expression of these candidate genes using quantitative real-time polymerase chain reaction (qPCR). Candidate genes revealed by qPCR will be presented and their potential uses as targets for improving guayule will be discussed.

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DOWNREGULATION OF ALLENE OXIDE SYNTHASE IN GUAYULE INCREASES NATURAL RUBBER CONTENT

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In this study, we report the phenotypes and impact of the allene oxide synthase gene in *Parthenium argentatum* (*PaAos*) with respect to natural rubber production. Even though *PaAos* constitutes most of the protein found in *P. argentatum* rubber particles, we interestingly discovered that after down-regulating *Aos* gene by RNAi method ($PaAos_{RNAi}$), guayule plants exhibited very distinguishable phenotypes, including agricultural traits conducive to enhancing rubber yield. $PaAos_{RNAi}$ plants have higher leaf and stem biomass, thicker stembark tissues, higher numbers of stem branches and an increased photosynthetic rate. Most importantly, the rubber content significantly increased in comparison to the wild-type *G7-11*, empty vector (*pND6*) and over-expressed *AOS* ($PaAos_{OE}$) both in tissue-cultured and soil-grown controlled environments. The increase in rubber content maybe be due to the influence of salicylic acid induction, which leads to the down-regulation of *PaAos*, and the mediation of hydrogen peroxide molecules providing the signal that stimulate rubber synthesis. We are now conducting a two year field trial for these plants in Eloy, AZ.

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SILICA AND EGG SHELLS SYNERGISTICALLY REINFORCE GUAYULE (*Parthenium argentatum*) NATURAL RUBBER COMPOSITES

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Increased concerns about carbon footprint and controlling production costs have led to research on the replacement of the traditional reinforcing fillers, carbon black and silica in the US rubber industry. Mechanical properties, dynamic mechanical properties, and polymer-filler interactions of guayule rubber, reinforced with single and mixed fillers, are not yet fully understood. Previous research showed that eggshells have a significant reinforcing effect in carbon black filled guayule rubber composites. In this study, we investigated the reinforcing effect of eggshells in silica filled guayule rubber composites. Eggshells are produced in enormous quantities (601,000 metric tons/yr) sufficient to replace or supplement the current reinforcing filler amounts. Furthermore, both silica and eggshell fillers are white so these composites can be easily dyed colors other than black. The hypothesis of this research is egg shells filled guayule rubber composites can match or exceed the mechanical properties of silica solely filled guayule. Egg shells (supplied by Michael Foods) were ground to small particles (size < 38μm), then the ground egg shells and silica (170m^2/g, Hi-Sil 190G, PPG Silica Products) were added into guayule natural rubber as fillers in a standard rubber compound. Tensile tests, dynamic mechanical analyses, swelling tests, and scanning electron microscopy (SEM) were used characterize the rubber composites.
Our results showed guayule composites containing both egg shell and silica fillers had superior tensile strength and elongation at break, due to uniform filler dispersion, which was confirmed by the scanning electron microscope (SEM) results. Also, the addition of egg shells reduced energy consumption during compounding. The estimated rolling resistance was reduced and wet traction improved as egg shells were added to guayule natural rubber. The pale color of egg shells and silica, allowed the silica and egg shells filled guayule natural rubber composites to be dyed different colors instead of black. The egg shells and silica proved synergistic in the guayule natural rubber composites. Compared with the silica filled guayule rubber composites, the egg shells and silica filled guayule rubber had advantages in mechanical properties, energy-saving properties and dyeability. Also, the cost and carbon emission for producing those bio-composites were reduced. Therefore, adding egg shells into guayule natural rubber improved the material performance and controlled the cost of production cost at the same time. The silica and egg shells filled guayule natural rubber is expected to open new markets for colored rubber products.

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HEREDITY OF TAPROOT PHENOTYPE IN *TARAXACUM KOK-SAGHYZ* (RODIN)

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A taproot phenotype, which consists of one large singular root, is preferred over a multiple root phenotype to maximize harvest efficiency and decrease yield loss in the new Ohio rubber crop *Taraxacum kok-saghyz* (Rodin) (TK). TK plants have several natural root phenotypes or architectures: a taproot with no branching, a multiple root system where 2, 3, 4 or more roots develop from the crown, and also a taproot phenotype that develops branched roots toward the middle or tip. In this study, rare field-grown taproot plants were interbred and the incidence of tap-root phenotype quantified in their F1 progeny and compared to controls. Half of the F1 seed and a complimentary control seed lot were direct seeded into treepots in the greenhouse. In order to induce multiple roots, the other half of the F1 and control lots were seeded into transplant trays and grown for two months before being transplanted into treepots and grown in the greenhouse. Six-month-old plants were harvested, root fresh weight was measured, root phenotype recorded, and root rubber concentration was quantified using Near Infrared Spectroscopy (NIRS). Direct seeding into pots showed that most TK plants (90% of F1 and control lot) will form a taproot under soft soil conditions. This method prevented detection of any improvement of taproot percentage achieved by interbreeding the field tap-rooted plants. Transplanting the F1 and control plants increased the pressure on the plants to form multiple roots and this allowed us to detect plants genetically programmed to be a taproot (74% of F1, 47% control lot). This 25% increase in taproot incidence in the F1 plants, compared to the incidence of their parental taproot in the original population (<0.001%), indicates that genetic heterozygosity for the genes regulating taproot was present in the parental genotypes. Taproots were, in general, smaller than multiple root systems, but large taproots do occur, especially in planting boxes. No correlations were found when comparing root fresh weights between F1 and control plants but the F1 plants were generally larger than the controls. An analysis of variance (ANOVA) found no significant difference in root rubber concentration between taproots and multiple root phenotypes, or between the control and F1 plants. Taproot is a heritable, likely multigenic, trait in TK. The taproot incidence in the F2 generation will further elucidate the inheritance of taproot in TK. Development of a tap-rooted TK crop should reduce loss of rubber-containing roots at harvest, increasing yield per acre.

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WATER-BASED PROCESSES FOR THE EXTRACTION OF NATURAL RUBBER FROM *Taraxacum kok-saghyz* (TK) ROOTS

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Natural rubber (NR) is a raw material essential to the modern economy the supply of which is insecure due to burgeoning demand, price instability, labor shortage, and disease. *Taraxacum kok-saghyz* (TK), a rubber-producing dandelion, is currently being investigated as an alternative source of NR. Water based processes for the recovery and purification of NR from TK date to the 1940's. However, the rubber recovered using these methods does not meet industry standards for dirt content. Since then, little if any research on TK processing has been conducted and limited literature is available. In order to commercialize TK as an alternative source of NR, new processes to produce quality rubber that meet industry standards need to be developed. In this study, various methods to extract NR from TK roots were compared in order to identify those that result in NR with low dirt content at high yield and quality. Roots from TK planted in spring 2016 at the Ohio Agricultural Research and Develop Center (OARDC), Wooster, were harvested, washed, dried, and prepared for this study during November 2016. The dried roots were stored at 4°C until use. Half of these roots were roller cut and flattened into pieces with a maximum length of 2 cm. Approximately 800g samples of milled roots and whole roots were independently extracted with water at 100°C for 20 min, 6 times. Water extracted roots were then processed by four different treatments: 1) two sequential pebble millings; 2) enzymatic digestion (cellulase 18 µg protein/g of dry roots, 50°C, pH 5.5, 48 h, plus pectinase); 3) alkaline pretreatment (66 mg NaOH/g dry root at 160°C for 20 min); and 4) alkaline pretreatment followed by enzymatic digestion. Rubber recovered using these previous treatments was further treated with 2% NaOH, 120°C for 20 min. The yield and purity of rubber samples from each treatment were measured. In addition, rubber was characterized by FTIR, GPC, TGA, DSC and SEM. Results showed that whole roots resulted in lower yields but higher rubber purity than chopped and flattened roots. Treatment 4 resulted in the highest TK rubber purity, 99.4% w/w dry weight of rubber. Alkaline treatment applied to the extracted rubber samples improved rubber purity but reduced rubber yield. The molecular weight characteristics of the recovered TK NR were similar to those of Hevea natural rubber (SVR-L). Based on these results, the combination of alkaline pretreatment and enzymatic digestion is proposed as a promising process for development into a commercial process for the production of TK NR that meets industry standards.

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Oral Presentations: Fibers & Cellulosic Crops Division

COMPARATIVE STUDIES AMONG SEVERAL KENAF VARIETIES IN GREECE

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Kenaf (*Hibiscus cannabinus* L.), originated from Africa, was introduced in China in the beginning of 20th century, reaching its highest planting area in 1980s. In Europe, kenaf research started in the 1990s as non-food multipurpose crop since it could be used for the production of many biobased products. Kenaf varieties could be grouped as early- and late-maturing based on the timing of their flowering. The flowering for the late-maturing varieties initiate only when the day length is less than 12.5 h. It is cultivated at high plant populations varying from 200,000 to 500,000 plants/ha. Recently, kenaf had been evaluated in a European research project entitled FIBRA (www.fibrafp7.net; 2012-15), which also included a mirror research group from China. For four consecutive years (2012-5) a total of twelve varieties were cultivated in the same area, located in central Greece. The varieties studied were imported from: a) Israel (DGG, RAZ, E2, GG1, Sunshine, GG3, GG4, GGMN, GGM, EF1, and CHW), b) USA (Tainung 2, G4 and Whitten), and c) China (H328 & H368). Five of them (underlined ones) were tested in all four years. The experimental layout was a randomized complete block in three replications and the size of the plot was 49 m^2. The sowing took place from the middle of April (2014) till the beginning of May (2012 and 2013). Each plot had nine rows and the distance between the rows was 70 cm. Harvests (0.7 m^2 per plot) were conducted every three weeks from July to mid-December. The harvested biomass was first weighed and then separated into leaves and stems. Samples from stems and leaves were taken to estimate the moisture content of the harvested materials. The stems were further separated into bark and core. The leaf and stems (bark and core) samples were first weighed and then dried in the oven (85^0 C) till constant weight. The flowering for the early varieties in all years started two months from emergence, while for the late-maturing ones flowering initiated in mid-September when the day length was shorter than 12.5 h. Thus, the late-maturing varieties developed into taller plants and gave higher yields compared to the early-maturing ones. The dry matter yield from the early-maturing varieties peaked in the first half of September, while that of the late-maturing ones occurred in the second half of October. The late Chinese varieties H328 and H368 gave the highest yields among the late-maturing plants evaluated, producing 23.3 Mg ha^{-1} and 24.5 Mg ha^{-1} (mean dry matter yields of the years 2014 & 15), respectively. The corresponding mean dry matter yields for the two late-maturing varieties imported from the USA were 21.32 Mg ha^{-1} (Tainung 2) and 19.9 Mg ha^{-1} (Whitten). Averaged over all years, the early varieties gave 20-25% lower dry matter yields compared to late ones. The bark accounted for one third of the total dry stem weight for biomass harvested when yields were at their peak. Although the early-maturing varieties were less productive compared to the late-maturing ones, their shorter growing season could be important for the rotation systems that will be adapted in each specific area of cultivation.

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INVESTIGATION OF KENAF FOLIAGE AS A POTENTIAL BIOCIDE IN COMPOSITON PANELS

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Kenaf (*Hibiscus cannabinus* L.) is a warm season annual fiber crop widely used as a cordage crop to produce twine, rope, and sackcloth. It yields 6 to 10 tons of dry fiber per acre per year generally, which is 3 to 5 times greater than the yield for Southern pine trees. Kenaf bast and core fibers are commonly used in industrial products; however the leaves of the plants, which are rich in phenolic and aromatic compounds, are not utilized due to lack of applications and information on their potential applications. The objective of this study was to evaluate the efficacy of kenaf foliage (leaves) as a natural biocide against brown and white rot fungi and its impact on the physical and mechanical properties of the medium density composition panels. Medium density particleboards with varying amounts of kenaf leaves (0%, 5%, 10%, 15% and 20%) and remaining pine wood flour were manufactured in the laboratory using a Carver hydraulic hot press. Kenaf leaves and pine wood flour were sized to 0.5-1 mm particles and dried to 7% moisture content. Both the raw materials were thoroughly blended in a mechanical rotary mixer before adding 10% melamine formaldehyde resin and 10% wax emulsion. The test samples from five compositions were exposed to two fungi, brown rot (*G. trabeum*) and white rot (*T. versicolor*) following the ASTM D1413 test method. The weight-loss exhibited by the test samples was measured to determine the fungal resistance of particle boards containing kenaf leaves. The physical and mechanical properties of the particleboards were analyzed following the guidelines described in ASTM D1037 standard. The physico-mechanical properties evaluated were modulus of elasticity, modulus of rupture, internal bond strength, thickness swell, water absorption, and screw holding capacity. The preliminary test results showed that medium density particleboards can be successfully made from blends of kenaf leaves and pine wood flour. Addition of kenaf leaves had minimal impact on the mechanical properties of the boards. The water absorption of the boards increased with higher amount of kenaf leaves. The addition of kenaf leaves in the boards showed variable impact on the fungal resistance of the boards. More details on the weight-loss by different fungi will be discussed.

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SEEDING DATE, CULTIVAR, AND SEED TREATMENT EFFECTS ON INDUSTRIAL HEMP (*Cannabis sativa* L.) STAND ESTABLISHMENT IN NORTH DAKOTA

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Achieving proper stands is essential for optimum crop performance and influenced by many factors, some controlled by the producer (seed quality, seed treatments, seeding date, rate, and depth), and others largely by mother nature: soil moisture, temperature, crusting, and pests related to weeds, diseases, and insects. For new crops, such as industrial hemp, researchers initially provide producers with stand establishment information to define management approaches for controlled factors and improve management for mother nature issues. A multi-year field study was initiated at the Langdon REC to determine the effects of seeding date, cultivar, and seed treatment on industrial hemp stand establishment and crop performance in 2017. The experimental design was a RCBD with a split-plot arrangement with seeding date as the main plot and a factorial arrangement of cultivar and seed treatment as the subplot. Two industrial hemp cultivars, Delores and Katina, were sown on May 20, June 1, and June 12. Two seed treatments (ipconazole plus metalaxyl and metalaxyl alone) and an untreated check were included for each cultivar. Analysis indicated the main effects of seeding date and seed treatment significant for stand density, pure live seed emergence (PLSE), and mortality. The main effect of cultivar and all interactions were not significant for stand density, PLSE, and mortality. Stand density (145 plants/m^2) and PLSE (84%) were greater for the May 20 seeding date than seeding dates June 1 and June 12, that were 128 plants/m^2 and 75% for stand density and PLSE, respectively. Stand density (143 plants/m^2) and PLSE (83%) were greater for the ipconazole plus metalaxyl seed treatment compared to the untreated check with 126 plants/m2 and 73% PLSE. Stand density and PLSE were similar for the untreated check and the metalaxyl alone seed treatment. Seed/seedling mortality was approximately 9% lower for the May 20 seeding compared with the later seeding dates and 10% less for the ipconazole plus metalaxyl seed treatment compared with the untreated check. Based on year-one results, earlier seeding date and seed treatment increased stand establishment and PLSE, and reduced seed/seedling mortality for industrial hemp.

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COMPATIBILIZATION IMPROVES PERFORMANCE OF BIODEGRADABLE BIOPOLYMER COMPOSITES WITHOUT AFFECTING UV WEATHERING CHARACTERISTICS

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Due to the negative impacts of petroleum-based plastics on the environment and ecosystem health, as well as uncertainty in supplies of fossil fuels, there is a great impetus on replacing conventional plastics with biodegradable biobased alternatives. Biobased polymers are often blended with natural fibers because of cost concerns, and to achieve desired properties such as biodegradability, specific strength and stiffness. Despite its advantages, addition of natural fibers to polymer matrices weakens some strength properties due to poor interfacial adhesion between the hydrophobic polymer matrix and hydrophilic fiber. However, compatibilizers are shown to improve fiber-matrix interaction in biocomposites. It is important to study the behavior of biopolymer composites under weathering conditions to understand the influence of degrading factors on the long-term performance of composites. Only very few studies have reported on the effect of compatibilizers on biodegradable biocomposites and their behavior under accelerated weathering. The objectives of this study are: 1) to quantify changes in physico-mechanical, thermal, and visual properties of different biodegradable biopolymer-based composites resulting from weathering exposure, and 2) to compare the property variations between composites with and without compatibilizer after weathering exposure. In this study, five types of biopolymers were compatibilized with maleic anhydride (MA) to develop biocomposites by compounding 30% by weight of wood fiber (WF) utilizing twin-screw extrusion process and then compression molding. The five biobased biodegradable polymers used are poly(lactic acid) (PLA), Bioflex (PLA blend), Solanyl (Starch), poly(3-hydroxybutyric acid) (PHB), and poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV). To investigate the effects of weathering on morphological, physico-mechanical, and thermal properties, samples were exposed to accelerated UV/moisture weathering up to 2000 h. The effect of WF loading and MA on the properties was evaluated before and after weathering. Morphological changes were characterized by using optical microscopy and color changes. Thermal properties were studied using differential scanning calorimetry. Physical and mechanical properties such as water absorption, flexural and impact strength, and hardness were evaluated according to ASTM standards. With the addition of MA, composites exhibited improved mechanical and thermal properties, and reduced water absorption. The observed improvements were attributed to the increased fiber-matrix interaction. Upon accelerated weathering, overall thermal and physico-mechanical properties of the materials decreased. Surfaces of the specimens were roughened and drastic color changes were observed. Water absorption increased with weathering exposure. Even though the compatibilized composites showed improved properties before weathering, no considerable differences in properties were exhibited with weathering. The results suggest that compatibilization improves composite material performance without affecting its UV degradation properties.

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EPOXIDIZED SUCROSE SOYATE AS A PRIMARY BINDER IN PARTICLEBOARD MANUFACTURING

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In the U.S., wood composites are an integral part of the residential construction market, making up over 100 billion dollar industry. This industry relies heavily on petroleum and formaldehyde-based resins. These are not ideal options because petroleum-based products are not a renewable resource and formaldehyde is classified as a carcinogenic compound according to the EPA. Thus, the industry is looking for alternatives and soy based resins could be the answer. It has already been shown that Epoxidized Sucrose Soyate (ESS) can be used to replace formaldehyde resin with the current equipment used to manufacture particleboard. This would lower the risk a business would have to take if they chose to adopt an ESS product. It has also been shown that ESS with the right catalyst and cross-linker can outperform Methylene Diphenyl Diisocyanate (MDI), which is popular in particle board manufacture. The downside of ESS, however, is that it has a longer cure time than MDI. The objective of this study is to find a formula of ESS plus a cross-linker and catalyst that increases or maintains the strength of the particleboard while simultaneously decreasing or maintaining the cure time as compared to MDI the current market standard. A set of novel cross-linkers and catalysts were evaluated in the ESS resin for manufacturing particleboards. Initial characterization was conducted through evaluating curing kinetics via differential scanning calorimetry (DSC) and bond strength using lap shear testing. The DSC helped to determine the temperature and time required to fully cure the resin system. The lap shear test, ASTM D2339, was used to verify the assertions made through the DSC testing. The data obtained from this testing was compared to the control, MDI resin, to see if the formula meets the criteria to move to the next phase: manufacturing particleboards for testing. A handful of formulations were identified for manufacturing lab scale particleboards. The particleboards were made using a hot press and then cut for various tests per ASTM D1037 standard. The performance characteristics of the particleboards were evaluated by measuring density, water absorption, dimensional stability, flexural strength and modulus, hardness, screw withdrawal and internal bond strength. This study helped to identify two or more promising cross-linking chemistries which can reduce the cure time of ESS based particleboards without compromising the physico-mechanical properties. The current direction of the research is using anhydrides namely methylhexahydrophthalic anhydride (MHHPA) and methyltetrahydrophthalic anhydride (MTHPA) as a cross-linker with a fast acting catalyst in BV7 and BV7-FC. The low curing temperature of this resin system is expected to help in conserving energy. ESS has potential as a safe renewable epoxy in particleboard manufacture offering an alternative to petroleum formaldehyde based resins.

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TECHNO-ECONOMIC ANALYSIS AND LIFE CYCLE ASSESSMENT OF BIO-ADHESIVES DERIVED FROM GLYCEROL

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With increasing environmental concerns in the petroleum-based adhesives production process, biobased adhesives have been explored as a promising replacement. The purpose of this paper is to explore the economic feasibility and environmental impact of structural bio-adhesives made from a byproduct of the biodiesel production, i.e. glycerol. SuperPro Designer v9.5 software was employed to perform the techno-economic analysis. Several key parameters for the techno-economic analysis were analyzed, such as total capital investment, annual operating cost, and revenues. It was found that the unit production cost of the structural bio-adhesives (2.45 $/kg) is compatible with the structural adhesives in the current market. Three different scenarios were built to investigate the worst- and the best-case scenarios associated with this process. Sensitivity analysis was performed to evaluate the key parameters that have significant influence on the economic results. Discounted cash flow analysis (DCF) was conducted to explore the influence of the time value of money. The minimum selling price (MSP) obtained when net present value 0 is 3.11 $/kg for this bioadhesive production. GaBi 6.4 software was employed to perform the cradle to gate life cycle assessment (LCA), and TRACI 2.1 and Ecoindicator-99 were used as the life cycle impact assessment methods. Several key parameters for life cycle analysis were analyzed, for instance: global warming potential, acidification potential, eutrophication potential, ozone depletion potential, and human health cancer effects. The main finding is that 12.39 kg CO_2-eq greenhouse gas was observed when producing 1 kg bioadhesive. When replacing bio-glycerol with petro-glycerol, the overall environmental impact was 22.8% higher, and the petro-glycerol process required higher energy consumption. Sensitivity analysis was conducted in order to determine the key factors that influence the greenhouse gas (GHG) emissions. We found that the bioadhesive's production process was highly sensitive to electricity sources, followed by product yield. Underlying issues and areas needed for improvement were discussed in this study as well.

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Posters: Oilseeds Division

PRODUCTIVE PERFORMANCE OF WINTER CAMELINA GROWN IN CONTRASTING ENVIRONMENTS: NORTHERN ITALY VS. MINNESOTA, USA

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Winter genotypes of camelina (*Camelina sativa* [L.] Crantz), i.e., those requiring vernalization to trigger reproduction, could expand the potential growing areas of this crop. Certain winter cultivars have been shown to thrive as winter annual crops in cold temperate continental environments like those typical of the northern United States. Conversely, the adaptability of these genotypes to milder climates, like the Mediterranean, is still poorly studied. Therefore, a common field experiment was initiated in 2016-17 in two contrasting environments, Bologna (Italy, 44°30' N, 11°21' E) and Morris, Minnesota (USA, 45°35' N, 95°54' W), to evaluate the productive performance of winter camelina. Despite their similar latitudes, the two locations are characterized by diverging climatic conditions. The mean annual temperature is 5.6 °C in Morris and 13.4 °C in Bologna. Annual precipitation is similar for both locations (~650 mm year^{-1}), but in Italy, the majority of rainfall occurs during winter, while in Minnesota it occurs during the summer months. A winter camelina cultivar (Joelle) was compared in randomized complete block design consisting of two sowing densities (500 vs. 250 seeds m^{-2}) and two sowing times (typical vs. delayed). Sowing times corresponded to the beginning and end of October in Bologna, and early September and early October in Morris. The trials evaluated emergence rate, winter survival, 50% flowering date, final plant density, aboveground biomass, seed yield, TKW (thousand kernel weight), HI (Harvest Index), and seed oil and protein contents. Winter survival of Joelle camelina in Morris averaged 54% and 61% for the typical and delayed sowing dates, respectively; while in Bologna it averaged 87% and 77% for the typical and delayed sowings, respectively. A more quantitative and qualitative characterization of the first year's data will be presented enabling a comparison of Joelle's performance in the two contrasting environments.

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PROGRESS TOWARDS DEVELOPING EARLY MATURING WINTER VARIETIES OF *Camelina sativa* AS OILSEED COVER CROPS FOR NORTHERN CLIMATES

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Winter camelina [*Camelina sativa*, (L.) Crantz] is being evaluated as an oilseed cover crop for the northern USA. This cover crop is a marketable oilseed feedstock for biofuels and bioproducts, and also provides beneficial ecosystem services that can reduce soil erosion and nutrient leaching, suppress early season weed establishment, and provide early-season nutrition for pollinators. Although the winter camelina cultivar 'Joelle' has excellent winter hardiness and other desirable agronomic traits, an earlier maturing trait is desired for developing relay- and double-cropping systems for northern agroecosystems as it would allow more time for the second crop to develop. RNAseq was used to characterize several transcripts involved in key flowering-time pathways of a summer 'CO46' and winter 'Joelle' genotype of camelina. The results indicated that one of three genes encoding *FLOWERING LOCUS C* (Csa20g015400), a transcription factor involved in floral repression, was 16 fold greater in Joelle compared with CO46 prior to vernalization. Abundance of this transcript decreased slightly in CO46 post-vernalization, compared with a significant decrease in Joelle. Abundance of transcripts mapping to the three chromosomes encoding *MADS AFFECTING FLOWERING 2* (*MAF2*), another floral regulating transcription factor known to undergo temperature-dependent alternative splicing, were also significantly greater in Joelle compared with the minimal abundance observed in CO46. *MAF2* transcript specific to chromosome 18 (Csa18g038750) was preferentially expressed in Joelle pre- and post-vernalization; whereas, changes in *MAF2* expression were minimal in CO46. Gene set enrichment analysis highlighted differences in gibberellic acid (GA) pathways between summer and winter camelina prior to vernalization, and topical application of bioactive GA induced internode elongation in Joelle without a vernalization treatment. Further, preliminary results from reciprocal crosses between CO46 and Joelle produced an F_2 population with a 3:1 segregation ratio for freezing tolerance, and variability in bolting and flowering rates following vernalization. These ongoing studies are expected to enhance our understanding of genetic factors impacting freezing tolerance and early-season maturity in winter camelina.

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ACETYL-DIACYLGLYCEROL PRODUCED BY MODIFIED CAMELINA (*Camelina sativa*)

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Acetyl diacylglyceride (acetyl-TAG) is a component of a commercial product, ACETEM, manufactured by transesterification reaction of triglycerides, glycerol, and triacetin or by acetylation of mono- and diglycerides with acetic acid anhydride. ACETEM is commonly used as foaming agents and coatings in food, lubricants in food processing, emulsifiers in cosmetic preparations, slip agents in paper products, and as a plasticizer in plastics processing. Acetyl-TAG can now be produced by camelina (*Camelina sativa*), which was engineered by incorporating the diacylglycerol acetyltransferase gene isolated from Burning Bush (*Euonymus alatus*). Successful grow outs of the genetically engineered camelina produced seeds needed to initiate processing trials and with acetyl-TAG representing 85 mol% of oil content. The goals of this work were to develop a process of separating acetyl-TAG from the oil and to produce purified acetyl-TAG for further testing. The oil was extracted from the seeds by prepressing followed by hexane extraction and then was degummed, neutralized, and bleached. The acetyl-TAG was separated from the refined oil by distillation. A centrifugal-type laboratory still running at 190 ^{o}C and 0.07 mbar vacuum pressure produced high-purity acetyl-TAG distillate but yield was <10%. A pilot plant wiped-film short-path still operated at 250 ^{o}C and 0.0005 mbar recovered >80% of the acetyl-TAG in 150 L oil while removing almost all long-chain TAG. The distilled acetyl-TAG is yellowish in color and contained some diacylglycerides and trace amounts of free fatty acids and other unidentified impurities.

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OIL CONCENTRATION AND FATTY ACID PROFILE OF NATURALIZED WILD *Helianthus annuus* POPULATIONS FROM AUSTRALIA

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Sunflower (*Helianthus annuus* L.) as a crop has been researched for biomass production and as a biofuel crop. While sunflower is indigenous to North America, crop wild relatives of sunflowers have been inadvertently and intentionally introduced into countries, such as Australia, where they have become sporadically naturalized. Since wild annual sunflower, *H. annuus* L. has been naturalized in Australia, the possibility exists that populations may contain distinct traits such as oil content and fatty acid composition differing from their North American progenitors due to the different environments, diseases, and insect pest complexes. The objective of the study was to analyze wild naturalized wild annual *H. annuus* populations from the five states of Australia for oil content and fatty acid composition. Fifty-six populations collected throughout the broad distributional range of the wild annual species were analyzed for oil content and fatty acid composition. The mean oil content of the wild *H. annuus* populations was 280 g/kg, ranging from a low of 190 g/kg to a high of 310 g/kg, similar to populations of this species collected in its native habitat of the USA, but lower than that of cultivated sunflower. The average fatty acid composition for the four major acids was 63 g/kg palmitic, 35 g/kg stearic, 290 g/kg oleic, and 583 g/kg linoleic acid. The naturalized wild sunflower had a similar fatty acid profile to the native populations, and to cultivated sunflower. Oil concentration of interspecific hybrids can be rapidly increased to acceptable levels by backcrossing with cultivated sunflower. Based on this fact, there should be little concern about the lower oil content of this wild species when it is used as a source of other unique traits for cultivated sunflower improvement. Since the fatty acid profiles are similar for wild, naturalized, and cultivated sunflower, there should be no negative effects of utilizing them for sunflower improvement. Since the naturalized Australian populations did not appear to have any significantly different oil content or fatty acid profile, this would indicate that if this species was used for any other breeding purpose (such as disease resistance or abiotic traits), the fatty acid composition and oil content would not be detrimental to oil content and quality.

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BIOBASED LUBRICANT FROM USED COOKING OILS

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As more and more people look for healthy alternatives for cooking and frying oils, the opportunity to develop high value products from these waste streams increases. Cooking oils that are often described as healthier contain higher levels of monounsaturated fats. NuSun® sunflower oil is an example of a healthier cooking/frying oil that is monounsaturated and rich with oleic type fats. Vegetable oils do not meet the current standards for industrial lubricants because of unacceptable low temperature properties, pour point (PP) and/or cloud point (CP). Estolide esters made from these used cooking oils could not only make biobased lubricants with excellent properties, but also aid with the disposal/resale of these waste oils. During the cooking/frying process many oxidative products are produced, but it was unclear how this used oil would affect the estolide synthesis and resulting properties. Both new and used NuSun® cooking oils were used in the synthesis of the estolide 2-EH esters. The new and used cooking oil estolide esters had their physical properties reported and compared. From the series of different NuSun® cooking oil estolide esters produced, the used NuSun® cooking oil estolide ester displayed PP/CP = -33/-33°C while the new NuSun® cooking oil estolide ester showed PP/CP = -36/-34°C. As saturated fatty materials were added to the used NuSun® fatty acids during the estolide ester synthesis, the physical properties were improved. The coco-capped estolide esters had the best low temperature properties; the used coco-capped NuSun® cooking oil estolide ester had a PP/CP = -39/-35°C. The viscosities of the used NuSun® cooking oil estolide esters ranged from 109.5-118.3 cSt at 40°C to 17.2-18.4 cSt at 100°C, while the new NuSun® cooking oil estolide esters ranged from 101.9-102.5 cSt at 40°C to 16.3 cSt at 100°C. These estolide esters had excellent physical properties without the need for additives and no adverse effects from the unwanted oxidative products found in used cooking oils.

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Poster: General Crops & Products Division

SCREENING FORAGE SORGHUM [*Sorghum bicolor* (L.) Moench] GENOTYPES FOR COLD TOLERANCE

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Forage sorghum [*Sorghum bicolor* (L.) Moench] is a warm-season annual grass used mainly as a silage or hay crop in the USA with the potential to become a bioenergy feedstock. Its minimum temperature for growth is 15˚C, limiting its planting early in the growing season. Cold-tolerant forage sorghum genotypes would allow an earlier planting and optimum use of the growing season. This will likely lead to an increase in productivity of forage sorghum in the North Central Region. The objective of this study was to screen and select potential cold-tolerant forage sorghum genotypes. The experiments were conducted in Fargo and Hickson, ND. First, 74 commercial cultivars of forage sorghum and 10 cold-tolerant genotypes of grain sorghum were tested at 24˚C and 12˚C in controlled temperature and light growth chambers at the USDA-ARS laboratory. Fifty seeds of each cultivar were germinated in Petri dishes. Experimental design was a completely randomized design with three replicates. Seed germination rate, vigor index, and dry weight of seedlings were recorded. The genotypes were ranked from high to low cold-tolerance and a cluster analysis was conducted. The eight highest ranked cultivars, two lowest ranked, and two cold-tolerant grain sorghum genotypes (BTx 623, SC 265) were selected and planted on two seeding dates: normal (27 May 2017) and early (10 May 2017) in Fargo and Hickson, ND. The experimental design was a randomized complete block design with four replicates. Evaluations included: emergence index, soil coverage, chlorophyll content, and NDVI. Soil temperature and rainfall were recorded with sensors installed in each field. In the growth chamber screening, forage sorghum genotypes showed variable response to cold stress and potential cold-tolerant genotypes were selected. These selected genotypes can be utilized to improve cold tolerance in forage sorghum with the aim of breeding cultivars adapted to grow in northern regions as forage or feedstock for bioenergy.

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Poster: Fiber & Cellulosic Crops Division

YIELD AND BIOMASS QUALITY OF KENAF (*Hibiscus cannabinus* L.) IRRIGATED WITH TREATED WASTEWATERS – THE EFFECT OF AMMONIUM ION AND NITRATES

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The aim of this work was to evaluate growth responses, as well as the quality and biomass productivity of the G4 variety of kenaf, irrigated with treated wastewaters (TWW) containing 0, 50 and 100 mg.L^{-1} nitrate ion (NO_3^-) concentrations; and 0, 15, 30 and 60 mg.L^{-1} ammonium ion (NH_4^+) concentrations. Wastewater after secondary treatment was obtained from Campo de Tiro de Alcochete. The assays were conducted in small pots and were done in triplicate. A control assay was also performed using tap water and NPK fertilization. Throughout the experiment, samples of water that percolated through the pots were analyzed for ammonium ion, nitrites, and nitrates. Results show that the concentration of 15 mg.L^{-1} of NH_4 led to the highest yields of biomass with low ash and nitrogen contents. Increasing the ammonium ion to 60 mg.L^{-1} in the wastewaters led to the decrease in biomass productivity and to higher amounts of ash and nitrogen in the biomass, which can compromise its use for combustion purposes. Irrigation with wastewater enriched with nitrate ion did not affect the growth and productivity of kenaf even at the highest concentration (100 mg.L^{-1} NO_3) used in this study. However, in terms of the biomass quality, increasing the level of nitrate ion in the irrigation water also increased the amount of nitrogen in the biomass. No effect was observed for ash, phosphorus, and potassium contents. Heat of combustion and fiber content were also not affected by the amount of nitrate or ammonium ion in the wastewater. The biomass and the soil effectively removed nitrates and ammonium ions from the wastewater (circa 90-100%) when the plants reach major development (90 days after sowing). Therefore, aside from producing good quality biomass, kenaf may be used in remediating water bodies laden with ammonium and nitrate ions and, at the same time, lower the cost of kenaf production by reducing the amount of nitrogen fertilizer needed.

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Posters: Medicinal & Nutraceutical Plants Division

GUAR, ROSELLE, AND SESAME GENETIC RESOURCES CURRENTLY USED AS INGREDIENTS IN SOME MEDICINAL PRODUCTS AND SEVERAL POTENTIALLY NEW MEDICINAL USES

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The objective of this presentation is to report a review of industrial crop species in the USDA, ARS, Plant Genetic Resources Conservation Unit's (PGRCU) collection for current and potential uses as medicinal plants in humans. Three industrial crop species including guar [*Cyamopsis tetragonoloba* (L.) Taub.], roselle (*Hibiscus sabdariffa* L.), and sesame (*Sesamum indicum* L.) contain several phytochemicals and extracts which have currently been reported to be used or have potential to be used as medicine, nutraceutical, or functional vegetables worldwide. Biochemicals including guar gum, hydroxypropyl guar, flavonoids, polyphenols, sesamin, episesamin, and tocopherol from guar, roselle, and sesame accessions will be discussed. The reported uses such as, lowering hypotension, cardiovascular improvement, ocular surface protection, decrease harmful gut bacteria, reduce and relieve dry eye severity, antimicrobial activity, counteract ultraviolet radiation impairments, anti-leukemia, anti-inflammatory, antioxidant, reduce blood pressure, anti-mutagenic, chemopreventive, cytotoxic to prostate cancer, and anti-melanoma in human and animal models, will be discussed. These species may provide the medicinal, nutraceutical, and functional food arenas with valuable health products and can provide other scientists with plant germplasm for the potential development of advanced cultivars with one or more of these traits. Plant germplasm species in the PGRCU collection require evaluations for the identification, quantification, and variability of potentially very valuable health traits which are currently unknown.

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DEVELOPMENT OF EDIBLE NANO-LAMINATED COATINGS WITH ANTIMICROBIAL RESINS OF *Flourensia cernua* AND THEIR APPLICATION TO EXTEND THE SHELF-LIFE OF TOMATO (*Solanum lycopersicum* L.) FRUITS

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Tomato is a crop of great commercial importance in Mexico. However, it is one of the vegetables that suffer large post-harvest losses due to physical and biological factors. To prolong the shelf life of horticultural products, several techniques have been implemented. Chemical treatment of fruits has raised some concerns, such as, increased pathogen resistance and its negative effects on the environment and human health. Recently, edible nano-laminate coatings have been of great interest to food industry. *Flourensia cernua* is a plant from the semi-arid region of Mexico that had been reported to have antifungal properties against post-harvest fungi. The aim of the present research was to develop and evaluate edible nano-laminate coatings with antimicrobial resins of *F. cernua* to extend the shelf life of tomato fruits. The nano-laminated coatings were built by alternate deposition of five nano-layers of a sodium alginate (Alg) polyelectrolyte solution (Alg, 0.02%, w/v, glycerol and Tween 80 at 0.05%, w/v at pH 7.0), and a chitosan (CH) polyelectrolyte solution (CH, 0.06%, w/v, glycerol and Tween at 0.1%, w/v at pH 3.0), with the ethanol extract of leaves of *F. cernua* (5000 mg/L). They were initially built on a support film of aminolized/charged polyethylene terephthalate (PET A/C) in order to be characterized in terms of charge of the polyelectrolyte solutions (zeta potential), contact angle analysis, thickness of the coating, water vapor permeability, permeability to oxygen, and SEM analysis. The experiment was conducted using a completely random design, with three treatments and three replications per treatment. Phytochemical and microbiological analyses were performed. Results showed that the tomato fruits coated with nano-laminates of *F. cernua* showed 50% of reduction ($p<0.05$) of fungal growth after 15 days of storage. Also, the fruits coated had 30% less weight loss ($p<0.05$) compared with uncoated fruits (6.93% and 9.83%, respectively). The edible nano-laminate coatings of *F. cernua* prolonged the shelf life of tomato fruits.

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APOPTOTIC ACTIVITY OF *Flourensia* spp

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Nowadays, colon cancer is one of the most common forms of cancer affecting both men and women. Several treatments have been evaluated to fight cancer and one of the most studied is the programmed cell death called apoptosis. However, the synthetic chemicals used have negative collateral effects. Recently, plant extracts have been studied widely due to the properties of their bio-compounds, and also, for its use as an alternative treatment against several diseases, including cancer. In Mexico, *Flourensia* species have been used as traditional medicine to treat gastrointestinal diseases. The aim of this research was to study the apoptotic activity of leaf extracts from *F. cernua* and *F. retinophylla*, endemic plants of the Mexican semi-desert, *in vitro* on HT-29 colon cancer cells. The plants samples were collected randomly from two wild sites of Coahuila State, Mexico. The leaf extracts were prepared by agitation with ethanol as solvent and the total phenolic content and antioxidant activity by 2,2- diphenyl-1-picrylhydrazyl (DPPH) were evaluated. The identification of bioactive compounds of ethanol extracts was performed using a gas chromatograph-mass spectrometer system (GC-MS). Cellular viability of HT-29 colon cancer cells treated with the extracts was analyzed by MTT assay. The apoptotic activities of *Flourensia* spp extracts were evaluated on HT-29 cells with a Human Apoptosis microarray kit. Results showed that *Flourensia* spp extracts are a great source of antioxidant compounds with apoptotic activity. Extracts from both plants activate the intrinsic and extrinsic pathways of apoptosis by the expression of caspase 3. Thus, *F. cernua* and *F. retinophylla* could be used as a natural treatment to prevention of colon cancer.

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PHYSICAL CHARACTERIZATION OF CHITOSAN/MONTMORILLONITE INCORPORATED WITH *Rosmarinus officinalis* L. ESSENTIAL OIL

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Active compounds such as essential oils have been tested for its antioxidant and/or antimicrobial activity in biopolymers. Yet, the incorporation of these compounds may also result in changes in the properties of the polymer. Therefore, the aim of this work was to develop and evaluate the physical properties of bionanocomposites based on chitosan incorporated with rosemary essential oil (REO) and reinforced with Cloisite®Na^+ (a commercial montmorillonite - MMT) to improve its mechanical and barrier properties. Chitosan film forming dispersion (FFD) was prepared by dissolving the polymer (1.5% w/v) in acetic acid solution (1% v/v) with agitation for 24 h. Montmorillonite was incorporated (2.5% w/w chitosan) into the FFD, and exfoliation was done by employing 3 cycles of 15 min ultrasonic bath intercalated with 5 min ultra-turrax agitation, and final 5 min degassing at ultrasonic bath. Rosemary essential oil was incorporated in the proportion of 0, 0.5, 1 and 2% (v/v FFS) before the last agitation cycle. Pristine chitosan films were used as control. Bionanocomposites were casted in glass molds and naturally dried for 72 h at room temperature. The samples were tested for mechanical, colorimetric properties, Fourier transform infrared spectroscopy (FTIR), swelling degree, water content and solubility. The exfoliation was assessed by X-ray diffraction (XRD). Biofilms produced were thin (60-63 μm), homogeneous, transparent, and yellowish. Incorporation of REO resulted in a less bright and darker film. The opacity of films increased, thus improving the blocking barrier property of the film. The addition of Cloisite®Na^+ and REO resulted in higher tensile strength and elastic modulus of the films. From XRD and FTIR spectra, it was observed a good interaction between REO, MMT and chitosan, indicating a successful exfoliation of the nanoclay into the polymeric matrix. The changes in the physical properties were correlated to the amount of REO incorporated: higher REO resulted in significantly more changes, except the mechanical properties. In conclusion, the addition of REO imparted bioactive properties to the film which may be useful as food packaging. REO also improved the interaction among components resulting in improved mechanical and barrier properties of the bionanocomposite film.

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Poster: Natural Rubber & Resins Division

MULTI-ENVIRONMENT PERFORMANCE OF *Taraxacum kok-saghyz* (Rodin) CLONES TO VALIDATE INDIRECT SELECTION

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Reliable selection is essential in successful crop domestication. To test current selection methods in the highly diverse germplasm of emerging natural rubber crop, *Taraxacum kok-saghyz* (Rodin) (TK), clonal plants of individual TK genotypes with known root rubber concentration were generated by root cuttings and planted in three growing locations; field, outdoor planting boxes, and raised beds in a controlled environment greenhouse. Six-month old plants were harvested from all locations and root size and root rubber concentration at harvest were compared within and between genotypes. Root rubber concentration was quantified using Near Infrared Spectroscopy (NIRS). Mean root rubber concentrations of each genotype were generally consistent across the different environments but mean root fresh weight was highly variable as greenhouse grown plants were the largest and field grown plants the smallest. Intra-clonal variation for both traits was high causing overall low (but positive) correlation coefficients of genotype performance among environments. Genetically identical plants behaved very differently even in the same environment. This variation may result from the position of the specific cutting on the original root. This study suggests some heritability of both root rubber concentration and root size, however root cuttings are unsuitable clonal material for comparisons among genotypes and environments. Root rubber concentration is much less variable within a clonal genotype than root size across environments. Selection for heritable large plant phenotypes cannot be done in a greenhouse, but we can use the greenhouses to select against small plant phenotypes.

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